

Anthropometric analysis of auricular indices for sex and stature determination among Okun and Igala ethnic groups of Kogi State, Nigeria

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ABSTRACT

Knowledge of auricular anthropometrics is important for sex and stature determination in forensic science, as variation exist based on gender, age, ethnicity as well as environmental influences. This study is designed to provide auricular anthropometric data for the estimation of sex and stature among Okun and Igala ethnic sub-populations of Kogi state in North central Nigeria. Two hundred male and 200 female adult volunteers (aged 18-65 years), with no evidence of prior trauma to the ear or any congenital anomalies was used for this study. Six variables of the ear were measured: Auricular Length (AL), Auricular Width (AW), Lobular Length (LL), and Lobular Width (LW) using a Digital Vernier Caliper. Values for Auricular Index (AI) and Lobular Index (LI) were mathematically calculated. Height measurements were taken using a Stadiometer. SPSS (IBM, Version 23, Armonk, New York, USA) was used, while Pearson's Chi-square trend analysis and t-test analysis of mean difference was used to analyze data obtained. Results obtained shows that both auricular and lobular indices are higher in males than females, hence a significant level of sexual dimorphism is present in the Auricle. A significant relationship exists between Stature, Auricular and Lobular Indices in both males and females respectively; and this serves to provide accurate and up-to-date auricular morphometric data for a significant part of the Kogi State sub population (Okun and Igala ethnic groups). The information provided from this study can be used in anthropometric, forensic and ergonomic studies as well as reconstructive surgeries that involve individuals from these two ethnic groups.

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1. INTRODUCTION

Anthropometry is the scientific study of the differences in the dimensions of the human body [1], measurements in anthropometry are collected through careful and organized processes with the primary aim of providing data which is useful in the fields of ergonomics, reconstructive surgery and prosthesis. This vast field of anatomical science also helps to provide unique information that is crucial to the understanding of human physical variations [2].

The ear is a very important organ that is significant to the human face esthetics. Wearing of ear rings, punching a hole on the external

part of the ear has become a general practice among different populations across the globe, and this practice is important to influencing the appearance of an individual. The auricle is the external part of the ear and is also one of the most definitive features of the human face.³ Anthropometrists and anatomists have extensively studied the auricle and the role it plays as an identification marker based on the morphologic variations that exist as a result of age, gender, sex and ethnic origins.⁴ It is also worthy of note that the dimensions, shape and position of the auricle is just as specific to every individual as the fingerprint [3].

A detailed knowledge of the anatomy of the ear

is also important in forensic science (especially in the case of facial reconstruction), surgical procedures which involve ear reconstruction and in the design of ergonomic hearing aids for individuals with hearing impairments [4]. Surface anatomy of the auricle can also be used as a diagnostic tool for detecting certain syndromes and genetic malformations (Turner's syndrome, potter's syndrome, Down's syndrome) [5].

In forensic science, surgery and anthropometry, a detailed analysis of the observable features, shape, position and orientation of the auricle is essential for many processes⁴. The definition and analysis of age, sex and ethnic related variations in morphometric data can serve as the scientific basis of personal identification and individual discrimination, this is because facial characteristics play a very essential role in human identification [6].

As a result of its vast importance, there are a lot of studies on the anthropometry of the auricle in literature,³ however, little or no data on auricular morphometric indices exists among Okun and Igala ethnic sub-populations of Kogi state Nigeria.

2. MATERIALS AND METHODS

2.1 Animal care and ethical approval

This study involved the use of most of the common and approved anthropometric tools in order to obtain measurements and generate data that are free of error and with a high degree of accuracy. The tools/instruments used in this study include;

- Digital Vernier Caliper (Fig. 1); with accuracy of 0.01 mm [7].
- Stadiometer (Fig. 2); with accuracy of 1cm [7].
- Blue writing pen
- Paper
- Recording book

A sample size of four hundred subjects was obtained randomly from the population of individuals above the age of 18 in the Okun and Igala ethnic groups of Kogi State for this study. The sample population is composed of 200 males and 200 females respectively. The method used in data collection for this study was non-invasive, not painful and not potentially harmful to all volunteers as their full consent was granted for this study; great care was also taken to ensure that there is minimal disturbance to all subjects. Information concerning age in years, local government of origin, sex and parent's origins were supplied by individual volunteers and computed in the questionnaire. All volunteers were asked to assume a sitting position and look straight ahead. Measurements were taken using the auricular landmarks that are both modified and standardized [1]. All dimensions of Auricular Length (AL), Auricular Width (AW), Lobule Length (LL), Lobule Width (LW) were done

using a digital vernier caliper (Fig. 3) that reads values to the nearest 0.01mm. Height was measured using a stadiometer, calibrated in centimeters.



Figure 1. Vernier Caliper



Figure 2. Stadiometer



Figure 3. External Ear Anatomy



Figure 4. Image showing the measurement of auricular length



Figure 5. Anatomical landmarks of the auricle. (1) supraurale, (2) subaurale, (3) preaurale, (4) postaurale, (5) concha superior (6) incisura intertragica inferior, (7) incisura anterior auris posterior, (8) strongest helical fold anthelical curvature, (9) lobule anterior, (10) lobule posterior [1].

2.1.1 Parameters measured

- Auricular Length (AL); This is a dimension that is obtained by measuring a straight distance between the highest point on the Auricle (super-aurale) to the lowest point on the Auricle (sub-aurale) [1].
- Auricular Width (AW); this dimension is measured as the straight distance between preaurale and postaurale [1].
- Lobule Length (LL); The Lobular Length was measured as the distance between incisura intertragica inferior and subaurale [1].
- Lobule Width (LW); this is the distance between the lobule anterior and the lobule posterior [1].
- Auricular and Lobular Index; to properly assess the ratio of the length and width of the auricle and lobule, it is essential to incorporate the measured data into their respective indices [1].
- Auricular Index; width of auricle $\times$ 100/length of auricle.
- Lobular Index; lobular width $\times$ 100/lobular length [1].

2.1.2 Exclusion Criteria

Individuals who have any form of auricular deformity, suffered from physical trauma to the auricle were excluded from the study. Individuals who do not have parents from Kogi state were also excluded.

2.1.3 Inclusion Criteria

- Both parents of all subjects must be indigenes of the Okun and Igala ethnic groups of from Kogi State
- Subjects must not have any auricular deformity
- All volunteers must not have any auricular injury or trauma
- Subjects must fall within the age range of 18-65

2.2 Statistical Analysis

The data were subjected to statistical analysis using SPSS Version 23 (IBM corp., Armonk, New York, USA). Pearson's Chi-square trend analysis and t-test analysis of mean difference were the statistical tool used to analyze the data.

3. RESULTS

The results presented are the anthropometric measurements (height and ear dimensions) of the adult Kogi State Nigeria population. The discrete variables were presented as frequencies and percentages while the continuous variables are presented as mean (S.D), minimum and maximum values. Graphical and tabular charts are used in presenting the results.

Table 4.1: The Distribution of the Studied Population by LGAs Grouped by Sex

Sex	Ankpa	Dekina	Ibaji	Idah	Igalamela	Ijumu	Kabba/Bunu	Mopa-Muro	Ofu	Olamaboro	Omala	Yagba/East	Yagba/West
Male (%)	22 (11.0)	17 (8.5)	1 (0.5)	5 (2.5)	11 (5.5)	20 (10.0)	22 (11.0)	24 (12.0)	12 (6.0)	14 (7.0)	25 (12.5)	12 (5.5)	16 (8.0)
Female (%)	16 (8.0)	11 (5.5)	3 (1.5)	10 (5.0)	5 (2.5)	33 (16.6)	27 (13.6)	6 (3.0)	18 (9.0)	14 (7.0)	20 (10.1)	18 (9.0)	18 (9.0)
Total (%)	38 (9.5)	28 (7.0)	4 (1.0)	15 (3.8)	16 (4.0)	53 (13.3)	49 (12.3)	30 (7.5)	30 (7.5)	28 (7.0)	45 (11.3)	29 (7.3)	34 (8.5)

Table 4.2: The Distribution of the Studied Population by Age Groups Stratified by Sex

Sex	Age groups			
	18-25yrs	26-35yrs	36-45yrs	above 45yrs
Male (%)	106 (52.5%)	71 (35.5%)	0 (0.0%)	24 (12.0%)
Female (%)	96 (48.2%)	62 (31.2%)	11 (5.5%)	30 (15.1%)
Total (%)	201 (50.4%)	133 (33.3%)	11 (2.8%)	54 (13.5%)

The population of Okun and Igala indigenes involved in the study grouped into their respective local government areas (LGAs) is represented in Table 4.1, according to Table 4.2 which shows the classification of all subjects

based on sex, males between the ages of 18-25 years make up 52.5% of the male population involved in the study, male subjects between the ages of 26-35 years constitute 35.5% of the male sample size and the final 12% include

male subjects above the age of 45. Table 4.2 also shows that 42.2 % of the female sample population are made up of subjects between the ages of 18-25 years, 31.2% includes subjects between the ages of 26-35, 5.5% of the female

sample population is made up of subjects between the ages of 35-45 years while the concluding 15.5% of the female population involved in the study is made up of volunteers above the age of 45.

Table 4.3: The Mean (S.D) and Test of Mean Difference of the Measured Parameters

Parameters	Male (200)	Female (200)	T-test		Total (400)		
	Mean±S.D	Mean±S.D	t-value	p-value	Mean±S.D	Min	Max
Height (cm)	175.72±6.58	168.65±6.91	-1.612	0.11	172.19±7.61	150.00	189.00
Lobular length (mm)	15.11±2.59	15.5±2.21	-1.38	0.17	15.31±2.41	9.00	23.70
Lobular width (mm)	21.34±3.90	22.02±5.67	4.489	<0.01	21.68±4.87	7.50	59.80
Auricular length (mm)	56.20±4.96	53.72±6.02	5.101	<0.01	54.96±5.65	24.00	69.70
Auricular width (mm)	37.55±6.35	34.29±6.41	10.461	<0.01	35.92±6.58	20.40	61.30

Note: S.D=Standard deviation, Min=Minimum, Max=Maximum

Table 4.4: Sex-specific Height Estimation using Ear Dimensions

Variables	correlation with Height (cm) in males				correlation with Height (cm) in females			
	R	R ²	P-value	R _E	R	R ²	P-value	R _E
Auricular length (AL)	0.115	1.32%	0.1047	N/A	0.151	2.29%	0.033	0.174(AL) + 159.32
Auricular width (AW)	0.040	0.16%	0.5786	N/A	0.130	1.68%	0.068	N/A
Lobular length (LL)	0.086	0.74%	0.2253	N/A	-0.072	0.52%	0.311	N/A
Lobular width (LW)	0.083	0.69%	0.2428	N/A	0.116	1.34%	0.103	N/A

Note: r=Pearson's coefficient, R²=Coefficient of determination, R_E=Regression Equation; N/A= not available (reason; no significant relationship)

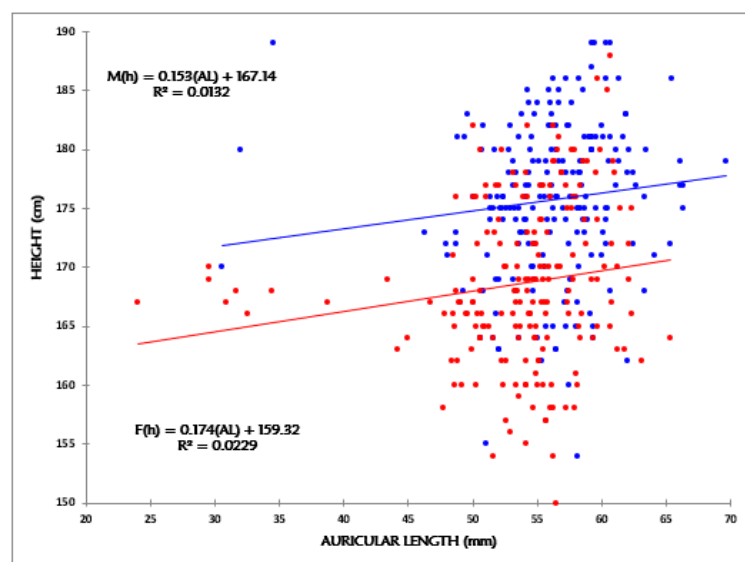


Fig 4.0: Scatter plots of Height against Auricular length in males (blue) and female (Red)

Mean (SD) values and test of mean value differences for all measured parameters in male and females subjects are expressed in Table 4.3, the mean (SD) values and test of mean differences for Auricular and Lobular indices are expressed in Table 4.7. In males, the following mean±S.D values were obtained; Height (175.72±6.58), LL (15.11±2.59), LW (21.34±3.90), AL (56.20±4.96) AW (37.55±6.35), LI (67.63±15.94) and AI (144.21±31.16). Females have the following values; Height (168.65±6.91), LL (15.5±2.21), LW (22.02±5.67), AL (53.72±6.02), AW (34.29±6.41), LI (65.12±18.52) and AI (143.96±38.59).

Table 4.4 shows the possibility of sex-specific height estimation using the auricular dimensions

obtained in the course of this study, of the four auricular and lobular dimensions obtained, only Auricular Length demonstrates a significant relationship with height in females ($r = 0.151$, $p = 0.033$).

Fig. 4.0 shows the relationship between Auricular Length and Height with lines of best fit plotted to display this relationship in male and female subjects respectively. The figure also displays the regression equations aimed at calculating the efficacy of Auricular Length in stature estimation in males and females respectively. Other dimensions of Auricular Width, Lobular Length and Lobular Width show no significant relationship in both male and female subjects.

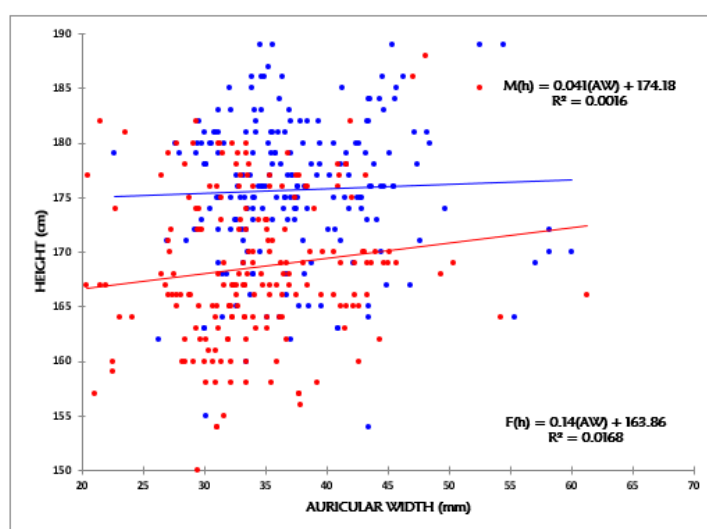


Figure 4.1: Scatter plots of Height against Auricular Width in Males (blue) and Female (Red)

The relationship between Auricular width and Height is expressed using a scatter plot (Fig 4.1) with lines of best fit and regression equations derived to display the relationship between

auricular width and stature in both male and female subjects. However, in this study, there was no significant relationship between auricular width and height.

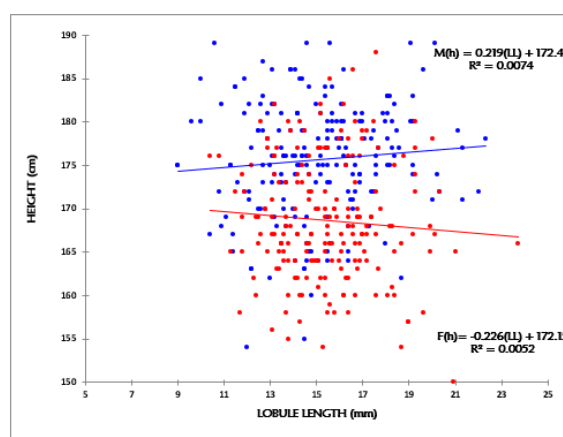


Figure 4.2: Scatter plots of Height against Lobular length in males (blue) and female (Red)

Fig. 4.2 shows the relationship between Height against Lobular length using a scatter plot, regression equations and lines of best fit for both male and female subjects. In this study, there was no significant relationship between Height and Lobular length in male and female subjects respectively.

Fig. 4.3 shows the relationship between Lobular width and Height using a scatter plot, regression equations and lines of best fit for both male and

female subjects. In this study, there was no significant relationship between lobular width and height in male and female subjects respectively.

Fig. 4.4 displays a scatter plot which describes the relationship between height and lobular index in males and females respectively. Lack of any significant relationship between auricular dimensions and height in the selected sample population is expressed in Table 4.5.

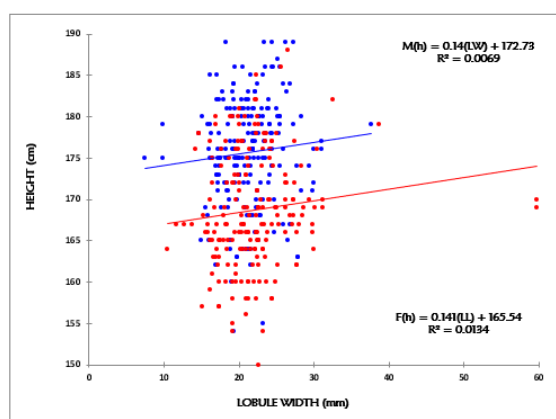


Figure 4.3: Scatter plots of Height against Lobular Width in Males (blue) and Female (Red)

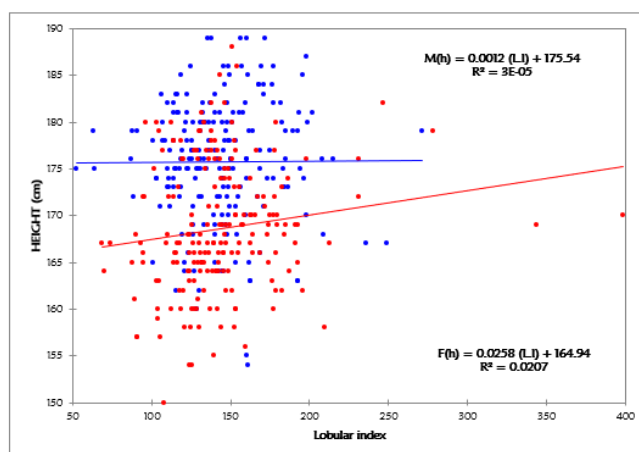


Figure 4.4: Scatter plots of Height against Lobular Index in Males (blue) and Female (Red)

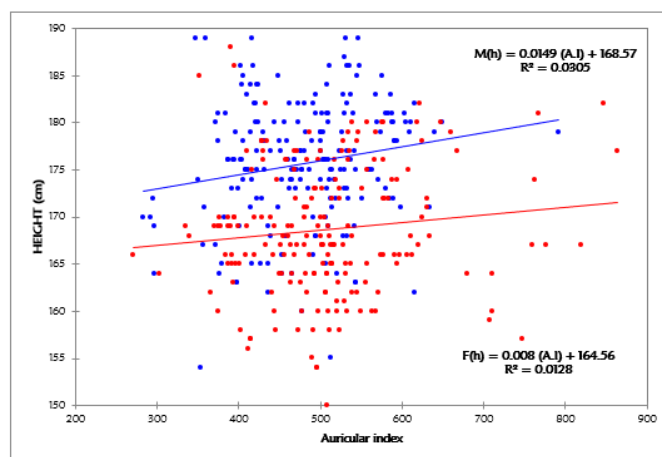


Fig 4.5; Scatter Plots of Height against Auricular Index in Males (blue) and Female (Red)

Table 4.5: Regression Model Characteristics and Variables Predictability of Stature for the General Male Population

Term	Coef	SE Coef	T-Value	P-Value	Inf.
Constant	163.2490	6.3937	25.5326	< 0.0001	
Auricular (AL) length	0.1293	0.1001	1.2912	0.1981	NS
Auricular (AW) width	0.0437	0.0763	0.5725	0.5677	NS
Lobular (LL) length	0.1110	0.2014	0.5512	0.5821	NS
Lobular (LW) width	0.0882	0.1282	0.6882	0.4922	NS

Note: Coef.=Coefficient; S.E=Standard error; R²=Coefficient of determination; Inf.=Inference (NS, Not Significant; S, Significant)

Table 4.6: Regression Model Characteristics and Variables Predictability of Stature for the General Female Population

Term	Coef	SE Coef	T-Value	P-Value	Inf.
Constant	154.9170	6.5222	23.7523	< 0.0001	
Auricular (AL) length	0.1997	0.0831	2.4016	0.0173	S
Auricular (AW) width	0.0867	0.0812	1.0672	0.2872	NS
Lobular (LL) length	-0.2395	0.2217	-1.0803	0.2814	NS
Lobular (LW) width	0.1700	0.0952	1.7851	0.0758	NS

Note: Coef.=Coefficient; S.E=Standard error; R²=Coefficient of determination; Inf.=Inference (NS, Not Significant; S, Significant)

Regression Equation:

HEIGHT(cm) = 154.917 + 0.120 × AL(mm) + 0.087 × AW(mm) - 0.239 × LL(mm) + 0.170 × LW(mm) (R sq. = 5.8%)

Table 4.7: The Mean (S.D) and Test of Mean Difference of the Calculated Indices

Parameters	Male (200)	Female (200)	T-test		Total (400)		
	Mean±S.D	Mean±S.D	t-value	P-value	Mean±S.D	Min	Max
Lobular index	67.63±15.94	65.12±18.52	1.453	0.146	66.38±17.29	36.56	196.08
Auricular index	144.21±31.16	143.96±38.59	0.07	0.944	144.09±35.02	52.45	398.00

Note: S.D=Standard deviation, Min=Minimum, Max=Maximum

Table 4.8: Sex-specific Height Estimation using Lobular and Auricular Indices

Variables	correlation with Height (cm) in males				correlation with Height (cm) in females			
	R	R ²	P-value	R _e	R	R ²	P-value	R _e
Lobular Index	0.006	0.00%	0.937	N/A	0.113	2.10%	0.043	0.0258 (L.I) + 164.94
Auricular Index	0.174	3.05%	0.013	0.0149 (A.I) + 168.57	0.144	1.30%	0.112	N/A

Note: r=Pearson's coefficient, R²= Coefficient of determination; R_e=Regression Equation; N/A= not available (reason; no significant relationship)

Table 4.5 shows that auricular length (p = 0.181) auricular width (p = 0.5677) lobular length (p = 0.5821) lobular width (p = 0.4922). Regression Equation: HEIGHT (cm) = 163.249 + 0.129 × AL (mm) + 0.044 × AW (mm) + 0.111 × LL (mm) + 0.088 × LW (mm) (R sq. = 2.10%).

The regression model characteristics and variables predictability of stature for the general female population is displayed in Table 4.6. Of all measured variables, only Auricular Length (p=0.0173, t=2.4016) demonstrates a statistically significant relationship for

predictability of stature in females. Auricular Width ($p=0.2872$, $t=1.0672$), Lobular Length ($p=0.2814$, $t=-1.0803$), Lobular Width ($p=0.0758$, $t=1.7851$) were all not statistically significant for predictability of stature in females.

Table 4.7 shows the mean (S.D) and test of mean difference of the calculated Auricular and Lobular indices for both male and female subjects. The mean (SD) for male subjects are; Lobular index (67.63 ± 15.94), Auricular Index (144.21 ± 31.16). For female subjects, mean (SD) is; Lobular Index (65.12 ± 18.52) Auricular Index (143.96 ± 38.59). The mean (SD) of the total population for Lobular Index is (66.38 ± 17.29) and that of Auricular index is (144.09 ± 35.02). The results of the test of mean difference for both calculated indices in the total population is; Lobular index ($p=0.146$, $t=1.453$) and Auricular index ($p=0.944$, $t=0.07$).

Table 4.8 displays sex-specific height estimation using lobular and auricular indices calculated from the measured anthropometric parameters. This table also demonstrates the correlation that exists between the calculated indices and stature in both male and female subjects, this possible correlation was expressed. In males, for lobular index; $r=0.006$, $R^2=0.00\%$, P test= 0.937 and there was no (R_E) therefore, no significant relationship exists between Lobular Index and Height in males. Concerning Auricular Index; $r=0.174$, $R^2=3.05\%$, P test= 0.013 and an (R_E) = 0.0149 (A.I) + 168.57 was generated as a result of the statistically significant relationship that exists between Auricular Index and stature in the male sample population. In females, for lobular index, $r=0.113$, $R^2=2.10\%$, P test= 0.043 and an (R_E) = 0.0258 (L.I) + 164.94 was generated as a result of the statistically significant relationship that exists between Lobular Index and stature in the female sample population. For Auricular Index, $r=0.144$, $R^2=1.30\%$, P test= 0.112 , no (R_E) due to the lack of a significant relationship between Auricular Index and Height in the female sample population.

4. DISCUSSION

No significant relationship between the measured auricular dimensions of Auricular Length, Auricular Width, Lobular Length and Lobular Width and stature in males. However, a significant correlation was observed between Auricular Index and Stature. No significant relationship exists between Lobular Index and stature. Concerning females, only Auricular Length has a significant relationship with stature. Other measured dimensions of Auricular Width, Lobular Length and Lobular Width display no significant relationship with stature.

A significant relationship exists between Lobular Index and stature in females, however, there was no observed relationship between Auricular Index and stature. All auricular measurements

except lobular width are higher in males than in females. This study has proven that sexual dimorphism as regards auricular dimensions also exist in the Nigerian population.

Compared to the Indian men studied by Lian and his colleagues in 2008[8], Nigerian men from Kogi state (Okun and Igala ethnic groups) have smaller auricles. The mean Auricular Length obtained from the studied Indian men was 62.85 ± 3.35 mm⁸ while results from this study indicates that Nigerian men from Kogi state have a mean Auricular Length of 56.20 ± 4.96 . Concerning dimensions of Lobular Length, Nigerian men from the sample population have been observed to possess shorter lobules than their Indian counterparts, with mean values of 18.99 ± 2.47 mm and 15.11 ± 2.59 mm in Indians and Nigerians respectively. The male subjects involved in this study possess wider lobules (21.34 ± 3.90 mm) than their Indian counterparts (19.54 ± 2.24 mm).

Nigerian women in the studied population have been observed to have a mean Auricular Length of 53.72 ± 6.02 which is lesser compared to the value of 59.42 ± 3.56 mm obtained from Indian women [8]. Lobular Length was also observed to be larger in the Indian population compared to females from the studied Nigerian population, with mean values of 18.76 ± 2.48 mm and 15.5 ± 2.21 mm in Indian women and Nigerian women respectively. Concerning Lobular Width, Nigerian women in the studied population have wider lobules (22.02 ± 5.67 mm) compared to their Indian counterparts (18.54 ± 1.77 mm).

In a study involving people from the North American continent, it was observed that the mean total length of the left ear was 62.4 mm in men and 58.5 mm in women [9], which is larger than the mean of measured dimensions of Nigerians from the Okun and Igala ethnic groups involved in this study. Compared with indigenes of cross river state in Nigeria, this work has proven that both males and females of the Okun and Igala ethnic groups have shorter auricles. Mean values of 56.29 ± 3.82 mm and 59.12 ± 4.58 mm for Auricular Length were obtained from male and female subjects indigenous to Cross River state [1], these values are significantly higher than those obtained from volunteers indigenous to the Okun and Igala ethnic groups of Kogi State.

This ethnic dimorphism is also expressed in dimensions of Auricular Width, with cross river indigenes having values of 34.66 ± 3.68 mm and 36.02 ± 4.02 mm for male and female subjects respectively[1], these values are slightly less than the mean values obtained from indigenes of Okun and Igala ethnic groups of Kogi State in this study.

Concerning Lobule length, the mean value previously obtained [1] male Cross-River indigenes is 16.67 ± 3.70 mm, which is slightly larger than the values obtained for males in this

study. For women, mean lobular length values of 16.34 ± 3.51 mm was previously reported [1], which is also slightly larger than the mean values obtained from the women involved in this study. Regarding Lobule Width, the values obtained in the study conducted by¹ are slightly less than the mean values obtained in this study.

Regarding auricular length, Oludiran and Omotoso [10] reported a mean value of 56.0 (6.1) mm for men which is less than the mean value of $56.20 (\pm 4.96)$ mm obtained from this study. In women, the study previously conducted [10], produced a mean ear height of 55.2 (5.8) mm which is larger than the mean value of $53.72 (\pm 6.02)$ mm obtained from the women involved in this study.

CONCLUSION

The human auricle can be described as a definitive feature of the human face esthetics whose primary function is the reception of sound impulses and transmission of sound waves. Anthropometric studies have shown that the morphometric dimensions of the auricle display a significant level of sexual dimorphism, hence, it can be used as a suitable tool for sexual determination. It has also been observed that auricular morphometric data has also been shown to exhibit a significant level of variation according to stature. The results of this study have also shown that auricular dimensions can be used for personality identification in forensic investigation.

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AUTHOR CONTRIBUTIONS

ASA and AA initiated the research; SBK, SFL and AO participated in the design and

implementation of the experiments while TTA and EOY were involved with manuscript writing.

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