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# Ear morphometry on Indian Americans and its clinical importance

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**Abstract**
**Objectives:** The aim is to determine the normal average values of ear liner measurements and to determine any significant sex differences exists in Indian Americans.
**Methods:** The direct ear anthropometric measurements were carried out using digital caliper in 100 (men, women) Indian American students (18 to 30 years) of American University of Antigua (AUA), Antigua and compared between the sexes.
**Results:** Ear linear measurements showed higher value in men than women. The length of the ear was higher when compared to width in both sexes. Ear index was higher in men than women. These results support the sexual dimorphism does exist and shows the statistically significant difference between the sexes.
**Conclusion:** The ear anthropometry clinically important for the treatment of congenital deformities, traumatic injured ears and also for establishing baseline data for forensic scientists in personal identification. Present study's data can be used as a reference value for Indian Americans which can be made use of if they need to undergo otoplasty in the USA.

**Keywords:** Ear; morphometry; ear width; ear index; ear length

## 1. Introduction
The outer ear is a defining feature for the face. The studies of the outer ear is clinically important for the treatment of congenital deformities and the traumatic injured ears. The outer ear consists of the auricle (pinna), ear canal and an eardrum outer layer, which collects sound waves and directs them into the ear. The only visible part of the ear is auricle, which is made up of cartilage and soft tissue that helps in keeping a particular shape, with flexibility (Standring, 2008) [1]. The auricular appearance and symmetry contribute enormously to the facial aesthetics. Malformations of the external ear can be a consequence of hereditary disease, or injuries due to environmental factors such as trauma, radiation and infection. Otoplasty can improve the shape, position or proportion of the ear. It can correct a defect in the ear structure that is present at birth or it can treat misshapen ears caused by injury. Otoplasty surgery is becoming popular, nowadays [2, 3].
In 2014, nearly 16 million cosmetic procedures were performed in the Unites States of America (USA) alone [4]. The number of cosmetic procedures performed in the United States has almost doubled since the start of the century. 92% of cosmetic procedures were performed on women in 2014 up from 88% in 2001 [5]. Otoplasty made up 10.7 percent of all cosmetic surgical procedures performed in 2013, with more than 6,871 procedures in the USA [6].
However, before rectifying such abnormalities, a otoplastic surgeon should have data available to define the limits of normal ear shape, size and orientation. The human ear can be found in many shapes and sizes and are influenced by various factors including age, sex, ethnicity, socioeconomic status, environment and region (Heidari *et al*. 2009; Last, 1981) [7, 8]. The increased use of cosmetic procedures crosses racial and ethnic lines in the U.S.A, with the increase seen among African-Americans, Asian Americans and Hispanic Americans as well as Caucasian Americans. In Asia, cosmetic surgery has become more popular, and countries such as China and India have become Asia's biggest cosmetic surgery markets [9].

In the field of facial anthropometry, Farkas' has done the research extensively in many ethnic groups (Farkas *et al*., 2005) [10]. Facial morphometry is well discussed in Caucasians (Farkas *et al*., 2005) [10] and African Americans (Ofodile *et al*., 1993) [11] but, only a limited number of studies exist for Asian Americans (Sim *et al*., 2000) [12].

Results of the studies conducted in certain ethnic groups or regions may not be applicable to the populations elsewhere (Siddiqui and Shah, 1944) [13]. Therefore there is a need for systematic study for each ethnic groups or region.

There are very few anthropometric studies that have dealt with different migrant ethnic groups in the USA. Indian Americans are the second-fastest growing ethnic group in the United States of America (USA). Most of the studies on ear anthropometric measurements in the USA have been done in Caucasians and therefore may not be applicable for Indian Americans.

A study carried out in India observed that North-west Indians have smaller ear lobules when compared to Caucasian and Japanese populations but similar to those found among the Onge tribe of Andhra (India) and Newars of Nepal (Sharma *et al*., 2007) [14].

A few studies have been conducted on ear anthropometry in Indian populations within India (Purkait, 2015a; Purkait, 2015b; Mohamed *et al*., 2014; Deopa *et al*., 2013; Alexander *et al*., 2011; Purkait and Singh, 2007) [15-20]. But, the available literature search shows a study performed by Husein *et al*. (2010) [21] dealing only with 100 Indian American Woman's face by using photographs. However, there are no reports available on the ear anthropometry in Indian American population. Ear anthropometric data specific to Indian Americans will be useful if in case they need to undergo otoplasty surgeries.

Hence, the aim of the present study is to determine the normal average values of ear liner length and width measurements and ratios in Indian Americans, and if there exist any significant differences in the measurements among the sexes.

## 2. Materials and Methods

### 1. Subjects

The study group consisted of 100 Indian American students of American University of Antigua (AUA), Antigua, with equal number of men and women. To minimize the effect of aging on the facial proportion, the subjects were between the ages of 18-30 years. This study was approved by AUA ethics committee. The subjects with previous history of developmental and neurological defects of facial region, tumor, trauma or previous surgery to the pinna and mixed parental ethnicity were excluded in this study.

This study was funded by School of Medicine, AUA, Antigua. The study was explained and the standard informed consent was obtained from the participants prior to the study. The anthropometric landmarks were identified on the subjects with careful inspection and then marked on the ear with black liquid eye liner (Table1) (Figure 1).

### 2. Landmarks (ear) (Table1) (Figure 1)

**Paired landmark:** pra, preaurale; pa, postaurale; sa, superaurale; sb, subaurale; t, tragion.

**Table 1:** Ear anthropometric land marks

| | | |
|---|---|---|
| **pra** | preaurale | most anterior point of the ear |
| **pa** | postaurale | most posterior point on the auricle |
| **sa** | superaurale | highest point on the auricle |
| **sb** | subaurale | lowest point on the free margin of the auricle |
| **t** | tragion | upper margin of the tragus |

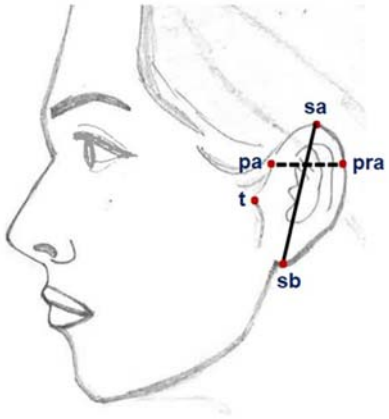


**Fig 1:** Photograph shows the ear anthropometric landmarks and linear measurements. pra, preaurale; pa, postaurale; sa, superaurale; sb, subaurale; t, tragion. Ear linear measurements: ear width (pra-pa); ear length (sa-sb).

### 3. Position of the subjects

Subjects were asked to sit in an upright relaxed position "natural and normal" erect posture of head and shoulders, with both arms hanging free beside the trunk for the linear measurements of the ear (Farkas *et al*., 2005) [10].

### 4. Direct Anthropometric measurements (Manual measurement) (Packiriswamy *et al*., 2012) [22]

The following measurements were done up to 0.5 degree and 0.5 mm accuracy on the subjects with maximum care and comfort by using Neiko 01407A stainless steel digital caliper with extra-large LCD (liquid crystal display) screen and instant SAE-metric (Society of Automotive Engineers) conversion, New York, USA. Every measurement was obtained thrice by the same observer. A third reading was taken if the initial two measurements showed a large discrepancy, and the two closer readings were used (Figure 2).

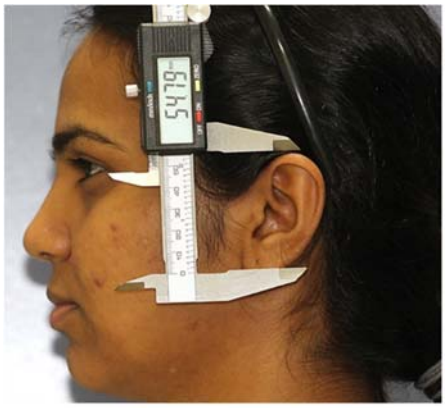

**Fig 2:** Photograph shows the sample nose linear measurement using digital caliper.

**4.1. Ear linear distances (unit: mm)** (Figure 1)
Ear width (pra-pa)
Ear length (sa-sb)

**4.2. Ear ratio**
**4.2.1. Ratio of vertical to horizontal measurement:**
Ear width to ear length (pra-pa/sa-sb)

**5. Statistical analysis**
Data was collected and analyzed in accordance with the current law about personal data and privacy. The statistical analysis was performed using "Graph pad instat" (Version 3.06, Graph pad Software Inc.), San Diego, CA. The ear linear distances were presented as mean and standard deviation (SD). Right and left side mean ear linear distances were compared by using "paired *t*-test". The ear linear distances were compared between sexes by using "Independent t test". Values of $p < 0.05$ were considered as significant. Ear ratio was calculated.

**3. Results**
The present study establishes the basal values for various parameters of the ear amongst Indian American students of American University of Antigua (AUA).

**Descriptive statistics of the ear anthropometric measurements**
The mean and standard deviation (SD) of right and left ear linear anthropometric measurements of Indian Americans are shown in Tables 2 and 3. The mean values of ear anthropometric measurements of Indian American men showed higher value when compared to Indian American women. On comparing length and width of the ear, it was found to be higher in the length of the ear in both sexes (Tables 2 and 3).

**Table 2:** Comparison of ear measurements in Indian American men (mm) (n=100)

| Measurements | | Mean | | Mean | | Mean | | p value |
|---|---|---|---|---|---|---|---|---|
| | | Right side (SD) | | Left side (SD) | | (rt & lt) | | |
| 1 | ear width (pra-pa) | 32.04 (6.96) | | 32.25 (7.19) | | 32.15 | | 0.030* |
| 2 | ear length (sa-sb) | 60.27 (8.46) | | 60.29 (8.61) | | 60.28 | | 0.814 |
| 3 | ear width to ear length ratio | 0.56 (0.27) | | 0.56 (0.29) | | 0.56 | | 0.018* |
| Ear width to length ratio (pra-pa/sa-sb); SD - standard deviation; * - significant; rt -right; lt - left; | | | | | | | | |
| p < 0.05 were considered as significant. | | | | | | | | |

**Table 3:** Comparison of ear measurements in Indian American women (mm) (n=100)

| Measurements | | Mean | | Mean | | Mean | | p value |
|---|---|---|---|---|---|---|---|---|
| | | Right side (SD) | | Left side (SD) | | (rt & lt) | | |
| 1 | ear width (pra-pa) | 28.33 (3.04) | | 28.48 (3.24) | | 28.41 | | 0.229 |
| 2 | ear length (sa-sb) | 54.52 (3.49) | | 54.54 (3.45) | | 54.53 | | 0.803 |
| 3 | ear width to ear length ratio | 0.52 (0.06) | | 0.52 (0.07) | | 0.52 | | 0.311 |
| Ear width to length ratio (pra-pa/sa-sb); SD - standard deviation; * - significant; rt -right; lt - left; | | | | | | | | |
| p < 0.05 were considered as significant. | | | | | | | | |

In this study, right and left side ear linear distances were compared by using "paired t-test". On comparison, the Indian American men ear width (p=0.030*) showed statistically significant whereas the ear length (p=0.814) in Indian American men and ear width (p=0.229) and length (p=0.803) in Indian American women were not statically significant (Tables 2 and 3).

**Comparison of ear anthropometric measurements by sex**
The mean values of ear length, width and ear index in Indian American men showed higher value when compared to Indian American women. The ear length (p<0.0001) and width (p<0.0001) in Indian Americans showed statistical significant sexual difference (Table 4).
These results support the findings that sexual dimorphism does exist and showed the statistically significant difference between the sexes.

**Table 4:** Comparison of Indian American ear measurements by sex

| using "independent t test" | | | | |
|---|---|---|---|---|
| Measurements | | Mean | right side | left side |
| | | p value | p value | p value |
| 1 | ear width (pra-pa) | < 0.0001* | < 0.0001* | < 0.0001* |
| 2 | ear length (sa-sb) | < 0.0001* | < 0.0001* | < 0.0001* |
| * - p value highly significant. | | | | |

**4. Discussion**
The outer ear plays an important role in hearing. Specifically, it alters the amplitude of the incoming sound wave and, in doing so, provides a mechanism for amplifying differentially sounds within the range of frequencies that make up human speech. The outer ear size, shape and spatial location on the face are important from an aesthetic point of view (Purkait and Singh, 2007) [20]. The knowledge of outer ear dimensions may be useful as a guideline for the plastic otoplastic surgeon rectifying possible defects. Ear dimensions vary in different ethnic groups, which is necessary for the otoplastic surgeon's base their examination on the data specific to the ethnic group (Bozkir *et al*., 2006; Ferrario *et al*., 1999) [23, 24]. Comparison of the present study with other studies revealed variations and similarities in the ear measurement. The ear results were compared with the other available data for Indian, Indian American, Caucasian and North American Whites as given in Tables 5 and 6. In Table 5 we have compared men of the present study with men of previous studies and in Table 6 comparison of women of the present study with women of previous studies.
In the present study, the ear anthropometric measurements of Indian American men showed higher value when compared to Indian American women. On comparing length and width of the ear, it was found to be higher in the length of the ear in both sexes. The mean value of the ear width of Indian

American women was consistency with previous study done on Indian women (Deopa *et al*., 2013) [18]. But, the ear width observed on Indian men was higher in the Purkait and Singh's study (2007) [20] and lower in the Deopa *et al*. (2013) [18] study.

The mean value of the ear length of Indian American men had lower value when compared to previous studies done on Indian, Caucasian (Alexander *et al*., 2011) [19] and North American White men (Farkas *et al*., 2005) [10] whereas higher value in Purkait and Singh's Indian study (2007) [20]. But, the ear length of Indian American women had lower value when compared to previous studies done on Indian, Caucasian, North American White and Indian American women (Deopa *et al*., 2013; Alexander *et al*., 2011; Husein *et al*., 2010; Farkas *et al*., 2005) [10, 18, 19, 21]. In this study, the ear length and width in Indian Americans showed statistical significant sexual difference.

**Table 5:** Compilation of ear linear measurements in Indian, Indian American and Caucasian men (mm).

| Authors | Population | Ear width (pra-pa) | | Ear length (sa-sb) | | Ear ratio | |
|---|---|---|---|---|---|---|---|
| | | Right | Left | Right | Left | Right | Left |
| **Present study** | **Indian Americans** | **32.04** | **32.25** | **60.27** | **60.29** | **0.56** | **0.56** |
| Farkas et al. (2005) [10] | Indian | | | 61.1 | 61.1 | | |
| Farkas et al. (2005) [10] | North American White | | | 62.4 | 62.4 | | |
| Deopa et al. (2013) [18] | Indian | 30.2 | 30.6 | 60.4 | 60.3 | 0.5 | 0.5 |
| Alexander et al. (2011) [19] | Indian | | | 68.9 | 68.9 | | |
| Alexander et al. (2011) [19] | Caucasian | | | 65.2 | 65.2 | | |
| Purkait and Singh, (2007) [20] | Indian men | 34 | 33.1 | 58.2 | 57.7 | 0.59 | 0.57 |
| Ear ratio, ear width to ear length (pra-pa/sa-sb). | | | | | | | |

**Table 6:** Compilation of ear linear measurements in Indian, Indian American and Caucasian women (mm).

| Authors | Population | Ear width (pra-pa) | | Ear length (sa-sb) | | Ear ratio | |
|---|---|---|---|---|---|---|---|
| | | Right | Left | Right | Left | Right | Left |
| **Present study** | **Indian Americans** | **28.33** | **28.48** | **54.52** | **54.54** | **0.52** | **0.52** |
| Farkas et al. (2005) [10] | Indian | | | 57.1 | 57.1 | | |
| Farkas et al. (2005) [10] | North American White | | | 58.5 | 58.5 | | |
| Deopa et al. (2013) [18] | Indian | 28.8 | 28.7 | 57.4 | 57.7 | 0.5 | 0.49 |
| Alexander et al. (2011) [19] | Indian | | | 60.9 | 60.9 | | |
| Alexander et al. (2011) [19] | Caucasian | | | 60.4 | 60.4 | | |
| Husein et al. (2010) [21] | Indian women | | | 58.6 | 58.6 | | |
| Ear ratio, ear width to ear length (pra-pa/sa-sb). | | | | | | | |

According to Purkait and Singh's study (2007) [20], Indian auricular length is lower than that of any ethnic groups whereas, Alexander *et al.* (2011) [19] study showed the higher value. Our study supports the Purkait and Singh (2007) [20] report. The present study data were compared with Indians, Indian American women, Caucasians and North American Whites. We did not compare with other ethnic groups. The auricular length and width can be useful in diagnosing syndromes including microtia or craniofacial syndromes that may present 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 (Purkait and Singh, 2007) [20].

The auricular size continues to increase even during adulthood (Heathcote, 1995) [25]. Our study are mainly from an adult population and show generally good symmetry between left and right ears which concurs with previous study (Sforza *et al*., 2009) [26]. The auricular index in general exhibits a decrease with age, indicating a faster increase in length than in width with aging (Purkait and Singh, 2007) [20]. In this study, ear indices in men were significantly higher than those in women. Deopa *et al*. (2013) [18] found that the ear indices of the both sides showed no statistical difference although left ear indices were found to be higher than the right ear indices for all Indian subjects. Purkait and Singh's study (2007) [20] on ear indices of Indian men showed higher value when compared to present study.

The mean values for all parameters of ear morphometry reported in the literature by different scientists vary in different populations. This could be due to several factors such as differences in age, number of subjects, gender of the subjects and geographical conditions, moreover the method adopted.

These results support the findings that sexual dimorphism does exist and showed the statistically significant difference between the sexes. Kunjur *et al*. (2006) [27] suggested that the aesthetic standards of a particular group may not suit other patients belonging to diverse racial and ethnic background.

It becomes clear from the available literature/data that the soft tissue relationship of Indian adults differs from the North American White standards or others and cannot be applied on each other. Therefore, these findings suggest that it will help to correct the inappropriateness of using other population data as different populations need different standards to carry out otoplastic surgery.

The study done on Indian American women (Husein *et al*., 2010) [21] was based on photographic data. The results possibly due to difference in methodology. The present study has been done by direct measurements, which is more reliable. Significant difference was observed between men and women when compared to the present study; working on live material is found to be superior over photograph. No authentic published data on the Indian American population was available and the available data from the Indian population and Indian American women were significantly different. Hence the need for baseline data for such a big Indian Americans in USA though earlier published data on Indians and North American Whites have shown significant racial differences. The present study clinches on to the racial significant data apart from sex dimorphism.

The climate, dietary, and environment are different in USA when compared to India. The Indian Americans born and bought up in USA environment are quite high. Parameters can be affected by all these factors. But this will not harm the study because our primary aim is to generate preliminary data and this will provide useful information and will be helpful in further study. Further research is very much required on age, ear lobule, shape, axis and angles of Indian Americans to lay down the standards of adoption for otoplastic surgery; however, these preliminary data will provide useful information.

This study also seeks to expand scientific research on ear anthropometry for establishing baseline data for forensic scientists in personal identification (Purkait, 2015a; Purkait, 2015b) [15, 16] and treating congenital or post-traumatic ear disfigurements (Pawar *et al*., 2015) [28] of Indian Americans in the USA.

## 5. Conclusion

The ear anthropometric measurements of Indian American men showed higher value when compared to women. These results support the findings that sexual dimorphism does exist and showed the statistically significant difference between the sexes. The length of the ear was found to be higher when compared to width of the ear in both sexes.

The ear anthropometric measurements are clinically important for the treatment of congenital deformities, traumatic injured ears and also for establishing baseline data for forensic scientists in personal identification. The otoplasty surgeon must understand the common variations of ear anatomy seen in various races of individuals. A successful outcome in otoplasty requires a thorough and accurate preoperative planning, and awareness of the morphological differences. The present study's ear anthropometric data can be used as a reference value for Indian Americans which can be made use of if they need to undergo otoplasty in the USA.

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## Conflict of interest

There are no conflicts of interest to disclose.

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