Morphometric Analysis of External Ear to Estimate the Stature and Sexual Dimorphism in North Indians: A Cross-sectional Study

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ABSTRACT

Introduction: Anthropometry is an essential technique to understand the variations in the human body that is implicated during various reconstructive surgical procedures, and for the identification of individual during crime scene in forensics. Analysis of ear morphology plays a role in understanding the sexual dimorphism and stature in the human population. It has been found that the ear morphology changes from one region to another.

Aim: To study the morphometric parameters of external ear for stature estimation, and to identify sexual dimorphism in north Indian population.

Materials and Methods: This cross-sectional study was conducted among 200 subjects (100 males and 100 females) aged 17-25 years in the Department of Anatomy, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India. The study participants were selected from the medical, dental and nursing undergraduates studying in Banaras Hindu University (BHU). The various aspects of ear morphology (ear length, ear width, lobule length, lobule width) were measured. Student's t-test, Karl Pearson's Coefficient of Correlation and Linear regression equation were calculated.

Results: The mean age for males were 19.17 years and females were 19.52 years. Measurements for ear length, width and lobule width of both ears were higher in males than females. The mean right and left ear length in males were 60.77±3.74 and 59.99±3.83 mm, and that for females were 56.59±3.044 and 55.55±3.68 mm, respectively. The mean right and left ear width in males were 30.60±2.81 and 30.81±2.69 mm and that for females, the values of ear width for right and left ears were 28.55±3.12 and 28.81±2.80 mm, respectively. A strong correlation between right and left ear length and stature in females were observed using linear regression coefficient analysis. The correlation coefficient between stature to right and left ear length in females were 0.55 and 0.51, respectively (p-value=0.030).

Conclusion: Ear length and width, and lobule width of the right and left ears were significantly higher in males. There were no significant differences observed in lobule length. There was a strong correlation between the stature and right and left ear length in females, moderate strength of association was seen in stature with ear width and lobule length in females.

INTRODUCTION

Anthropometry refers to the measurements of living human body dimensions to understand human physical variation. Anthropometric measurements play an important role in plastic surgery, and prosthetics [1,2]. Personal identification means a determination of individuality based on certain morphological criteria unique to that individual. In the case of skeletal remains, identification is more complicated and requires accurate examination of these remains [3]. In humans, the ear is the most defining feature of the face and its structure shows the signs of age and sex [4]. The study of the morphological parameters of the ear like ear length, width as well as measurements of ear lobular length and width can serve as useful tools for estimation of stature and sexual dimorphism [5,6].

The external ear constitutes certain distinctive design features and peculiarities, similar to fingerprints [7]. The size, shape and spatial location of the ear also contribute to the aesthetics of the face [8,9]. The appearance and symmetry of the auricle are essential for facial harmony. The anatomical appearance of the auricle varies from individual to individual and between ethnic races [10]. The shape, size and orientation of each external ear is specific [11]. Features of auricle have been recognised as an important anthropological variable for studying racial variability and for a few genetic abnormalities at an early stage of life [12].

The use of ear morphology and the variations created by its anatomical form are implemented principally for the identification of perpetrators concerning criminal activity [13]. The auricle has been utilised as useful tool by physicians to detect underlying pathologies, by psychologists to provide clues for personality disorders and by criminologists for racial differentiation [14]. As ear morphology tends to be hereditary, ear characteristics may be used for assessment of familial relationships [15]. The external ear is made up of auricle and external acoustic meatus which is utilised in forensic science, for individual identification and authentication [16]. The shape of the ear is fixed since birth and never changes unless there is physical trauma/congenital abnormalities [17].

According to Altmann, the free lobule of the ear is a dominant trait, whereas the attached part of the ear lobule is a recessive trait [18]. The ear morphology and biometric measurements may be used for the identification of bodies in any crime scene [19,20]. It was also shown that in comparison to Caucasian and Japanese populations, the Indian population has smaller ear dimensions morphometrically [21,22]. For forensic investigations, reference databases on ethnic groups are required. People having an abnormal set of ears due to either congenital or acquired causes can undergo corrective surgery, according to the normal measurements based on their ethnicity [23]. For rectifying such abnormalities, plastic surgeons require information about normal auricular dimensions, auricle bilateral position on the face, the general conformations and its variation. However, this auricular data varies in different ethnic groups [24,25].

Hence, the present research aimed to study the morphometry of the ear for stature estimation and to identify sexual dimorphism in

the northern Indian region of Varanasi, Uttar Pradesh. This data may be helpful for forensic experts and cosmetic surgeons.

MATERIALS AND METHODS

This cross-sectional study was conducted among 200 subjects (100 males and 100 females) in the Department of Anatomy, Institute of Medical Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India from October 2018 to July 2020. Purposive sampling was followed, and the first year professional students of the MBBS, BDS and Nursing undergraduates were included. The study was approved by the Institutional Ethical Committee, IMS, BHU (No. Dean/2018/EC/939).

Inclusion criteria: Participants aged between 17-25 years, who were residents of Northern India with parents origin from the same regions were included in the study.

Exclusion criteria: Those participants having obvious deformity of the ear either congenital or acquired were excluded from the study.

Procedure

The procedure and purpose of the study was explained to the students, thereafter consent was taken from them. The basic information of the students was collected like- age, sex, Unmarried, Local Residents of Varanasi. Students were made to relax and sit on a chair with their heads in anatomical positions. A total of five parameters were recorded, that is, the height of the individual, ear length, ear breadth, lobule length, and lobule breadth.

Anthropometric measurements: All the measurements were taken in a well-lit and ventilated room, by one observer to avoid an inter-observer error. Digital Vernier calliper (Aerospace R) for ear measurements and steel tape roll for height measurements were used. All the measurements were taken between 2.00 to 4.30 pm. Standardised measurements of the ear pinna were taken according to the landmarked points for accurate measurement, defined by DeCarlo LT and the methodology was adopted from those stated by Garba SH and Brucker P et al., [26-28].

Parameters:

1. **Stature:** Stature was measured as a vertical distance from the vertex to the floor using a standard anthropometric Frankfurt plane [29].
2. **Total ear length:** Distance between the highest point of the auricle and the lowest point of the ear lobe.
3. **Ear width:** Distance between the most anterior and posterior points.
4. **Lobule length:** Distance from the intertragicincisure to the caudal part of the lobule.
5. **Lobule width:** Horizontal width of the lobule at the midpoint of the lobular height.
- **Total ear length: (A-B)=**
   Highest point of the auricle- Lowest point of the ear lobe

Most anterior point of the auricle-Most posterior point of the auricle

STATISTICAL ANALYSIS

All the data was entered in Microsoft excel sheet 2007. Analysis was done using the Statistical Package for the Social Science (SPSS). Student's 't-test' was applied as a test of significance. The p-value <0.05 was taken as a statistically significant difference. Karl Pearson's Coefficient of Correlation was used to check the strength of correlation. Analysis was done in the form of male to male, female to female and male to female comparison. A linear regression equation was calculated.

RESULTS

Total 200 (100 males and 100 females) participated in the study voluntarily. The mean age of the male and female participants were

19.17±1.11 years and 19.52±1.45 years, respectively. The two-tailed p-value was 0.057 [Table/Fig-1], which was not a significant difference. The mean length and width of the right and left ears in males was found to be 60.77±3.74 mm, 30.60±2.81 mm and 59.99±3.83 mm, 30.81±2.69 mm, respectively; and in females was 56.59±3.04 mm, 28.55±3.12 mm and 55.55±3.68 mm, 28.81±2.80 mm, respectively. There was no significant difference in the mean values of right and left ear length (p-value=0.148), and width (p-value=0.584) in males, but in females it showed a significant difference (p-value=0.030). However, no statistically significant difference was observed between the right and left ear width (p-value=0.542) [Table/Fig-2].

Parameters	Male	Female
No. of participants	100	100
Age (Mean±SD)	19.17±1.11 years	19.52±1.45 years
p-value (two tailed test)	0.057	

[Table/Fig-1]: Showing the mean age distribution and number of participants in the study.

Sex	Side	Ear Length Mean±SD (mm)	p-value	Ear Width Mean±SD (mm)	p-value (two tailed test)
Male	Right	60.77±3.74	0.148	30.60±2.81	0.584
	Left	59.99±3.83		30.81±2.69	
Female	Right	56.59±3.04	0.03	28.55±3.12	0.542
	Left	55.55±3.68		28.81±2.80	

[Table/Fig-2]: Shows the comparison of mean ear length and ear width in males and females.
p-value <0.05 considered significant

No statistically significant difference was observed between right and left ear lobule lengths (p-value=0.094), which were found to be 16.48±2.37 mm and 17.04±2.30 mm, respectively in males. Measurements of the right and left ear lobule widths were 18.21±2.75 mm and 18.08±2.31 mm, and were statistically insignificant (p-value=0.735) in males. The right and left ear lobule length and width of females were 15.97±1.77 mm, 16.53±1.57 mm, (p-value=0.019) and 15.93±2.18 mm, 16.31±2.10 mm, showed no significant difference (p-value=0.212), respectively [Table/Fig-3].

Sex	Side	Ear lobule length Mean±SD (mm)	p-value	Ear lobule width Mean±SD (mm)	p-value (two tailed test)
Male	Right	16.48±2.37	0.094	18.21±2.75	0.735
	Left	17.04±2.30		18.08±2.31	
Female	Right	15.97±1.77	0.019	15.93±2.18	0.212
	Left	16.53±1.57		16.31±2.10	

[Table/Fig-3]: Shows the comparison of mean ear lobule length and ear lobule width in males and females.
p-value <0.05 considered significant

The correlation coefficient between stature and right and left length was found to be 0.22 and 0.23 in males, and 0.55 and 0.51 in females, respectively. Correlation coefficient values for right and left ear widths were found to be 0.10 and 0.23 in males, and 0.39 and 0.24 in females. This is suggestive of a significant correlation between stature and right and left ear lengths in females [Table/Fig-4]. Similarly, the correlation coefficient between stature and right and left ear lobule length and width was significant in females [Table/Fig-5].

DISCUSSION

This study aimed to provide an insight that can strengthen the medical and judiciary system. The study was carried out on 200 individuals, to find the correlation between stature and four ear parameters i.e., ear length, ear breadth, ear lobule length, and ear lobule breadth. A strong correlation was observed between the stature and ear lengths of both ears in females (R=0.5) as compared to males. Moderate strength of association was seen in stature with ear width and lobule length in females.

Sex	Side	Regression equation	Ear length					Ear width				
			Standard error of estimation	Correlation coefficient	p-value	Actual stature	Estimated stature	Standard error of estimation	Correlation coefficient	p-value	Actual stature	Estimated stature
Male	Right	145.34+0.404× Right ear length	6.47	0.22	0.148	169.91± 6.62 cm	169.91±1.51 cm	6.62	0.10	0.584	169.91± 6.62 cm	169.91±0.67 cm
	Left	145.97+0.399× Left ear length	6.47	0.23			169.91±1.52 cm	6.46	0.23			169.91±1.55 cm
Female	Right	93.719+1.110× Right ear length	5.09	0.55	0.030	156.54± 6.08 cm	156.54±3.37 cm	5.62	0.39	0.542	156.54± 6.08 cm	156.54±2.40 cm
	Left	109.943+0.838× Left ear length	5.27	0.51			156.54±3.09 cm	5.94	0.24			156.54±1.46 cm

[Table/Fig-4]: Shows the correlation of ear length and width with stature in males and females.

Sex	Side	Regression equation	Ear lobule length					Ear lobule width				
			Standard error of estimation	Correlation coefficient	p-value	Actual stature	Estimated stature	Standard error of estimation	Correlation coefficient	p-value	Actual stature	Estimated stature
Male	Right	166.53+0.205× Right ear lobule length	6.63	0.07	0.094	169.91± 6.62 cm	169.91±1.51 cm	6.54	0.160	0.735	169.91± 6.62 cm	169.91±1.19 cm
	Left	166.53+0.198× Left ear lobule length	6.64	0.07			169.91±1.51 cm	5.96	0.179			169.91±1.19 cm
Female	Right	135.88+1.293× Right ear lobule length	5.67	0.38	0.019	156.54± 6.08 cm	156.54±2.29 cm	5.96	0.220	0.212	156.54± 6.08 cm	156.54±1.34 cm
	Left	133.924+1.368× Left ear lobule length	5.73	0.35			156.54±2.14 cm	5.61	0.398			156.54±2.42 cm

[Table/Fig-5]: Shows the correlation of ear lobule length and ear lobule width with stature in males and females.

[Table/Fig-6,7] discuss the findings of the present study (ear length and width and ear lobule length and width) with the findings of other research workers [6,29-36].

The mean value of right and left ear length observed in males was 60.77±3.74, 59.99±3.83 mm and in females 56.59±3.044, 55.55±3.69 mm, respectively. Similar findings have been observed in the South Indian population, as well as in North Indian population [Table/Fig-6] [29-32]. In the present study, regression equation was calculated for stature estimation in males for right ear lobule width and the correlation coefficient was found to be 0.16 with Standard Error of Estimation (SEE) ±6.56 [Table/Fig-7].

The findings differ from a study done in Tamil Nadu by Srijith and Murugan M which reported a correlation coefficient of 0.97. with SEE 1.83 [35]. A study done in the Egyptian population by Abdelaleem S and Abdelbaky FF reported a correlation coefficient of 0.829 with SEE 3.37, which again differs from the present study [Table/Fig-6] [36].

In the present study, in females, regression equation for stature estimation with respect to right ear lobule width shows the correlation coefficient 0.220 with SEE 5.96, and that for left ear lobule width correlation coefficient 0.398 with SEE 5.6 [Table/Fig-5]. These findings differ from those of Srijith and Murugan M, and Abdelaleem S and Abdelbaky FF, who reported correlation coefficient of 0.98 with SEE 1.76, and correlation coefficient of 0.806 with SEE 4.98, respectively [35,36]. In this study, the regression constant was higher but the regression coefficient was found to be lower than those by Srijith and Murugan M, and Abdelaleem S and Abdelbaky FF [Table/Fig-7] [35,36]. This highlights the regional differences.

Authors names	Study location	Sex	Sample size	Mean stature	Side	Ear length		Ear width	
						Mean±SD	Correlation coefficient	Mean±SD	Correlation coefficient
Present study	IMS,BHU Varanasi, Uttar Pradesh	Male	100	169.91±6.62 cm	Right	60.77±3.74 mm	0.22	30.60±2.81 mm	0.10
					Left	59.99±3.83 mm	0.23	30.81±2.69 mm	0.23
		Female	100	156.54±6.08 cm	Right	56.59±3.04 mm	0.55	28.55±3.12 mm	0.39
					Left	55.55±3.68 mm	0.51	28.81±2.80 mm	0.24
Srijith and Murugan M [35]	KFMS and Research, Tamil Nadu	Female	50	162.47±8.7 cm	Right	63.74 ±7.19 mm	0.97	36.45 ±3.13 mm	0.97
					Left	63.73±7.21 mm	0.98	36.44±3.15 mm	0.97
Abdelaleem S and Abdelbaky FF [36]	MU and FM Egypt	Male	120	167.83±8.38 cm	Right	65.41±5.89 mm	0.96	63±6.83 mm	0.93
					Left	65.72±5.49 mm	0.96	62.15±6.7 mm	0.829
		Female	80	164.2±9.91 cm	Right	-	0.898	-	0.925
					Left	-	0.863	-	0.825
Laxman K [6]	OMC Hyderabad	Male	180	-	Right	-	0.963	-	0.930
					Left	-	0.956	-	0.930
		Female	120		Right	-	0.898	-	0.94
					Left	-	0.898	-	0.930

Taura MG et al., [34]	BU Nigeria	Male+Female	219	-	Right	-	0.29	-	0.35
					-	-	0.28	-	0.30
Nigam R et al., [32]	RMCH&RC Kanpur, Uttar Pradesh	Male	62	-	Right	6.25±0.88 cm	-	31.47±2.77 mm	-
					Left	6.22±0.69 cm	-	31.61±2.636 mm	-
		Female	58	-	Right	5.93±0.52 cm	-	30.09±2.876 mm	-
					Left	5.91±0.44 cm	-	30.16±2.741 mm	-
Sangeetha S and Venkata Krishna BR [30]	TOMCH and RC Bangalore Karnataka	Male	192	-	Right	6.12±0.40 cm	-	3.38±0.33 cm	-
					Left	6.03±0.54 cm	-	3.35±0.68 cm	-
		Female	192	-	Right	5.55±0.44 cm	-	3.14±0.47 cm	-
					Left	5.48±0.38 cm	-	3.14±0.36 cm	-
Yadav VD et al., [31]	SMS Medical College Jaipur Rajsthan	Male	129	-	Right	6.12±0.40 cm	-	3.24±0.34 cm	-
					Left	6.03±0.54 cm	-	3.09±0.39 cm	-
		Female	129	-	Right	5.55±0.44 cm	-	2.80±0.37 cm	-
					Left	5.48±0.38 cm	-	2.65±0.36 cm	-
Sidera S and Vrushali P [29]	BRIMS, Bidar, Karnataka	Male	77	-	Right	6.42±0.61 cm	-	3.24±0.34 cm	-
					Left	6.19±0.44 cm	-	3.09±0.39 cm	-
		Female	70	-	Right	6.34±0.39 cm	-	2.80±0.37 cm	-
					Left	6.14±0.45 cm	-	2.65±0.36 cm	-

[Table/Fig-6]: Shows a comparative study on ear length and width of different researchers with the present study [29-32,34-36].

Authors names	Study location	Sex	Sample size	Mean stature	Side	Ear lobule length		Ear lobule width	
						Mean±SD	Correlation coefficient	Mean±SD	Correlation coefficient
Present study	IMS,BHU Varanasi, Uttar Pradesh	Male	100	169.91±6.62 cm	Right	16.48±2.37 mm	0.07	18.21±2.75 mm	0.16
					Left	17.04±2.30 mm	0.07	18.08±2.31 mm	0.179
		Female	100	156.54±6.08 cm	Right	15.97±1.77 mm	0.38	15.93±2.18 mm	0.22
					Left	16.53±1.57 mm	0.35	16.31±2.10 mm	0.398
Srijith and Murugan M [35]	KFMS and Research, Tamil Nadu	Female	50	162.47±8.7 cm	Right	20.30±4.09	0.98	20.29 ±4.00	0.98
					Left	20.28±4.08	0.98	20.24 ±3.98	0.98
Abdelaleem S and Abdelbaky FF [36]	MU and FM Egypt	Male	120	167.83±8.38 cm	Right	65.41±5.89	0.806	19.68±3.76	0.916
					Left	65.72±5.49	0.782	21.14±3.01	0.85
		Female	80	164.2±9.91 cm	Right	63±6.83	0.664	19.09±4.01	0.893
					Left	62.15±6.7	0.337	19.58±3.16	0.797
Nigam R et al., [32]	RMCH and RC Kanpur, Uttar Pradesh	Male	62	-	Right	1.90±0.30 cm	-	1.96±0.31 cm	-
					Left	1.83±0.31 cm	-	2.02±0.65 cm	-
		Female	58	-	Right	2.02±0.30 cm	-	1.89±0.35 cm	-
					Left	2.09±0.64 cm		2.00±0.54 cm	-
Sangeetha S and Venkata Krishna BR [30]	TOMCH and RC Bangalore Karnataka	Male	192	-	Right	2.21±0.34 cm	-	2.62±0.39 cm	-
					Left	2.12±0.27 cm	-	2.35±0.33 cm	-
		Female	192	-	Right	2.17±0.30 cm		2.44±0.42 cm	
					Left	2.07±0.23 cm		2.31±0.38 cm	
Yadav VD et al., [31]	SMS Medical College Jaipur Rajsthan	Male	129	-	Right	2.21±0.34 cm		2.62±0.39 cm	-
					Left	2.12±0.27 cm		2.35±0.33 cm	
		Female	129	-	Right	2.17±0.30 cm		2.44±0.42 cm	
					Left	2.07±0.23 cm	-	2.31±0.38 cm	
Japatti SR et al., [33]	ACPMD and H Maharastara	Male	49	-	Left	11.39±2.53 mm	-	19.69±3.33 mm	-
					Right	11.57±2.69 mm	-	20.14±2.872 mm	-
		Female	107	-	Left	11.28±2.53 mm	-	18.79±3.188 mm	-
					Right	11.27±2.58 mm	-	18.86±3.223 mm	-

[Table/Fig-7]: Published researches on ear lobule length and ear lobule width [30-33,35,36].

Linear regression equations for stature estimation was calculated using all the mentioned variables. These regression equations were checked for their accuracy by comparing the estimated stature and actual stature.

Limitation(s)

The present study was conducted on a limited number of participants. Study of a larger group may provide additional information and give further insight regarding ear morphometric correlation with stature. Measurements obtained may have been subjected to inter-observer variation. As this study was done exclusively on participants with ethnic origin from north India, variations in other ethnic groups were not assessed. These may be studied to get additional information regarding morphometric correlation of stature with ear dimensions in other populations.

CONCLUSION(S)

There was a significant correlation between stature and ear parameters such as ear length, width as well as lobular length and width. This positive correlation has been observed to be more significant about the stature estimation of females. In this regard, it may be thus concluded that ear parameters may serve as a useful tool for the determination of sexual dimorphism in case of unknown identity.

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