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Research Article

Sub-Saharan Human Morphological Variations in the External Ear (pinna): A Potential tool for Human Identification

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Abstract

The human pinna is the most defining feature of the face and used as a means for individual identification from morphological features. Studies on the morphological dimensions of the human pinna have been documented with high accuracy. This study attempted to explore the variations of the pinna features within and between an individual of Hausa ethnic group in Nigeria. The subjects used for this study were Hausa young adults within the age range of the 16 - 35 years. Digital camera was used to take photos of the participants 'pinnae which were processed and used in the face-arth software for the linear measurements. Independent Sample T-test was used to determine the differences between left and right pinnae dimensions and also for determination of sexual dimorphism. The results indicate no statistical differences between left and right pinnae of the same subject but indicate statistically significant sexual dimorphism for all the studied dimensions, except for the lobule's height.

Keywords: *Ear; Dimensions; Sexual Dimorphism; Hausa; Nigeria*

Introduction

The pinna, part of the external ear, has for long been used as a tool for human identification [1] in disaster conditions [2], in identifying criminals [3] and deceased individuals [4] and can also be used as an additional tool in estimating stature [5] and sex [6]. Similarly, the pinna is used in identifying familial relationship because its morphology tends to be hereditary [7] that requires only 4 characteristics to make the Pinna unique [8] for easy classification. It was previously classified according to the defined landmarks from photographs of the right and left pinnae of 500 men based on the pinna length, width, length of the lobe, distance between the tragus and the antitragus and morphological features i.e. general shape, knob of Darwin, curving of the antihelix, size of the tragus and antitragus, form of the antitragic notch [9]. The classification is important since anthropometric measures are affected by side [10,11], age (Pandit., *et al.* 2019), gender [6,10,11] and race [12,13] and thus a piece of equipment designed to fit one individual may not fit another.

Although various studies were conducted in various population with regards to Pinna, such data is scanty about the morphometric variations in terms of shape and size from within and between individuals from Hausa ethnicity in Nigeria, albeit its importance in the identification and medico legal purposes [14].

Aim of the Study

The aim of this study is to establish a baseline data of the Pinnae and study its morphologic variation among Hausa tribe students of Nigeria.

Materials and Methods

The study population was 200 male and female participants selected randomly across all Faculties of Bayero University Kano, Nigeria which Houses Hausa students from the neighboring countries (Niger, Cameroun, Ghana, and other Hausa speaking countries). The procedure as well as the intended use of the study was fully explained to each and consent for participation was sought from each. The materials used were Neiko digital Vernier caliper (01407A, UK) (Plate 1A), Tripod stand (Plate 1B), masking tape (Plate 1C) and measuring tape (Plate 1D). Other materials used but not shown include: Olympus digital camera (VG140, D715, China), Chair, Permanent marker, Dell computer with faceArth-software installed, Photo *and* picture resizer version 2 android software.

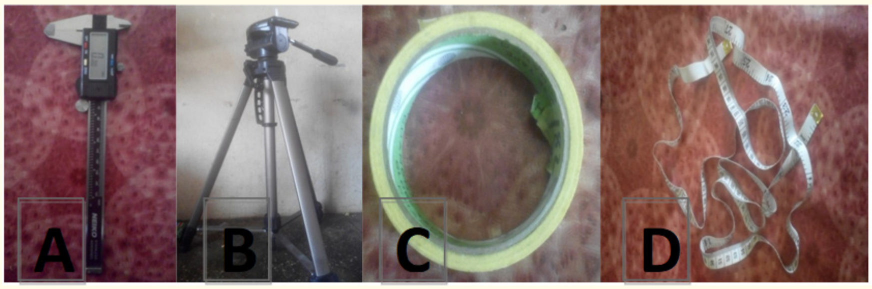

Plate 1: *A: Neiko digital vernier caliper, B: Tripod stand, C: Masking tape, D: Measuring tape.*

Neiko digital Vanier caliper (measuring accuracy: 0.001 and speed of 60/s) was used to measure the morphometric parameters of the pinna for the purpose of determining the multiplying factor that will be used in the faceArth- software to compare the actual measurement and the face-Arth software measurement (Adamu 2015).

The photograph of both left and right pinnae of each subject was taken using Olympus digital camera with model number VG140, D715. The camera was mounted on the tripod stand in which the tripod stand was adjusted according to the height of the subject. The chair was placed approximately 50 cm in front of the tripod stand with its center directly perpendicular to the centre of the tripod stand (Plate 1B). This distance was determined by setting the camera to a maximum zoom and adjusting the distance so that a large pinna is fitted into the shot.

Before photograph was taken, sex and identification number were recorded and any object that could interfere with the measurements such as ear rings, glasses as well as caps were removed from subjects. Each subject was asked to seat on the chair in a comfortable upright position, looking straight ahead. The identification number of the subject was written on the masking tape using the permanent marker and was attached just in front of each pinna. Each subject was tagged with a combination of number and letters as his/her photograph was taken, beginning from 1 and the letter L or R and M or F proceeded the number on the sticker according to weather it was fixed to the left (L) or to the right (R) of the pinna or is male (M) or a female (F) subject (Kearny 2003) as shown in plate 2. All measurements were taken when the head was in the Frankfurt horizontal position. Height was taken from the most superior point of the pinna to the most inferior point.

Plate 2: *Tagging of subject 100MR (indicating subject number 100, male, right ear).*

Image processing

After the photos were taken from the camera, the photos were then transferred to the android phone (HTC Desire 616 Dual sim) in which each photo was resized, cropped and scaled for the photos to be on the same scale before the photos were transferred for measurements in the face-arth software in the computer.

Measurements

Measurements for the purpose of getting the multiplying factor were taken using Vernier caliper according to the standard methods [15]. The measurements from the photos of the subjects were taken using the computer "Facearth" software (Departmental based software) which was calibrated and each of the measurement was from a pair of points adjusted according to the landmarks of the pinna to be measured (Adamu 2015). For example, point ps_1 was selected to indicate the lowest point of the ear, and point ps_2 was selected to mark the uppermost point of the ear, and the distance between these points (ps_1 and ps_2) measures the total pinna length, while other points were used for the rest of the measurements. Landmarks and measurements of Schwalbe, 1875 were adopted and four parameters were measured: Total pinna length (the distance between the most superior point of the pinna to the most inferior point of the lobule), pinna width (the distance between the point of the maximum convexity of the helix and the root of the ear), lobule height (the distance between the most inferior point of the pinna attachment head up to the free margins of ear lobe) and lobule width (the distance between outermost maximum transverse width of ear lobule and caudal most attachment of earlobe) as shown in plate 3.

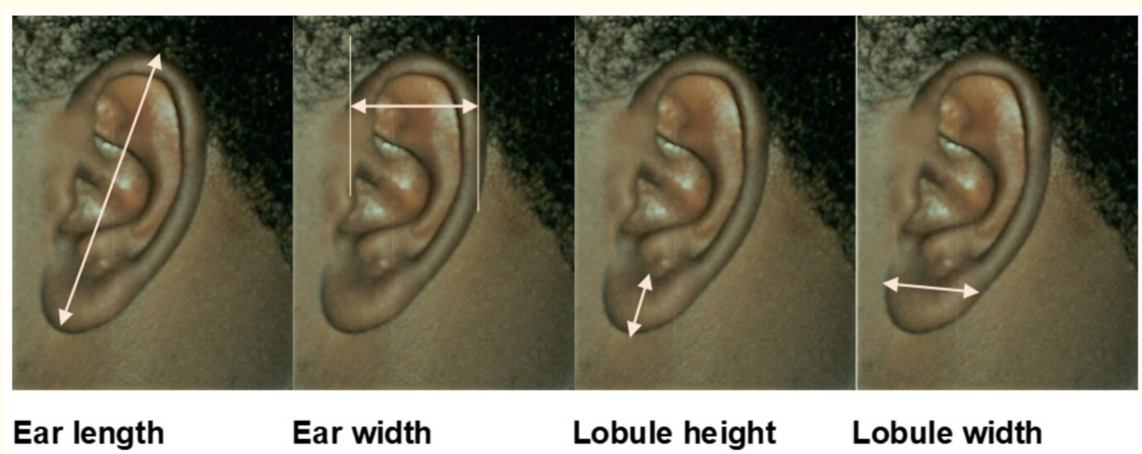

Plate 3: *A: Indicates pinna length, B: Indicates pinna width.*

Morphological shapes of the Ear

There are four basic morphological shapes of the pinna [16] which includes: Rectangular, Triangular, Round and Oval which were all observed in the subjects of the present study as shown in plate 4.

Ear lobule attachment

The ear lobule attachment is either Attached to the cheek or Free [15] as shown in plate 5. Shape of antitragus: the shape of antitragus is either Prominent, Medium or Flat [17] as shown in plate 6. Shape of concha: the shape of concha is either, Narrow, Proportionate or Broad [17].

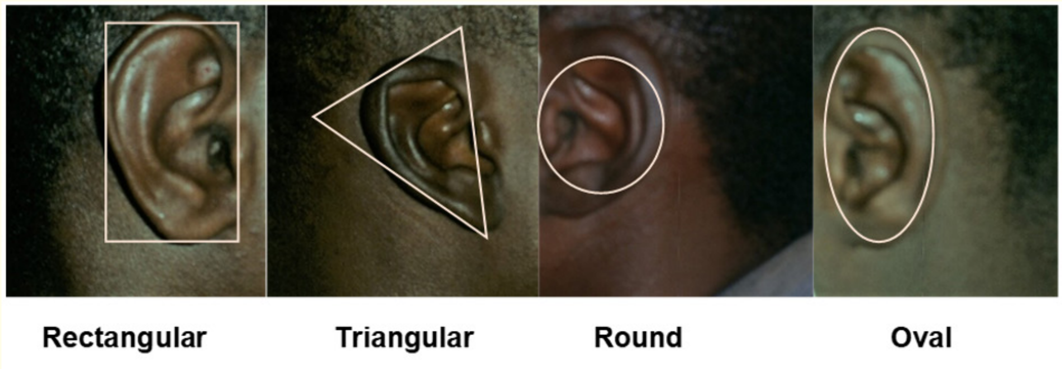

Plate 4: *Four basic morphological shapes of the ear.*

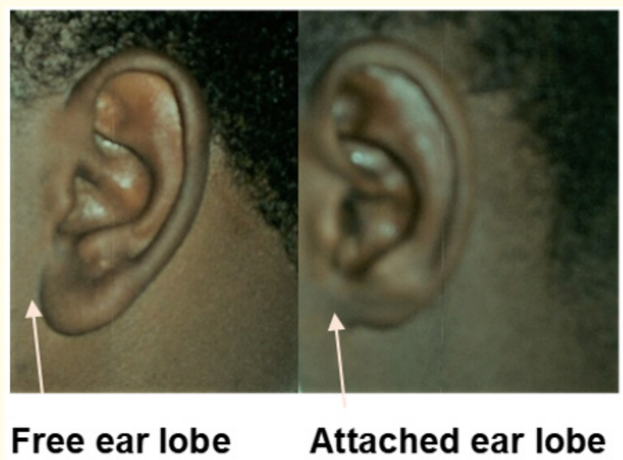

Plate 5: *Ear lobe attachment.*

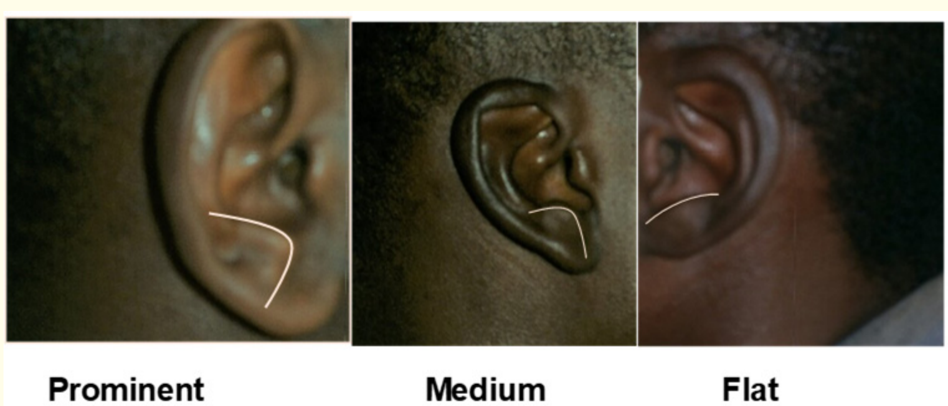

Plate 6: *Antitragus prominence.*

Statistical analyses

The statistical analysis was performed using "SPSS statistic version 20". The ear linear measurements were presented as mean and standard deviation (SD). Right and left side mean pinna linear distances were compared by using "independent sample *t*-test", likewise the test for the linear measurement between males and females. The crosstabulations were made and chi-square tests were performed on cross tabulations to evaluate significant relationship between the discrete parameters of both genders. Values of $P < 0.05$ were considered as significant.

Results

The total number of the participants was 200 (153 males, and 47 females) with age ranged from 16-35 years. From the analyses, the mean right pinna length for males was 56. 61 mm (SD = 4.20), for the left was 56.59 mm (SD = 4.23). The mean right pinna length for females was 53.82 mm (SD = 4.66). The mean right pinna width for males was 36.40 mm (SD = 2.55), for left was 36.53 mm (SD = 2.76), for the females' right and left pinna width was 32.06 mm (SD = 3.09) and 31.82 mm (SD = 3.16) respectively. Likewise, the mean lobule height of the males' right and left pinna was 14.08 mm (SD = 1.84) and 13.82 mm (SD = 2.02) respectively, and that of females was 13.67 mm (SD = 1.99) and 13.56 mm (SD = 1.90). Similarly, for the lobule width of males' right and left was 17.13 mm (SD = 2.0) and 17.11 mm (SD = 2.03) respectively, and that of females' right and left was 14.92 mm (SD = 1.74) and 14.72 mm (SD = 1.59) respectively.

To determine sexual dimorphism or right and left side variations, distances were compared using "independent sample t-test". Results indicated statistically significant sexual differences between males and females ($P < 0.05$) with males having larger values in all dimensions (Table 1 and 2) except in the lobule's height ($P > 0.05$). However, no significant differences between right and left pinnae in all distances in both males and females (Table 3 and 4) as P was greater than 0.05.

Variables	Males (n = 153) Mean ± SD	Females (n = 47) Mean ± SD	t-test	P-value
Ear length (mm)	56.61 ± 4.20	53.82 ± 4.66	3.88	< 0.001
Ear width (mm)	36.40 ± 2.55	32.06 ± 3.09	9.68	< 0.001
Lobule height (mm)	14.08 ± 1.84	13.67 ± 1.99	1.31	0.19
Lobule width (mm)	17.13 ± 2.00	14.92 ± 1.74	6.79	< 0.001

***Table 1:** Comparison of the measurements between males' and females' right pinnae (n = 200).*

Variables	Males (n = 153) Mean ± SD	Females (n = 47) Mean ± SD	t-test	P-value
Ear length (mm)	56.59 ± 4.23	53.57 ± 4.78	4.14	< 0.001
Ear width (mm)	36.53 ± 2.76	31.82 ± 3.16	9.86	< 0.001
Lobule height (mm)	13.82 ± 2.02	13.56 ± 1.90	0.78	0.19
Lobule width (mm)	17.11 ± 2.03	14.72 ± 1.59	7.39	< 0.001

***Table 2:** Comparison of the measurements between males' and females' left ear (n = 200).*

Variables (mm)	Right (n = 153) Mean ± SD	Left (n = 153) Mean ± SD	t-test	p-value
Ear length (mm)	56.61 ± 4.20	56.59 ± 4.23	0.25	0.8
Ear width (mm)	36.40 ± 2.55	36.53 ± 2.76	0.38	0.71
Lobule height (mm)	14.08 ± 1.84	13.82 ± 2.02	0.28	0.78
Lobule width (mm)	17.13 ± 2.00	17.11 ± 2.03	0.60	0.55

***Table 3:** Comparison of the measurements between males' right and left pinnae (n = 153).*

Variables	Right (n = 47) Mean ± SD	Left (n = 47) Mean ± SD	t-test	P-value
Ear length (mm)	53.82 ± 4.66	53.57 ± 4.78	0.25	0.8
Ear width (mm)	32.06 ± 3.09	31.82 ± 3.16	0.38	0.71
Lobule height (mm)	13.67 ± 1.99	13.56 ± 1.90	0.28	0.78
Lobule width (mm)	14.92 ± 1.74	14.72 ± 1.59	0.60	0.55

Table 4: *Comparison of the linear measurements between females' right and left ear (n = 47).*

Morphological shapes of the pinnae

The results showed that the percentages in males were 30% oval, 28.1% round, 30.7% triangular and 11.1% rectangular, while for the females were 21.3% oval, 31.9% round, 44.7% triangular and 2.1% rectangular (Figure 1). This shows that the triangular shape ear was dominant in both sexes, while the rectangular was the least, with symmetry of both left and right pinnae within individuals. Comparative analysis using chi-square test, showed no significant association in terms of morphological shapes of pinnae between males and females (P = 0.91).

Type of ear lobule attachments

The total percentages of the free and attached ear lobes (irrespective of sex) were noted in males as 82.4% attached and 17.6% free and 55.3% attached and 44.7% free in females. This shows that the attached ear lobes are more dominant in both sexes but with higher percentage in males than in females (Figure 1) without any statistically significant difference between sides or sexes using Chi-Square test.

The shape of antitragus

The percentages of prominent, medium and flat antitragus were noted as 5.9% prominent, 26.1% medium and 68% flat among males, while 10.6% prominent, 31.9% medium and 57.4% flat shapes in females (Figure 1). This shows that the flat shape antitragus is more dominant in both sexes, followed by medium, and then prominent. Analysis of chi-square test showed no association with regards to the shapes of the antitragus between males and females (P = 0.33).

Shape of concha

The percentages of narrow, proportionate and broad concha shapes were noted as 13% narrow, 51% proportionate and 36% broad in males, while 21.2% narrow, 59.6% proportionate and 19.2% broad in females. This shows that the proportionate shape concha is more dominant in both sexes (Figure 1). No side differences in both sexes and no sexual dimorphism was noted from the Chi-square test (P = 0.71).

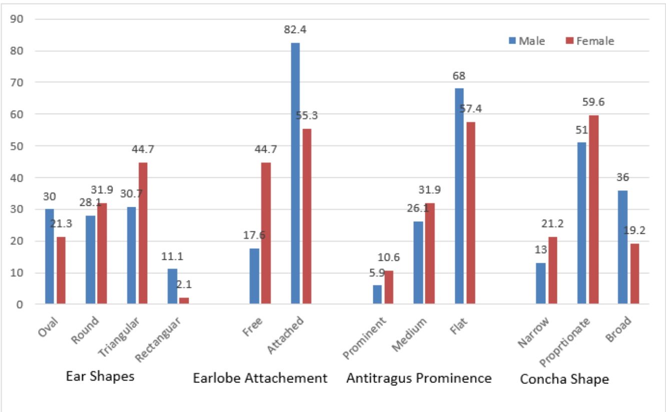

Figure 1: *Morphological ear shapes, earlobe attachment, antitragus prominence and concha shape.*

Discussion

In the present study, the measurements and morphological shapes were compared with those of the other races in the world. The ear morphometry of the subjects in the present study indicated some similarity with that of Indians, Caucasians and Afro-Caribbean adults [18] except for the pinna length which was slightly higher in their study. However, Skaria., *et al.* noted that Indians had the longest pinna, followed by the Caucasians and finally Afro-Caribeans [18].

Similarly, sexual dimorphism exists in most of the pinna dimensions, as seen in Nigerians [6,19], Indians [20,21] and in Chinees [22]. It has been opined that beyond 20 years of age, the size increase is basically attributable to secondary elongation of the earlobes due to gravitational forces (Manning., *et al.* 2002). Tan., *et al.* observed that auricular measurements increased significantly with age in both sexes and these changes were associated with changes in the elastic fibers which are noted faster in males than females (Tan., *et al.* 1994) and the ear height is significantly affected by aging [21].

The results of several studies have shown that the mean length of the male external ear is higher than that of the mean length of the female ear in different age groups and population [21,23,24]. In the present study, the mean difference of the ear length of both sides were significantly greater in males than that of the females. Kalcioglu., *et al.* revealed a statistically insignificant difference in the mean ear width between females and males [25]. *Farkas* have stated that male ears are wider than the females but are not significantly different. Ferrario worked out in Italy subjects in between adolescence to mid adulthood and found that males had wider ear than that of the females and also found that male mean length of ear is significantly higher than that of the females [24]. Healthcote., *et al.* [26] reported that men had larger ear in all the parameters than women, and also mentioned that ears increase in length and in width with increase in age. He concluded that inclusive size of the external ear varies according to the ethnic groups.

According to the research conducted in Maiduguri, Nigeria, the average lobular width and the average total ear height between the males and females were almost identical and, in all parameters, taken, the males had longer maximum distances when compared to those from females [19]. This is similar to what was obtained in the present study, but totally different to findings of Shireen., *et al* [27].

This similarity between the findings of this current study and those of Maiduguri study is very likely to be due to the similarity in both environment and genetic makeup (due to inter-marriage), which may also be the reasons for the differences between the findings of the present study and those from the study of Shireen., *et al* [27].

To buttress this statement, Purkait and Singh's study [28], reported different finding in Indian auricular length to be lower than that of any ethnic groups, whereas, Alexander., *et al.* [18] study, showed the higher value. It means therefore, ethnicity is an important factor in determining ear length apart from other factors. Thus, the auricular length, width and other ear parameters can be useful in diagnosing various ailments including microtia or craniofacial syndromes that can be observed with disproportionately wide or narrow ears. Wide ears are observed in Apert and Crouzon syndromes, and narrow ears are seen in patients with a cleft lip and palate [28]. The present study was from an adult population and show generally good symmetry between left and right ears which concurs with previous study [29].

With regard to the ear lobule attachment, it was clearly reported to be an interesting marker in population genetics [30] and in the present study, both populations showed greater percentage of attached ear lobe (76%), similar to what Sharma., *et al.* found on northwest Indian population [31]. However, the findings of the current study were contrary to the findings of Lai., *et al.* and Verma., *et al.'s* studies among the Japanese and rickshaw drivers of central India respectively [32,33]. This might possibly be due to the difference in ethnicity and genetic backgrounds of the study populations. Long ago, Gate observed that the attached ear lobule is possibly an African character with recessive inheritance pattern [34].

While comparing images of ear for identification in forensic cases, before forensic analyses, one can visually compare the ear shape characteristics to locate any variation. For example, if the shape of an ear is oval in the known subject and round in the subject in question, then there is absolutely no reason to proceed for any further investigation on the 'questioned' subject. Moreover, several ear characteristics are related to different features of the ear, hence even if partial image is available in a 'questioned' ear, the feature characteristics seen in the 'questioned' image can be compared to the known ear sample [33]. These applications are not restricted to a particular population but it can be applied to any ethnic group. In the present study, majority of the study population have triangular shaped ear, which is contrary to the ears of north Indian population where they have oval shaped ears [3] and thus Hausa population can be identified from north Indian population just from the shape of their ears. This is in keeping with the results of Purkait., *et al.*'s study on a large sample (2661 subjects) in Central India, where the authors indicated that the shape of ears, lobule, tragus, upper helix and anti-helical border around the concha are all different even bilaterally in the same individual [17,35].

Conclusion

It is clear that an ear aid for left will do for the right ear of the same subject but may not fit another individual. Similarly, an ear aid made for a man may not fit a female of the same age range and race because of sexual dimorphism. Identification of an individual's ear is easy since shapes vary between individual of the same tribe.

Acknowledgments

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Bibliography

1. Kritscher H., *et al*. "Identifying a bank robber". *Acta Medicinae Legalis* 19 (1994): 337-344.

2. Saul FP and Saul JM. "Planes, trains and fireworks". In Hard evidence: Case Studies in Forensic Anthropology (Ed. Steadman, D. W.). Engle wood Cliffs, NJ: Prentice Hall (2003): 266-277.

3. Pradhuman V., *et al*. "Morphological Variations and Biometrics of Ear: An Aid to Personal Identification". *Journal of Clinical Diagnostic Research* 10.5 (2016): ZC138-ZC142.

4. Abbas A and Rutty GN. "Ear piercing affects ear prints: The role of ear piercing in human identification". *Journal of Forensic Science* 50.2 (2005): 386-392.

5. Laxman Konduru. "A Study of Determination of Stature in Hyderabad Population from External Ear Morphometry". *Medico-legal Update* 19.1 (2019): 164-168.

6. Alabi AS., *et al*. "Anthropometric analysis of auricular indices for sex and stature determination among Okun and Igala ethnic groups of Kogi State, Nigeria". *Journal of Environmental Toxicology and Public Health* 4 (2019): 6-14.

7. Imhofer R. "Die Bedeutung der OhrmuschelFiirFeststellung der Identitat". *Archivfiir die Kriminologie* 26 (1906): 150-163.

8. Meijerman L., *et al*. "Inter- and intra-individual variation in applied force when listening at a surface and resulting variation in ear-prints". *Medical Science Law* 46.2 (2006): 141-151.

9. Van der Lugt C. "Report about the research on ears and earprints, Second International Ear Course. Zutphen (Netherlands)/Durham (UK): Dutch Police College/National Training Centre NTCSSCI, (1999) Research, Proceedings of the First International Conference on Forensic Human Identification in the Next Millennium (1999).

10. Arora L and Singh V. "Morphometric study of human auricle in the age group of 18-24 years in North West part of India". *Global Journal of Medicine and Public Health* 5.6 (2016).

11. Sangeetha S and Venkata Krishna. "Morphometric Measurements of Human External Ear in student Population". *Journal of Medical Science and Clinical Research* 6.6 (2018).

12. Jung SH. "Surveying the dimensions and characteristics of Korean ears for the ergonomic design of ear related products". *Journal of Indian Ergonomic* 31.6 (2003): 361-373.

13. Musa Acar., *et al*. "Comparison of some Morphometric Parameters of the Ear on Turkish and African Students". *Asian Journal of Biomedical and Pharmaceutical Sciences* 7.60 (2017).

14. Farkas LG. "Anthropometry of the normal and defective ear". *Clinical Plastic Surgery* 17.2 (1990): 213-221.

15. Schwalbe G. "Zur Methodic statischer Untersuchungen uber dieOhrformen von Geisteskranken und Verbrechem". *Archiv für Psychiatrie und Nervenkrankheiten* 27 (1875): 633-644.

16. Dhanda V., *et al*. "Studies on the development of latent ear prints and their significance in personal identification". *Problems of Forensic Science* 138 (2011): 285-295.

17. Purkait R. "Ear biometrics: an aid to personal identification". *Anthropologist* 3 (2007): 215-218.

18. Alexander KS., *et al*. "Anthropometric study of the human ear". *Journal of Plastic Reconstruction Aesthetic Surgery* 64.1 (2011): 41-47.

19. Ekanem AU., *et al*. "Anthropometric study of the pinna (auricle) among adult Nigerians resident in Maiduguri metropolis". *Journal of Medical Sciences* 10.6 (2010): 176-180.

20. Deopa D., *et al*. "Anthropometric measurements of external ear of medical students in Uttarakhand Region". *Journal of the Anatomical Society of India* 62.1 (2013): 79-83.

21. Ruku Pandit., *et al*. "Morphometric study of external ear of medical students in college of medical sciences and teaching hospital, Bharatpur, Chitwan, Nepal". *International Journal of Anatomy and Research* 5.3.2 (2017): 4269-4274.

22. Wang B., *et al*. "Computed tomography of the auricle in Han population of north China". *Journal of Plastic Reconstruction Aesthetic Surgery* 64.1 (2011): 34-40.

23. Farkas LG., *et al*. "Anthropometric growth study of the ear". *Cleft Palate-Craniofacial Journal* 29.4 (1992): 324-329.

24. Ferrario VF., *et al*. "Morphometry of the normal human ear: a cross-sectional study from adolescence to mid-adulthood". *Journal of Craniofacial Genetic Developmental Biology* 19.4 (1999): 226-233.

25. Kalcioglu MT., *et al*. "Anthropometric growth study of normal human auricle". *International Journal of Pediatric and Otorhinolaryngology* 67.11 (2003): 1169-1177.

26. Healthcote JA. "Why do old men have big ears?" *British Medical Journal* 311.7021 (1995): 1668.

27. Shireen S and Vrushali P. "Anthropometric Measurements of Human External Ear". *Journal of Evolution of Medical and Dental Sciences* 4.59 (2015): 10333-10338.

28. Purkait R and Singh P. "Anthropometry of the normal human auricle: a study of adult Indian men". *Aesthetic Plastic Surgery* 31.4 (2007): 372-379.

29. Sforza C., *et al*. "Age- and sex-related changes in the normal human ear". *Forensic Science International* 187.1-3 (2009): 110.

30. Bhasin MK. "Ear lobe attachment among the Newars of Nepal". *Human Heredity* 19.5 (1969): 506-508.

31. Sharma A., *et al*. "Morphometric study of ear lobule in northwest Indian male subjects". *Anatomical Science International* 82.2 (2007): 98-104.

32. Lai LY and Walash RJ. "Observation on ear lobe types". *Acta Genetica Basel* 16 (1966): 250-257.

33. Verma K., *et al*. "Morphological variations of ear for individual identification for forensic cases: a study of an Indian population". *Journal of Forensic Science* 2.1 (2014): 1-8.

34. Gates RR. "Etudes sur le croissement de races (III Nouvelles observations concernant les Oreilles, en particulier les lobes)". *Journal of Human Genetics* 3 (1954): 95-112.

35. Standring S., *et al*. "Gray's Anatomy". 40th edition. London: Churchill Livingstone External ear (2008): 618.

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