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Original Research Article

Estimating stature in females by using the external ear morphometry

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Abstract

Introduction: Identification refers to determining the individuality of a person. External ear has often emerged as a potential tool for forensic investigations and establishment of personal identification. The present study aims to estimate stature using external ear measurements in males thereby deriving at linear regression formulas and finding out the most reliable parameter.

Materials and Methods: The present study was conducted on 50 young and healthy female medical interns, within the age group 22-25 years. Besides stature, eight external ear parameters, namely, ear length, ear width, lobule length, lobule width, conchal length, conchal width, tragus length and tragus width were considered and their measurements obtained from both the ears of each participant.

Results: Obtained data were analysed by SPSS software version 20.There was a strong significant positive correlation between all measurements and stature. Linear regression formulas for the eight parameters were derived. Actual stature and estimated stature from measurements of both ears were compared.

Conclusion: The study concluded that the morphometry of the external ear can be used in the estimation of the stature and that the conchal length was the most reliable parameter to estimate stature.

Keywords: Correlation coefficient, Ear, Identification, Regression equation, Stature.

Introduction

Stature refers to body height. It is one of the most important parameters to determine the physical identity of an individual. There is a definite biological relationship of stature with all the body parts such as head, trunk, extremities, vertebral column, etc.[1-11]

It is a known fact from many studies that stature bears a direct relation to the length of long bones,[12-15] and linear regression formulas have been derived to estimate the stature from the length of long bones. These linear regression formulas are applied by the forensic experts to estimate the stature whenever skeletal remains are bought for examination.

Whenever fragmented or dismembered remains such as a decapitated head or only a portion of the face are bought for examination, it becomes a challenging task for a forensic expert to estimate the stature and thus establish the identity. In such scenarios, experts need to make an attempt to estimate stature from the cephalofacialdimensions[16-25] such as length, breadth, and circumference of head, nasal morphometry and external ear morphometry. However, studies with respect to the above dimensions are scanty.

The present study aims to estimate stature by using external ear measurements thereby attempting to derive at a linear regression formula for each of the parameters and finding out the most reliable parameter to estimate stature among females.

Materials and Methods

The present study was conducted on 50 young and healthy female medical interns, within the age group 22-25 years. Subjects with external ear deformities (either congenital or acquired) were excluded from the study.

The stature or height is the distance between the highest point on the head (vertex) and floor. It was measured in the standing position by using a height measuring scale and the height was recorded in centimetres (cm).

Standardized measurements of the external ear parameters were measured by manual verniercalipers and recorded in millimetres (mm) according to the landmarked points defined by DeCarloet al[26] and the methodology was adopted by Mckinney et al[27] and Bucker et al.[28]

The parameters measured in the present study were:

1. Ear length (EL)
2. Ear width (EW)
3. Lobule length (LL)
4. Lobule width (LW)
5. Conchal length (CL)
6. Conchal width (CW)
7. Tragus length (TL)
8. Tragus width (TW)

All the measurements were taken thrice to ensure accuracy and the mean of the three readings was considered as the final reading. All measurements were carried out by the same investigator in order to minimize bias and error of identification of the parts of the external ear involved in the measurements.

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The entire ear measurements were recorded in millimetres (mm), systematically tabulated and statistically analysed using SPSS version 20 to derive at a linear regression equation for estimation of stature. Correlation was calculated to assess the correlation between stature and external ear morphometry, and student t test was applied to test the significance. p value <0.05 was considered significant.

Results

The stature of the female medical interns ranged from 146cm-178cm.The mean values and standard deviation are depicted in Table1.

The descriptive statistics of the measurements of external ear (in mm) along with stature using t test are tabulated in Table2.

The correlation between different parameters of both ears and stature is shown in Table3.

Multiple stepwise linear regression analysis of the left and right ear parameters to predict stature is shown in Table 4 and Table 5 respectively.

Table 6 shows the comparision between the actual stature and estimated stature from measeurements of both ears.

Table 1:

	Females
Stature range(cm)	146-178
Mean+/-SD(cm)	162.47+/-8.7

Table 2:

	LT side	**RT side**	**p value**
EL(range) Mean ± S.D	(51.80- 75.70) 63.73 ± 7.21	(51.80- 75.70) 63.74 ± 7.19	0.37
EW(range) Mean ± S.D	(31.20- 42.10) 36.44 ± 3.15	(31.30- 42.10) 36.45 ± 3.13	0.29
LL(range) Mean ± S.D	(13.60 -27.90) 20.28 ± 4.08	(13.60 -28.00) 20.30 ± 4.09	0.017*
LW(range) Mean ± S.D	(13.20 -27.30) 20.24 ± 3.98	(13.10 – 27.40) 20.29 ± 4.00	0.00*
CL(range) Mean ± S.D	(20.60- 37.90) 27.34 ± 4.33	(19.80 – 36.90) 27.34 ± 4.27	0.94
CW(range) Mean ± S.D	(11.20-30.30) 24.21 ± 5.54	(11.0-30.0) 24.21 ± 5.52	0.85
TL(range) Mean ± S.D	(10.20- 17.20) 12.88 ± 1.58	(10.00 – 17.30) 12.92 ± 1.56	0.09
TW(range) Mean ± S.D	(4.20- 7.40) 6.30 ± 0.87	(4.20 – 7.50) 6.27 ± 0.85	0.22

*significant

Table 2-EL:Ear length,EW:Earwidth;LL:Lobulelength;LW:Lobulewidth;CL:Conchallength;CW:Conchalwidth;TL:Traguslength;TW:Tragus width; significant

Table 3:

		r value	p value
EL	Left	0.97	0.00*
	Right	0.97	0.00*
EW	Left	0.93	0.00*
	Right	0.93	0.00*
LL	Left	0.95	0.00*
	Right	0.95	0.00*
LW	Left	0.94	0.00*
	Right	0.94	0.00*
CL	Left	0.93	0.00*
	Right	0.94	0.00*
CW	Left	0.91	0.00*
	Right	0.90	0.00*

TL	Left	0.92	0.00*
	Right	0.92	0.00*
TW	Left	0.95	0.00*
	Right	0.95	0.00*

*significant
r-correlation
Table 3-EL:Ear length,EW:Earwidth;LL:Lobulelength;LW:Lobulewidth;CL:Conchallength;CW:Conchalwidth;TL:Traguslength;TW:Tragus width;

Table 4:

	B	SEM	r	SEE	p value	Regression Equation
Left EL	1.17	0.051	0.98	1.98	0.00*	S=87.51 + (1.17 x Left EL)
constant	87.51	3.17				
Left EL	1.55	0.23	0.97	1.92	0.00*	S=95.71 + (1.55 x Left EL)
Left EW	-0.89	0.53			0.105	S= 95.71 + (-0.89 x Left EW)
constant	95.71	5.85				
Left EL	1.23	0.25	0.98	1.78	0.00*	S=105.34+ (1.23 x Left EL)
Left EW	-0.94	0.49			0.06	S= 105.34 + (-0.4 x Left EW)
Left LL	0.64	0.27			0.026*	S= 105.34 + (0.64 x Left LL)
constant	105.34	6.77				
Left EL	1.23	0.26	0.98	1.81	0.00*	S=104.25 + (1.23 x Left EL)
Left EW	-0.90	0.51			0.09	S= 104.25 + (-0.90 x Left EW)
Left LL	0.34	0.93			0.71	S= 104.25 + (0.34 x Left LL)
Left LW	0.27	0.81			0.74	S=104.25 +(0.27 x Left LW)
constant	104.25	7.62				
Left EL	1.24	0.30	0.98	1.84	0.00*	S=104.23+ (1.26 x Left EL)
Left EW	-0.91	0.53			0.10	S= 104.23 + (-0.91 x Left EW)
Left LL	0.36	1.00			0.71	S= 104.23 + (0.36 x Left LL)
Left LW	0.26	0.86			0.76	S=104.23 +(0.26 x Left LW)
Left CL	-0.01	0.28			0.95	S=104.23 + (-0.01 x Left CL)
constant	104.23	7.78				
Left EL	1.16	0.29	0.98	1.76	0.001*	S=112.52+ (1.13 x Left EL)
Left EW	-1.08	0.51			0.047*	S= 112.52+ (-1.17 x Left EW)
Left LL	0.42	0.96			0.66	S= 112.52+ (0.64 x Left LL)
Left LW	0.06	0.83			0.93	S=112.52+(-0.11 x Left LW)
Left CL	0.13	0.28			0.64	S=112.52+ (0.11 x Left CL)
Left CW	0.27	0.15			0.08	S= 112.52 + (0.27 x Left CW)
constant	111.26	8.4				
Left EL	1.00	0.26	0.98	1.56	0.001*	S=106.16+ (1.00 x Left EL)
Left EW	-0.95	0.46			0.051	S= 106.16+ (-0.95 x Left EW)
Left LL	0.82	0.86			0.35	S= 106.16+ (0.82 x Left LL)
Left LW	-0.31	0.75			0.68	S=106.16+(-0.31 x Left LW)
Left CL	-0.25	0.29			0.38	S=106.16+ (-0.25 x Left CL)
Left CW	0.24	0.13			0.09	S= 106.16+ (0.24 x Left CW)
Left TL	1.38	0.50			0.012*	S=106.16 + (1.38 x Left TL)
constant	106.16	7.67				
Left EL	0.69	0.21	0.99	1.19	0.004*	S=97.74 + (0.69 x Left EL)
Left EW	-0.59	0.36			0.12	S= 97.74 + (-0.54x Left EW)
Left LL	0.30	0.67			0.65	S= 97.74 + (0.48 x Left LL)
Left LW	0.10	0.58			0.86	S=97.74 +(-0.09 x Left LW)
Left CL	-0.11	0.22			0.60	S=97.74 + (-0.03x Left CL)
Left CW	-0.12	0.13			0.38	S= 97.74 + (-0.11x Left CW)
Left TL	1.19	0.39			0.006*	S=97.74 + (0.89x Left TL)
Left TW	3.83	0.94			0.001*	S=97.74 +(3.88 x Left TW)
constant	98.10	6.21				

*significant

B-constant derived;r-correlation;SEM-standard error of measurement;SEE-standard error of estimate
Table 4-EL:Ear length,
EW:Earwidth;LL:Lobulelength;LW:Lobulewidth;CL:Conchallength;CW:Conchalwidth;TL:Traguslength;TW:Tragus width;

Table 5:

	B	SEM	r		SEE	p value	Regression Equation
Right EL	1.17	0.051	0.97	0.95	1.99	0.00*	S=87.35 + (1.17 x Right EL)
constant	87.35	3.29					
Right EL	1.58	0.23	0.97	0.95	1.91	0.00*	S=96.20 + (1.58 x Right EL)
Right EW	-0.95	0.53				0.08	S= 96.20 + (-0.95 x Right EW)
constant	96.20	5.92					
Right EL	1.25	0.25	0.98	0.96	1.76	0.00*	S=106.15 + (1.25 x Right EL)
Right EW	-1.01	0.49				0.052	S= 106.15 + (-1.01 x Right EW)
Right LL	0.65	0.27				0.023*	S= 106.15 + (0.65 x Right LL)
constant	106.15	6.84					
Right EL	1.25	0.26	0.98	0.96	1.80	0.00*	S=105.8 + (1.25 x Right EL)
Right EW	-1.00	0.52				0.06	S= 105.8 + (-1.00 x Right EW)
Right LL	0.58	0.90				0.52	S= 105.8 + (0.58 x Right LL)
Right LW	0.07	0.78				0.92	S=105.8 +(0.07 x Right LW)
constant	105.8	7.72					
Right EL	1.26	0.31	0.98	0.96	1.83	0.00*	S=105.8 + (1.26 x Right EL)
Right EW	-1.00	0.54				0.076	S= 105.8 + (-1.00 x Right EW)
Right LL	0.60	0.96				0.54	S= 105.8 + (0.60 x Right LL)
Right LW	0.05	0.82				0.94	S=105.8 +(0.05 x Right LW)
Right CL	-0.02	0.30				0.94	S=105.8 + (-0.02 x Right CL)
constant	105.8	7.88					
Right EL	1.13	0.30	0.98	0.96	1.75	0.001*	S=112.52+ (1.13 x Right EL)
Right EW	-1.17	0.52				0.035*	S= 112.52+ (-1.17 x Right EW)
Right LL	0.64	0.92				0.49	S= 112.52+ (0.64 x Right LL)
Right LW	-0.11	0.79				0.88	S=112.52+(-0.11 x Right LW)
Right CL	0.11	0.30				0.70	S=112.52+ (0.11 x Right CL)
Right CW	0.27	0.14				0.07	S= 112.52 + (0.27 x Right CW)
constant	112.52	8.30					
Right EL	1.01	0.27	0.98	0.97	1.58	0.001*	S=108.46+ (1.01 x Right EL)
Right EW	-1.06	0.47				0.036*	S= 108.46+ (-1.06 x Right EW)
Right LL	0.98	0.84				0.25	S= 108.46+ (0.98 x Right LL)
Right LW	-0.47	0.72				0.52	S=108.46+(-0.47 x Right LW)
Right CL	-0.15	0.29				0.60	S=108.46+ (0.15 x Right CL)
Right CW	0.26	0.13				0.06	S= 108.46+ (0.276x Right CW)
Right TL	1.19	0.48				0.021*	S=108.46 + (1.19 x Right TL)
constant	108.46	7.68					
Right EL	0.69	0.23	0.99	0.98	1.26	0.008*	S=97.74 + (0.69 x Right EL)
Right EW	-0.54	0.40				0.19	S= 97.74 + (-0.54x Right EW)
Right LL	0.48	0.68				0.49	S= 97.74 + (0.48 x Right LL)
Right LW	-0.09	0.59				0.88	S=97.74 +(-0.09 x Right LW)
Right CL	-0.03	0.23				0.88	S=97.74 + (-0.03x Right CL)
Right CW	-0.11	0.14				0.44	S= 97.74 + (-0.11x Right CW)
Right TL	0.89	0.39				0.03*	S=97.74 + (0.89x Right TL)
Right TW	3.88	1.06				0.001*	S=97.74 +(3.88 x Right TW)
constant	97.74	6.80					

*significant
B-constant derived;r-correlation;SEM-standard error of measurement;SEE-standard error of estimate
Table 5-EL:Ear
length,EW:Earwidth;LL:Lobulelength;LW:Lobulewidth;CL:Conchallength;CW:Conchalwidth;TL:Traguslength;TW:Tragus width;

Table 6:

		Left	Right
EL	Range	(146.92-174.33)	(147.91-175.91)
	Mean ± S.D	160.61 ± 8.27	161.93±8.42
EW	Range	(148.73-177.11)	(148.78-176.75)
	Mean ± S.D	162.25± 8.14	162.13± 8.13
LL	Range	(148.71-177.74)	(147.82-17686)
	Mean ± S.D	162.28±8.28	162.32±8.20
LW	Range	(148.73-177.97)	(147.57-176.89)
	Mean ± S.D	162.32±8.30	162.32 ± 8.20
CL	Range	(149.78-182.31)	(147.95-180.78)
	Mean ± S.D	162.47±8.15	162.43 ± 8.21
CW	Range	(143.80 – 171.11)	(143.70-171.25)
	Mean ± S.D	162.41 ± 7.92	162.86 ± 8.00
TL	Range	(148.75 – 184.31)	(147.41 – 184.78)
	Mean ± S.D	162.27 ± 8.06	162.39 ± 8.02
TW	Range	(197.41- 266.46)	(142.07 – 174.38)
	Mean ± S.D	225.09 ± 14.83	162.40 ± 8.32
Actual stature	Range	(146-178)	
	Mean ± S.D	162.47± 8.7	

Table 6-EL:Ear length,EW:Earwidth;LL:Lobulelength;LW:Lobulewidth;CL:Conchallength;CW:Conchalwidth;TL:Traguslength;TW:Tragus width;

Discussion

The earliest reference to individuality of the external ear was made by Bertillon[29] who mentioned in his book that it is almost impossible to meet with two ears which are identical in all their parts. Though Bertillon did not undertake any research work on the use of ear as personal identification tool, he had made the above observation from his experience gathered from working on anthroposcopy and anthropometry of criminals.

The identity of Veerappan, the notorious sandalwood smuggler in India who was killed by the Special Task Force in 2004 was at first established through the morphology of ear. While comparing the anatomical structure of Veerappan's external ear in antemortem and post-mortem photographs, the Forensic Scientist confirmed his identity on the basis of combination of various features. A large and squarish lobule with a flat tragus which is contiguous with the curved portion of the helix made Veerappan's ear unique, thus helping in his identification.[30]

The ear is more coplanar, less affected by ageing, unaffected by change of facial expression, though hair and ear ornaments can occlude its appearance. It is stated that the full length of the ear is reached by age 15 in males and age 13 in females.[31]The external ear does suffer from a few limitations. After the age of 60, the lobule continues to elongate contributing to the overall length of the ear.[32]

In a similar study conducted by Magaji Garba Tauraet al[17], ear index, a new parameter was considered as one of the variables to predict stature. Ear index was calculated by era width/ear lengthx100. However, the study observed the least correlation in ear index and the highest correlation in ear width.

Conclusion

Estimation of stature is considered an important parameter in medicolegal and forensic examinations.

The present study concludes that the external ear morphometry is an additional important tool useful in the estimation of stature by using statistical methods, and conchal length being the most reliable parameter. The regression equations generated from the external ear measurements can be a supplementary approach for the estimation of stature when the extremities are not available. Also, the regression formula derived in this study will be of potential use in clinical, medicolegal and anthropological studies. The authors plan to conduct a similar study on male subjects too. The authors recommend that more such studies need to be conducted on both sexes in different regions involving all age groups.

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Ethical Clearance

Issued by the Institutional Ethics Committee

Consent

Informed consent taken from medical interns for the study

Conflict of interest

None.

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