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Photometric Analysis of the Human Pinna: A Forensic Study among Southeast Nigerians.

OnyinyeMaryOzioko[1],Ogugua Augustine Egwu[2], Uche SebastineOzioko[3]
[1]*Designation…… Department of Anatomy, College of Medicine, Enugu State University of Science and Technology, Enugu State, Nigeria*
[2]*Designation…, Department of Anatomy, Alex Ekwueme Federal University of Ndufu Alike (FUNAI)*
[3]*Designation…… Department of Anatomy, College of Medicine, Enugu State University of Science and Technology, Enugu State, Nigeria*
Corresponding Author:OnyinyeMaryOzioko

Abstract
Background:*Ear morphology can be used for facial identification and reconstructive ear surgeries. This study was aimed at photoanalytically determining some parameters of the external ear.* ***Method:*** *514 subjects (16-30 years) comprising 258 males and 256 females were selected using simple random sampling technique . Total ear length (TEL), Total ear width (TEW), Total lobe width (TLW), Total lobular height (TLH) was measured and analyzed.* ***Results****: Males were observed to have higher TEL, TEW ear parameters than females, Females were also observed to have a longer TLH than males for both sides of the ear: All measured parameters in both sex showed higher values on the right side than the left, right lobular index was also found to be statistically higher (P < 0.05) when compared to the left one* ***Conclusion:*** *TEL and TEW measured from all angle are correlated and can be used to determine sex. It can also aid biological profiling, facial recognition from security cameras, planning of cosmetic surgery and product design for specific consumer auricular requirements.*

Key Words:*Photoanalysis, Pinna, Sexual dimorphism.*

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I. Introduction

Individual identification by means of age and sex has been a persistent challenge to forensic science. The human ear is the most defining feature of the face [1hence easily captured from a distance even if the subject is not fully cooperative. This makes ear recognition particularly interesting for smart surveillance tasks and for forensic image analysis.

The use of ear morphology and the variations created by its anatomical form are implemented principally for identification of perpetrators. Features pertaining to the human ear that may be used for identification include piercings, localized tattoos, pathologies or abnormalities, trauma, and surgery [2].

The lobe of the ear is deliberately an imperative feature of beauty in several other societies [3]. Ear piercing, which often occurs on the lobe, is also a useful attribute for forensic identification [4]. Auricle can be used efficaciously for the identification of disaster victims [5].

Nowadays the observation of characteristics is a standard technique in forensic investigation and has been used as evidence in hundreds of cases. In order to study the strength of ear prints as evidence, the Forensic Ear identification Project (FEARID) was initiated by nine institutes from Italy, the UK, and the Netherlands in 2006. In their test system, they measured an EER of 4% and came to the conclusion that ear prints can be used as evidence in a semi-automated system [6]

The German criminal police use the physical properties of the ear in connection with other appearance-based properties to collect evidence for the identity of suspects from surveillance camera images [7]. The science of biometrics has been developing approaches that can be used to automatically identify individuals by personal characteristics. The relationship of biometrics and forensics centers primarily on identifying people.As it stands, the ear clearly has the potential to be one of the stock of biometrics in digital forensics both for imaging and for recording prints given its proven identification capability.

It is worth noting that the habituation of suspects to surveillance video has led to a more routine use of concealment of the face and ears and this could be addressed by soft biometrics which is a much newer approach to the research area [8]Surveillance camera are located overhead to avoid vandalism perpetrators of some crimes sometimes wear face masks in order to cover their faces and avoid looking directly into overhead surveillance camera which makes their frontal images unavailable [9].This fact poses serious problem to biometric systems using facial features hence ear photo-analysis and use of high quality camera ,surveillance equipment with proper installation and handling were found to increase the chances of identifying an offender and serve as a valuable additional tool in forensic identification.

The possibility of identifying people by the shape of their outer ear was first discovered by the French criminologist Bertillon, and refined by the American Police Officer Iannarelli, who proposed a first ear recognition system. Bertillon and the prominent forensic scientists at that time considered the ear to be the most distinctive part of the body [10]. There is however, no published data that establishes that each individual's ear is different and distinct, or that an individual can be identified conclusively from comparison of the ear. Too little data exists to establish the accuracy of this controversial hypothesis hence more evidence-based research is required [7].

II. Materials And Methods

STUDY POPULATION

This was a cross sectional study carried out in Enugu State (Former Capital of Defunct Eastern Region).
The sample size was determined using Fisher's formula for population(> 10,000) asfollows.
$N = Z^2Pq/d^2$
Where ,
N= desired sample size
Z= 1.96 (at 95% confidence interval)
P= proportion of the target population estimated to have characteristics being measured from previous study (South East States constitute18% of Nigeria population- Nig Demographic Profile 2017)
d= error margin (error limit 0.035)
q=1-p
N= 462.87 (minimum sample size)

SAMPLE SIZE

514 apparently healthy subjects with normal ear**s** were selected in this study.
The cohort consisted of 258 males and 256 females within age range 16-30 years from Igbo people of South Eastern Nigeria resident in Enugu state . Subjects were divided into five age groups,
Group A…………….16-18 Years
Group B…………….19-21 Years
Group C…………….22-24 Years
Group D…………….25-27 Years
Group E…………….28-30 Years

Subjects & selection method

Individuals who meet the inclusion criteria were randomly selected from different states in south east Nigeria using purposive convenient sampling technique.

Study Duration: September 2019 To Febuary2020

EXCLUSION CRITERIA:-

Individuals whose normal ear morphology was altered by trauma, accidents or surgery or since birth were excluded from this study.

INCLUSION CRITERIA:-

a) Apparently healthy individuals within the age group of 16-30 years with no evidence of congenital ear anomalies or previous ear surgeries.
b) They must be of Igbo descent.
A total of 514 subjects were recruited for the study. Age of subjects ranged from 16-30 years because crime tends to peak in adolescence or early adulthood [11.The Ethical approval was obtained from the Ethical Review Committee for Human Experimentation**,** College of Medicine Enugu State University of Science and Technology, Enugu Nigeria

PROCEDURE METHODOLOGY

Consent was taken from each participant after explaining the purpose of study in accordance with World Medical Association Declaration of Helinski Ethical Principles for Medical Research Involving Human Subjects(2008)[12].

i Pre-Image Acquisition:

Before photography was taken, Subjects were numbered using self adhesive stickers of known length (45x13mm) at the sides of the face. Subjects' age, height, weight, sex and state of origin were recorded along with their identification numbers.

Female subjects were asked to clip back hair using hair clips to prevent it from obscuring the photograph of the ear. The tripod was adjusted so that it was equal with the height of the ear of the subject to ensure the ear was visible within the shots.

ii Image Acquisition:

- Images were acquired using Nikon D9O digital single lens reflex camera (manufactured by Nikon Corporation Tokyo, Japan) in the same lightening conditions with no illumination changes. Camera settings of 12.3 mega pixel, 600Dpi resolution, fixed local length 90 to150mm, high quality macro lens (which assures maximum depth of field) high aperture setting (f>16) and short exposure time(>125 milli sec) were also kept constant.
- Each subject was asked to position on a line marked 100cm from the camera [1][13][14].
- Camera was moved to either side in order to have photo taken at parallel to the subject to reduce possibility of Image perspective distortion due to poor positioning.

iii<u>Image Processing</u>

- When photos had been taken they were downloaded into Adobe illustrator version 17.(Adobe systems USA)
- All photos were cropped and sharpened if necessary for a clear picture. They were converted to gray scale (color removed) and contrast increased for the best possible definition. It was necessary for all photographs to be on the same scale for accuracy in measurement.
- Photographs with incorrect lightening or with unnoticed hairs concealing actual auricle dimensions were discarded.
- Image editing software (Image J 1.48 software j (v.j.48 ava 1.6.0 2064 bits written by Wayne Rasband, National institute of mental health, Bethsda ,Mary land, USA) process image option was used to

A: Process the images-Sharpen images(optimize brightness), enhance contrast, and size to produce a clear image,subtract background and image calculation

B:Furthermore, this program has an analyze option dimension tool used to set scale and create a vertical dimension line that measures vertical distance between any 2 landmarks using y axis.

Thus ear dimension could be easily and accurately calculated while comparing landmarks

iv. **Ear measurements Taken**

Auricular landmarks were tagged on photograph of the subjects' ear and then measurement**s** were taken and results were given to 2 decimal places. The present study included the following parameters for the measurements of the right and left external ear:

TOTAL EAR LENGHT:

Measurement of the distance between the most superior point of the ear or pinna and the most inferior point of the earlobe (Fig 1).

TOTAL EAR WIDTH: Measurement of the distance between the most anterior point and the most posterior point of the pinna. (Fig 2).

TOTAL LOBULAR HEIGHT: Measurement of the distance between the intertragic notch and the most inferior point of the ear lobule.(Fig 3).

TOTAL LOBULAR WIDTH: Measurement of the distance between the most anterior point and the most posterior point of the ear lobule (Fig 4).

HEIGHT (stature): Each subject was made to stand erect and height was measured using a stadiometer.

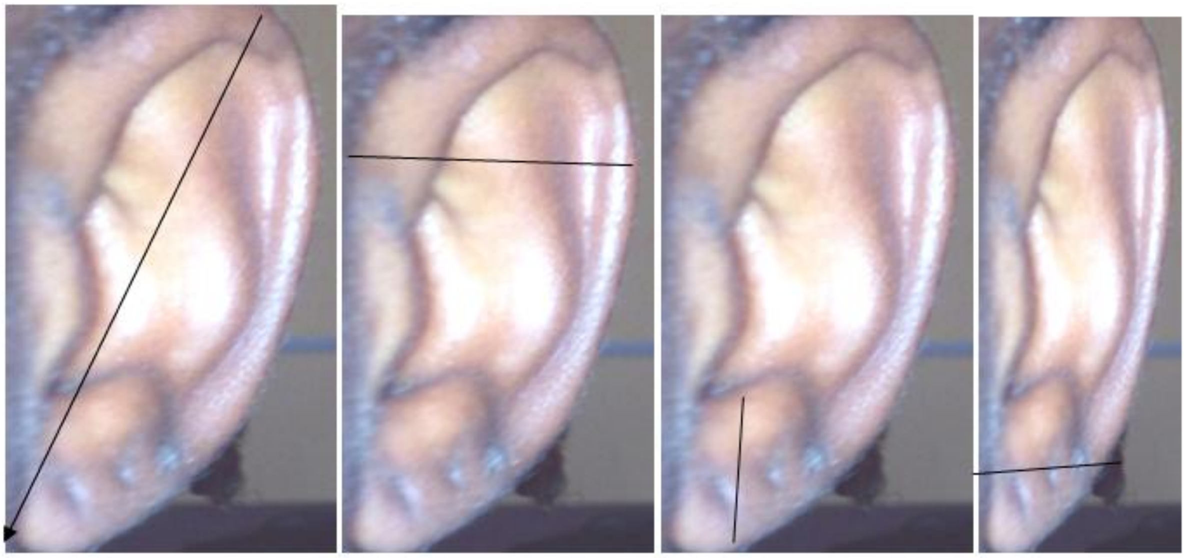
WEIGHT: Weight of each subject was checked using weighing scale. The subjects removed excess materials like shoes, belt, watche.t.c

EAR INDEX : Was calculated as $\frac{\text{Ear width}}{\text{Ear length}} \times 100$[15]

LOBULAR INDEX: was calculated as $\frac{\text{Lobule width}}{\text{Lobule length}} \times 100$

Age of participants was obtained from self-reported date of birth [16].

Fig 1: Total Ear Length **Fig 2:** Total Ear Width **Fig 3**: Total Lobule Length **Fig 4**: Total Lobule Width



III. Result

The present study provides valuable data pertaining to the ear morphology and their different parameters in south east Nigerians. There are 514 subjects (males and females) in our cohorts. Age and gender of participants in this study are almost pair-matched (P>0.05) and the male/ female ratio is 1:1.Age distribution of participants showed that majority of population belongs to Age group 19-21 while the less frequent age range was from 28- 30 age group.

TABLE NO 1: EAR MORPHOMETRIC MEASUREMENTS IN RELATION TO AGE IRRESPECTIVE OF SEX

Side	Parameter (cm)	Age groups (years), Mean ±SD					
		16-18yrs (n=40)	**19-21yrs (n=207)**	**22-24yrs (n=169)**	**25-27yrs (n=71)**	**28-30yrs (n=27)**	**P-value**
Left ear	TEL	6.06±0.56	5.95±0.51	5.90±0.52	5.84±0.43	5.68±0.22	0.016*
	TEW	3.47±0.37	3.48±0.35	3.44±0.35	3.49±0.29	3.14±0.39	0.001*
	TLH	1.54±0.21	1.54±0.23	1.52±0.21	1.48±0.19	1.59±0.16	0.094
	TLW	1.97±0.29	1.94±0.31	1.93±0.33	1.88±0.23	1.91±0.29	0.517
Right ear	TEL	5.93±0.49	5.94±0.50	5.92±0.52	5.86±0.39	5.70±0.26	0.169
	TEW	3.55±0.38	3.51±0.40	3.41±0.32	3.40±0.24	3.28±0.41	0.001*
	TLH	1.50±0.23	1.52±0.23	1.53±0.22	1.50±0.17	1.48±0.22	0.091
	TLW	1.98±0.27	2.02±0.31	2.06±0.39	1.94±0.34	1.94±0.38	0.491

* P<0.05 (Significant) irrespective of sex for both left and right ears.

The effect of age on the parameters measured was analyzed using one –way ANOVA when the cohort was broken into five age groups (Table 2).Results showed that at the left ear, TEL is significant (P<0.05) Also, TEW is significant (P<0.05) for both left and right ears.

TABLE NO 2: DESCRIPTIVE STATISTICS OF PARAMETERS MEASURED ACROSS COHORT IN RELATION TO SEX

Parameter	Side	Sex	Mean ±SD	P-value	Median	Range	Mode
TEL	Left ear	Male	6.00±0.50	0.001*	5.96	4.70-7.94	5.90
		Female	5.82±0.49		5.79	4.78-7.51	5.67
	Right ear	Male	5.96±0.48	0.013*	5.96	4.70-7.44	5.68
		Female	5.85±0.49		5.85	4.46-7.27	5.91
		Female	5.90±0.49		5.88	4.80-7.34	5.88
TEW	Left ear	Male	3.50±0.37	0.003*	3.52	2.46-4.35	3.62
		Female	3.41±0.33		3.43	2.46-4.41	3.52
	Right ear	Male	3.49±0.39	0.029*	3.46	2.32-4.57	3.53
		Female	3.42±0.32		3.43	2.52-4.58	3.17
TLH	Left ear	Male	1.45±0.18	0.001*	1.44	0.98-1.95	1.44
		Female	1.61±0.22		1.62	1.08-2.37	1.65
	Right ear	Male	1.45±0.19	0.001*	1.46	1.02-2.04	1.36
		Female	1.59±0.21		1.58	1.02-2.16	1.58
TLW	Left ear	Male	1.94±0.32	0.289	1.98	1.00-2.67	2.10
		Female	1.91±0.29		1.91	1.08-2.75	1.96
	Right ear	Male	2.00±0.34	0.444	2.03	1.12-2.91	1.48
		Female	2.02±0.34		2.00	1.33-3.58	1.85
		Female	1.94±0.29		1.91	1.20-2.82	1.83

* P<0.05 (Significant)

Data was analyzed using the t- test for independent samples.(Table 3). It was observed that there is significant difference in the different morphometric parameters of ears in relation to sex (P<0.05), except in TLW (P>0.05).

This implies that the male always has a longer TEL than the female, wider TEW than the female at both sides of the ear. Females were also observed to have a longer TLH than males at both sides of the ear.
TLW mean length values of the male left ear was higher than that of females while right ear TLW mean length values of the of females are higher than that of males.

TABLE NO 3: COMPARISON OF AURICLE INDICES AT DIFFERENT ANGLES

Indices	Side	Male (n=258)		Female (n=256)		Combined (n=514)	
		Mean ±SD	**P-value**	**Mean ±SD**	**P-value**	**Mean ±SD**	**P-value**
Ear index	Left ear	58.49±6.04	0.600	58.55±5.16	0.717	58.58±5.90	0.878
	Right ear	58.68±6.47		58.68±5.76		58.62±5.85	
Lobule index	Left ear	136.05±26.35	0.023*	120.71±22.58	0.000*	128.41±25.69	0.001*
	Right ear	140.04±26.20		129.10±24.23		134.59±25.80	

* P<0.05 (Significant)

Data was analyzed using paired sample/dependent t-test. Table 4 depicts combined data from left and right sides in both sex .It also shows the descriptive statistics for different indices of ear pinna when the cohort is broken down into male and female subgroup and it was observed that there is significant difference in most of the lobule indexes of the left and right ears (P<0.05). This implies that the lobule indexes of the right ear are always higher than that of the left ears. However, most of the ear indexes of the left and right ears showed no significant difference (P>0.05)

TABLE NO 4: DIFFERENT ANTHROPOMETRIC PARAMETERS IN RELATION TO SEX

Parameter	Sex	Range	Mean ±SD	P-value
Age (years)	Male	16-30	22.07±2.71	0.466
	Female	16-30	21.90±2.73	
	Total	16-30	21.99±2.72	
Height (m)	Male	1.52-1.94	1.73±0.07	0.001*
	Female	1.44-1.82	1.64±0.07	
	Total	1.44-1.94	1.69±0.08	

Weight (kg)	Male	45-100	69.92±9.31	0.001*
	Female	42-100	63.44±11.13	
	Total	42-100	65.69±10.49	

* P<0.05 (Significant)

Results from the data separated into male and female subgroups to analyze changes in known anthropometric parameters (Age, Height and Weight) in relation to sex showed that there is no significant difference in the age of male and female subjects used in this study (P>0.05) (Table 4. 5).This implies that the age distribution of the male and female are relatively uniform. However, there is significant difference in the height and weight of the study subjects in relation to their sex (P<0.05). This implies that the male are taller and equally heavier than the female subjects.

TABLE NO 5: RELATIONSHIP BETWEEN KNOWN ANTHROPOMETRIC VARIABLES (AGE, HEIGHT, WEIGHT) ON THE EAR PARAMETERS MEASURED IRRESPECTIVE OF SEX

Parameter	**Side**	**Age**		**Height**		**Weight**	
		Correlation coefficient (r)	**P-value**	**Correlation coefficient (r)**	**P-value**	**Correlation coefficient (r)**	**P-value**
TEL	Left ear	-0.169	0.001*	0.114	0.101	0.036	0.409
	Right ear	-0.111	0.012*	0.136	0.002*	0.089	0.044*
TEW	Left ear	-0.118	0.007*	-0.048	0.278	0.013	0.766
	Right ear	-0.168	0.001*	0.002	0.962	0.053	0.235
TLH	Left ear	-0.043	0.326	-0.308	0.001*	-0.040	0.362
	Right ear	-0.039	0.376	-0.200	0.001*	0.021	0.642
TLW	Left ear	-0.068	0.125	-0.047	0.288	0.049	0.268
	Right ear	-0.021	0.631	-0.043	0.327	0.017	0.705

* P<0.05 (Significant)

Data was further broken down in Table 6 to analyze possible relationship between parameters of both ear sides on anthropometric variables (Age, Height and Weight). Pearson correlation was done between right and left side in each of the parameters measured.

It was observed that in all cases there is significant positive correlation between weight, height and TEL TEL (P<0.05). This implies that an increase in height or weight produces a slight increase in TEL. Conversely, there is significant negative correlation between the age and TEW (P<0.05). This implies that an increase in the age produces a significant decrease in TEW. height has a significant negative effect on TLH (P<0.05). This implies that as the height increase, there is significant decrease in TLH. However, age and weight has no effect on TLH (P>0.05). There is no significant relationship between age and TLW, height and TLW, and weight and TLW (P>0.05). This implies that the age, height and weight has no effect on TLW.

TABLE NO 6: DIFFERENT ANTHROPOMETRIC PARAMETERS IN RELATION TO EAR SIDE

Parameter	**Side**	**Mean ±SD**	**P-value**
TEL	Left ear	5.91±0.49	0.926
	Right ear	5.91±0.50	
TEW	Left ear	3.45±0.35	0.854
	Right ear	3.46±0.36	
TLH	Left ear	1.52±0.22	0.105
	Right ear	1.53±0.22	
TLW	Left ear	1.93±0.31	0.001*
	Right ear	2.01±0.34	

* P<0.05 (Significant)

The comparison of different anthropometric parameters in relation to ear side using paired sample t-test, showed that TLW is significant (P<0.05). This implies that the lobule is wider at the right ear than the left ear.

IV. Discussion

Previously the study of the external ear parameters was limited to surgical treatment and auricular reconstruction of congenital deformities but in recent times, information about sex and age can be derived from the shape of the ear.

In our present study, left TEL was statistically significant (P<0.05) at when analyzed (Table 2) in relation to age. Also, TEW is significant (P<0.05) for both left and right ears.Results from (Table 3) of our study shows that males total ear length **(**TEL),total ear width **(**TEW) was significantly higher, ears than females.This is consistent with previous studies of [1][17]Significant difference in TLH in relation to sex (P<0.05) was also noted. This implies that females have a longer TLH than males. It was also noted that TLW mean values at right was higher in left ear of male subjects (Table 3) while mean TLW values was consistently higher in the right ear of females than the right lobule width of males. This has a close match with the findings of [18].

Data analysis in this present study (Table 4) showed that ear index mean values in both males and females of our cohort was higher in right ear than in left ear .This has a close match with the findings of [16]Taura*et al;* (2015) they reported a higher right ear index than the left ear index. Left ear index of females is higher than the left ear index of males in our study. Combined data from left and right ear sides in both sex (514 subjects) in our present study shows that lobule index of right ear is always higher than that of left ear. This corroborates with the findings of [19].Table 4 of this present studythe mean values obtained for male lobule index was higher than the female lobule index for both left and right ears this concurs with the findings of [20].

Table 5 shows data of different anthropometric parameters (age, height and weight) broken down to analyze possible differences in relation to sex .It was observed that though the age and gender of our cohort are almost pair matched, males are taller and equally heavier than the female subjects.

Analysis showing relationship between known anthropometric variables (age, height, weight) in table 6 shows that an increase in age produces a significant decrease in TEW. Also, significant decrease was noticed in TEW as height increases.

It was also noted that increase in height or weight produces a slight increase in TEL (table 6). Result from this study also shows that TLH decreases with increase in height. However age and weight has no effect on TLH (p>0.05).

Comparison of different anthropometric parameters in relation to ear side (table 7) showed that ear is longer at the right than at the left ear, Result of analysis of anthropometric parameters in relation to ear side (table 7) This has a close match with the findings of [16].Table 7 also shows that lobule is wider at the right ear than that at the left ear .This has a close match with the findings [1].

V. Conclusion

Findings from this study prove that sexual dimorphism exists in ear parameters and there is variation in advance age. This study can aid identification of individuals and facial recognition from security cameras.

Data generated will serve as base line for surgeons involved in the management of cases of the external ear including reconstruction and peri-auricular surgery.

It will also be useful to industries involved in product design for specific auricular requirements.

VI. Recommendation

The biological determination of ancestral origins of subjects should be carried out to provide definitive and representative anthropometric data of Nigerian ethnic groups. This will help to determine the true nature of the heterogeneity and ethnic diversity of the Nigerian population.

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