Original Article

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Does Ear Morphology Establish Automatic Extraction of Soft Biometric Traits?

Anatomy Section

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ABSTRACT

Introduction: The external appearance of auricle varies between ethnic groups. However, there have been no studies on external ear morphometry correlating soft biometrics of the same individual. Therefore, a morphometric databank for the same appears to offer useful data to doctors and computer engineers working with documentation system.

Aim: To correlate the external ear parameters (Total ear height, Lobular width and Lobular height) with biometric parameters (Height, Head circumference and shoulder breadth) of individuals of different Ethnic Group and to correlate the linear measurements of the external ear within individuals of different ethnic groups.

Materials and Methods: From four of Asian ethnic group, 160 students aged between 19 and 25 volunteered for the study. The races include Malaysians, Malaysian Chinese (Chinese residing in Malaysia); Indians; and Malaysian Indian (Indians residing in Malaysia). Linear measurements of ear pinna, Height, Head circumference, and Shoulder breadth of every participant were measured. The data were analysed using SPSS software, through one-way ANOVA and non-parametric Pearson's coefficient.

Results: Except Indian males there was significant correlation existing between height of individuals and total ear height (Malaysian Male $r=0.507$, $p<0.05$; Malaysian Female $r=0.452$, $p<0.04$; Malaysian Indian Male $r=0.463$, $p<0.05$; Malaysian Indian Female $r=0.583$, $p<0.007$; Malaysian Chinese Male $r=0.520$, $p<0.01$; Malaysian Chinese Female $r=0.514$, $p<0.05$. Positive correlation was also found between total ear height and lobular height in Malay (Male; $r=0.566$, $p<0.02$; Female; $r=0.507$, $p<0.009$) and Malaysian Chinese (Male: $r=0.717$, $p<0.001$; Female: $r=0.514$, $p<0.02$) samples. The correlation between shoulder breadth and total ear height was not significant in both males and females of Malaysian Indian ethnic group. There was no positive correlation between head circumference and total ear height in Malaysian Chinese males and Indian females.

Conclusion: From the present study, authors found that there exists a correlation between person's height to his or her total ear height. Correlation of ear morphometry to the head circumference and shoulder length of an individual varied in various ethnic groups. Correlation between different linear measurements of the ear in different ethnic groups also varied. The knowledge of external ear morphometry to the physical characteristics of an individual is necessary for reconstructive surgeries. This knowledge may be used as supportive evidence in the forensic field as the identification landmarks varied in different ethnic groups.

Keywords: External ear, Forensic examination, Identification landmarks, Morphometry, Reconstructive surgery

INTRODUCTION

Establishment of personal identity has widened its scope in recent times noticeably by integrating various morphological traits like face, iris, retina etc. [1]. In recent years the external ear emerged as a possible means for the forensic investigations and establishment of personal identification [2]. There are reports in the recent past that the pinna may be utilised for personal identification of both living and departed persons [3].

The anatomical appearance of the external ear varies from individual to individual and also between different ethnic groups. The adult population generally showed good symmetry between left and right ears, especially the linear dimensions [4]. Total linear height and ear width were the measurements showed differences for men and women [5,6]. Researchers claim that the ear morphometry can be used for estimation of sex and age of the individual [7]. All linear measurements increase steadily in size with age. Meijerman L et al., observed that the length of human pinna increased by 0.18 mm/year in men and 0.16 mm/year in women [8].

Biometrics is a programmed method of identifying or confirming the individuality of an individual based on the morphological and behavioural physical appearance. A flawless biometric should be universal, unique, permanent and collectable [9]. Studies stating the correlation between easy biometric values and ear morphometry is lacking in the literature. This anthropometric ratio is essential for identification purpose and also for medico-legal cases. Authors have undertaken a study to test individuality of the external ear by its relations to other biometric measurements like height, shoulder breadth and head circumference of the individual in different ethnic groups of 19-25 years of age. Here, authors tried to correlate different human biometric tools with that of ear in same individual to find out whether there is any correlation existing between both. This study also focused to correlate linear measurements of the external ear in same individual. Such studies need to be repeated in more populations to prove the 'uniqueness' of ear pinna so that it can be acknowledged as confirmation in the surgical field and Court of Law.

MATERIALS AND METHODS

A prospective observational cohort study was done to investigate the morphological variations of ear pinna and to correlate ear morphometry to different biometric parameters in individuals of selected ethnic groups of Asian population. After obtaining the Institutional Ethical Committee (IEC 386/2016) Approval, from four of Asian ethnic group, 160 students aged between 19 and 25 volunteered for the study (40 from each race, 20 males and 20 females). All of them were university students studying in India. Exclusion criteria were inherited deformities of the ear, trauma or previous surgical treatment of the ear, and visible scar or tumour of external ear, but no participants volunteered had fallen into exclusion criteria. Informed consent was obtained from every participant after giving time to read, understand and clearing their doubts from

participant information sheet. The data collection took three months from July to September 2016 and completed well within the time approved by Institutional Ethical Committee. The races include Malaysians; Malaysian Chinese (Chinese reside in Malaysia); Indians (from India); and Malaysian Indian (Indians reside in Malaysia). The age (in years), sex and ethnic origin of each volunteer were recorded. Observational differences in pattern of ear lobule attachment and presence or absence of Darwin's tubercle were noted. All measurements were done on right ear of the subjects by single investigator. Anthropometric measurements of the external ear were made in sitting position with the head in Frankfort horizontal plane, using Insize Digital Caliper 1112-150. All measurements are recorded in millimetres (mm). The Total Ear Height (TEH) was measured as the distance from the caudal most projection of the lobule to the highest point on the auricle. Lobular Height (LH) was measured as the distance from intertragic incisure from the caudal part of the lobule. Lobular Width (LW) was measured as the horizontal width of the lobule at the midpoint of lobular height [Table/Fig-1] [7]. Head circumference was measured as the maximum circumference of the head above the attachment of the ears to the head, with a HASTHIP non stretchable measuring tape passing just above the ridges of the eyebrows and around the back of the head. Shoulder breadth was measured as the length between tips of both acromion processes of the scapula. For measuring height, authors asked subjects to remove their shoes prior to taking the measurement and to stand with their back to the wall and look directly forward. The back of their feet, calves, bottom, upper back and the back of their head were in contact with the wall. The investigator marked a point (at the level of top of the subjects' head) against a wall and measured up to it from floor using the measuring tape.

[Table/Fig-1]: Linear measurements of external ear: a) total ear height; b) lobular length; c) lobular width

Ethical approval: All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

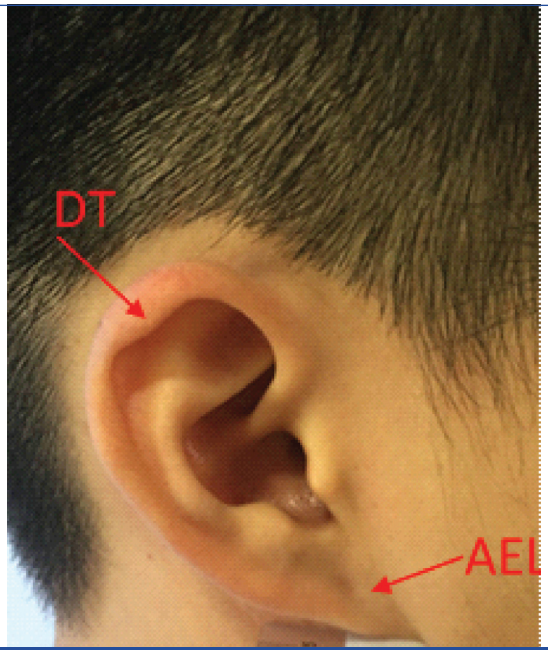
STATISTICAL ANALYSIS

The linear dimensions of the pinna in different ethnic groups were compared using SPSS software, through one-way ANOVA followed by Tukey's test. The p-value <0.05 was considered as significant. The correlation between ear parameters and other soft biometric data were analysed using SPSS, through non-parametric Pearson's coefficient.

RESULTS

55% of Malaysian Chinese had attached earlobes [Table/Fig-2]. Malaysian Chinese males had the largest total ear height (64.44±4.25 mm) when compared to that of other races {Indian male (61.58±2.43 mm), Malay male (62.84±4.76 mm), Malaysian Indian male (63.23±4.56 mm)}. The Malaysian Indian male had the highest lobular height compared to others (19.67±2.77 mm) [Table/Fig-3]. The Indian male had the widest lobular width (22.26±2.39 mm), and was statistically significant when compared to Malaysian Chinese male with p<0.001. The Malaysian Chinese female had ears with greater lobular height than the lobular width, which is found to be a unique pattern. Presence of Darwin's tubercle was more highest in Malaysian Chinese male and the least in Malaysian Indian males [Table/Fig-3].

Data analysis by Pearson's coefficient test revealed that in all ethnic group, except Indian males, there was significant correlation existing between total ear height and lobular height (correlation was significant at 0.05 level, two-tailed). Positive correlation was also found between total ear height and lobular width in Malay and Malaysian Chinese samples [Table/Fig-4]. There was positive correlation between head circumference and total ear height in all ethnic groups except Malaysian Chinese males and Indian females [Table/Fig-5]. The correlation between shoulder breadth and total ear height was found non significant in all ethnic groups except both



[Table/Fig-2]: Presence of Darwin's Tubercle (DT) and Attached Ear Lobules (AEL) in a Malaysian Chinese male.

Race	Sex	Presence of Darwin's Tubercle (N=20/Group)	Earlobe attachment (N=20/Group)	Total ear height in mm (mean±SD)	Lobular height in mm (mean±SD)	Lobular width in mm (mean±SD)
Malaysian Chinese (MC)	male	17	10	64.44±4.25	17.97±2.8	19.06±2.90
Malaysian Chinese (MC)	female	15	12	60.72±3.16	18±1.84	17.02±3.14
Malaysian Malay (MM)	male	16	9	62.84±4.76	18.33±2.30	20.43±2.76b
Malaysian Malay (MM)	female	15	10	59.49±4.45	18.22±3.71	19.13±4.03
Malaysian Indian (MI)	male	14	3	63.23±4.55	19.67±2.77a	20.69±2.04c
Malaysian Indian (MI)	female	16	6	59.68±4.48	18.52±3.06	18.78±2.67
Indian from India (II)	male	15	9	61.58±2.43	18.67±2.88	22.26±2.39d
Indian from India (II)	female	16	6	59.69±4.35	18.77±3.06	20.1±3.01e

[Table/Fig-3]: Observations and measurements of right external ear of different ethnic groups from Asian population. Each value is mean±SD, ANNOVA Significance; p<0.05 is considered as significant
a: MC male vs. MI male: p<0.01; b: MC male vs. MM male: p<0.05; c: MC male vs. MI male: p<0.001; d: MC male vs. MI male: p<0.001; e: MC male vs. II female: p<0.01

males and females of Malaysian Indian ethnic group [Table/Fig-6]. Except for Indian males there was significant correlation existing between height of individuals and total ear height [Table/Fig-7].

Total ear height (Ethnic Group)	Lobular Height p (r)	Lobular Width p (r)
Malaysian male	0.02 (0.566)	0.697 (0.093)*
Malaysian female	0.009 (0.507)	0.604 (0.124)*
Malaysian Indian male	0.001 (0.732)	0.004 (0.613)
Malaysian Indian female	0.007 (0.583)	0.02 (0.508)
Indian male	0.564 (0.137)*	0.702 (0.377)*
Indian female	0.001 (0.671)	0.245 (0.272)*
Malaysian Chinese male	0.001 (0.717)	0.264 (0.262)*
Malaysian Chinese female	0.02 (0.514)	0.05 (0.432)

[Table/Fig-4]: Correlation between linear morphometric ear measurements in different ethnic groups.
The p-value <0.05 considered as significant; r is Pearson's correlation coefficient; *Not significant

Head Circumference (Ethnic group)	Male			Female		
	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)
Malaysian	0.697 (0.093)*	0.360 (0.216)*	0.771 (0.069)*	0.796 (0.062)*	0.375 (0.210)*	0.009 (0.569)
Malaysian Indian	0.07 (0.404)*	0.02 (0.499)	0.02 (0.491)	0.392 (0.203)*	0.146 (0.337)*	0.75 (0.075)*
Indian	0.632 (0.114)*	0.231 (0.281)*	0.555 (0.14)*	0.01 (0.545)	0.184 (0.310)*	0.02 (0.504)
Malaysian Chinese	0.003 (0.636)	0.05 (0.443)	0.270 (0.259)*	0.069 (0.77)*	0.374 (0.210)*	0.63 (0.116)*

[Table/Fig-5]: Correlation between Head Circumference and linear morphometric ear measurements in different ethnic groups.
The p-value <0.05 considered as significant; r is Pearson's correlation coefficient; *Not significant

Shoulder breadth (Ethnic group)	Male			Female		
	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)
Malaysian	0.421 (0.19)*	0.969 (0.009)*	0.708 (0.089)*	0.626 (0.116)*	0.929 (0.021)*	0.46 (0.174)*
Malaysian Indian	0.02 (0.499)	0.03 (0.486)	0.001 (0.752)	0.10 (0.379)*	0.01 (0.559)	0.499 (0.160)
Indian	0.784 (0.065)*	0.334 (0.208)*	0.191 (0.305)*	0.185 (0.309)*	0.120 (0.359)*	0.04 (0.455)
Malaysian Chinese	0.434 (0.185)*	0.646 (0.11)*	0.115 (0.364)*	0.663 (0.104)*	0.401 (0.199)*	0.22 (0.287)*

[Table/Fig-6]: Correlation between Shoulder breadth and linear morphometric ear measurements in different ethnic groups.
The p-value <0.05 considered as significant; r is Pearson's correlation coefficient; *Not significant

Height (Ethnic group)	Male			Female		
	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)	Total ear height p (r)	Lobular Height p (r)	Lobular Width p (r)
Malaysian	0.05 (0.507)	0.674 (0.1)*	0.999 (0.00)*	0.04 (0.452)	0.623 (0.117)*	0.32 (0.235)*
Malaysian Indian	0.05 (0.463)	0.424 (0.189)*	0.821 (0.054)*	0.007 (.583)	0.349 (0.221)*	0.529 (0.15)*
Indian	0.483 (0.005)*	0.216 (0.289)*	0.731 (0.082)*	0.04 (0.545)	0.340 (0.205)*	0.005 (0.597)
Malaysian Chinese	0.01 (0.520)	0.579 (0.132)*	0.360 (0.216)*	0.05 (0.514)	0.382 (0.207)*	0.249 (0.27)*

[Table/Fig-7]: Correlation between Height and linear morphometric ear measurements in different ethnic groups.
The p-value <0.05 considered as significant; r is Pearson's correlation coefficient; *Not significant

DISCUSSION

The morphometry of ear pinna varies between ethnic groups. However, there have been no studies of external ear morphometry in different ethnic groups of Asian population, for the younger age groups. Therefore, a morphometric database for the same appears to offer useful data to doctors and computer engineers working with identification system. The variations in dimensions of ear pinna in different ethnic groups may necessitate the forensic anthropologist to determine the identification of the deceased remains. Knowledge of a normal ear dimension may be useful as a guideline for plastic surgeon to rectify possible defects based on their observation on the specific data to the ethnic groups.

Forensic science and to an extent plastic surgery are concerned with the detection and exploration of irregularities amongst the objects within classes [10]. Balding claims that it is difficult to prove any human characteristic to be different in each individual without examining every individual [11]. Some researchers' state that a specific sample of a population within a specific age bracket can give a substantial data [12,13]. Though the study of ear pattern has been a matter of observational study from many years, there are limited studies with empirical data to establish uniqueness [14,15]. There are studies on ear biometrics stating ear commands as much genuineness as thumbprints [16,17]. The present study investigates the correlation between different biometric data of an individual and ear measurements.

Ear morphometric measurements are highly variable even in genetically linked persons and so could be useful in individual identification study [18-20]. When authors compare the existing data in the literature, they found that there are differences in the values of ear measurements and these discrepancies could be the result of factors such as race, genetic variables individual constitution, environment and age. Studies state that there is a relationship between craniofacial parameters and height. Some craniofacial parameters found increased with body height, some decreased while others remain constant [13]. But no significant data found comparing height, head circumference and shoulder breadth with that of ear parameters. Alexander KS et al., noted ear size was independent of head size in a population from United Kingdom [4].

The present study reveals that there is a linear relationship between the height of the individual and total ear height of the same person. The only race authors found the above relation not existing is the Indian male gender group. The Indian male gender group was found to have smallest total ear height (61.58±2.432 mm) and widest lobular width (22.26±2.392 mm) [Table/Fig-3]. The varied ear morphometry explains the total ear height in Indian males is independent of their height. To conclude this, a study of the same in large population is required.

Shoulder breadth and head circumference were not found to have direct correlation with linear measurements of the ear in most of the ethnic groups. Those with significant correlation failed to express the same in their opposite gender of the same ethnic group. The Malaysian Indian male group was found to have significant correlation between shoulder breadth and head circumference to that of their ear morphometry, but the female group of their ethnicity failed to show the same. This clearly shows that these anthropological variables are sensitive to ethnicity, race and gender of an individual. The ear is a describing feature of human face. As it is well known fact that there are facial variations in the same gender even in the same genetic group, the pinna also has got the similar oddity. It is difficult to make a universal formula to derive the head size or shoulder breadth of an individual from the anthropometric measurements of the human pinna.

The present study shows there are some linear correlations existing between the ear morphometry and height, shoulder breadth and head circumference of an individual, but there exist race and gender differences. In the mission of establishing individuality of unknown cases, it becomes quite difficult for the examining officer especially in cases of mass disaster, burn, drowning etc., where the face is

severely defaced, and the limbs/body parts are amputated. If the ears are left undamaged, in such cases the identity, especially the race and gender can be proven using metric and morphological features of ear of the victim [2]. For the same, a lot of data need to be added to the literature.

This study shows that there is linear correlation existing between the total ear height and lobular height of the same individual in all the ethnic groups studied except the Indian Male group. There are no such reports in the literature so far. A similar study with large sample size may explore more details of the ear morphometry in the given population. This data may be helpful to surgeons treating congenital deformities of the external ear.

LIMITATION

Limitations of the study were small sample size and lack of comparison with higher age groups.

CONCLUSION

The present study explains the correlation between the height, head circumference and shoulder breadth with that of ear parameters. From this study authors found that a person's height can be correlated to his or her total ear height. Correlation between head circumference and shoulder breadth of an individual with that of ear morphometry varied in various ethnic groups. Correlation between different linear measurements of the ear in different ethnic groups also varied. This can be used as supportive evidence as having a role in forensic field as the identification landmarks varied in different ethnic groups. Understanding various measurements of external ears with regard to various physical characteristics of an individual is necessary for reconstructive surgeries. This will also serve as a baseline to guide surgeons involved in management of cases of external ear.

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