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Estimation of Stature in Upper Egypt Population from External Ear Morphometry

Research Article

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Abstract

Estimation of stature is considered an important parameter in medico-legal and forensic examinations. Therefore, this study was carried out to investigate the possibility of estimating stature from external ear morphometry in a sample of Upper Egypt population. This study was carried out on 200 persons (120 males and 80 females). Besides stature, eight measurements were obtained from both ears of each participant using manual vernier caliper. Data were analyzed by SPSS version 20. There was a strong significant positive correlation between all measurements and stature. A linear equation model for prediction of stature from given external ear dimension was generated. By simple linear regression analysis, the most accurate predictable variable of stature from both ears in males was ear length (R^2 = 0.928 in right ear and R^2 = 0.915 in left ear). While in females; right ear width (R^2 = 0.855) and left conchal width (R^2 = 0.771) are the most accurate variables that can predict stature. Finally, it is concluded that external ear morphometry can be used as an additional tool in the estimation of stature in Upper Egypt population.

Keywords: Forensic Examinations; Stature; Ear morphometry; Upper Egypt; Linear Regression.

Introduction

Personal identification means determination of individuality of a person. It is an important aspect in forensic science. In living subjects, identification was based on certain morphological criteria unique to that individual. In case of skeletal remains, identification is more complicated and requires accurate examinations of these remains [1].

Anthropometry refers to the measurement of living human body dimensions for the purpose of understanding human physical variations. Age, sex and stature are the primary characteristics of identification. Anthropometric data are believed to be objective and they allow the forensic anthropologist go beyond subjective assessments such as "similar" or "different". The forensic examiner must be able to quantify the degree of similarity or difference and finally decide how much confidence can be placed in this examination [2].

Establishment of alternative methodologies for personal stature estimation is very important for a number of reasons. Firstly, in instants where stature estimates needed to be made from bones in archeological procedures or in forensic examinations after mass disasters. When the body has been mutilated, it is common to have the extremities or head amputated from the trunk. An estimate must be then made on the known relationship of the remains to stature [3].

Also, estimates of pharmacokinetic parameters and evaluation of nutritional status relay on accurate measurement not only of body weight but also stature. However, a number of common diseases or deformities of the vertebral column make it difficult to accurately measure stature in standing position in many patients [4]. Many studies have been conducted on the estimation of stature from different body parts like hands, trunk, vertebrae, extremities and foot. Since, all these parts of the body and also bones are not always available for forensic examination. It becomes now

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necessary to make use of other parts of the body like head & face region [5].

Ears in humans are the defining feature of the face and its structure shows the signs of age and sex. The human ear is divided into external, middle and internal parts. Pinna and external acoustic meatus form the external ear. The lateral surface of the pinna is irregularly concave, faces slightly forward and displays numerous eminences and depressions [6].

Owed to the few number and scanty data that was concerned with the utilization of external ear morphometry for estimation of stature of individuals, the objective of this study was to estimate stature by using external ear measurements and derive an equation of linear regression that are specific for identification of stature in Upper Egypt population.

Subjects and Methods

This study was carried out on 200 persons (120 males and 80 females), with age ranges from 18- 25 years. Subjects were randomly selected from the Faculty of Medicine - Minia University- Egypt, as medical students and faculty employers. A written informed consent was taken from each participant. Any participant with physical deformity, tumors, congenital anomalies and previous surgeries of external ears were excluded from this study.

Anthropometric measurements

Eight measurements beside individual stature were taken from both ears of each participant. According to Krishan [7], stature was measured as a vertical distance from the vertex to the floor using a standard anthropometric Frankfurt plane. Stature was taken by making the subject stand on a horizontal resisting plane, with foot bared and heels together and they must not leave the ground.

Beside stature, standardized measurements of the external ear were taken according to the landmarked points defined by De Carlo et al., [8] and the methodology was adopted from Mckinney et al., [9] and Brucker et al., [10]. The parameters were measured in the sitting positing with the head in the Frankfurt horizontal plane by manual vernier caliper. They include Ear length (EL), Ear width (EW), Conchal length (CL), Conchal width (CW), Lobule length (LL), Lobule width (LW), Tragus length (TL) and Tragus width (TW). All ear measurements were taken in millimeters (Figure 1).

For each subject, the measurements were carried out twice to ascertain accuracy and the arithmetical mean of the two measurements was used for each dimension. Secondly, 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.

The data were analyzed using SPSS version 20. Mean and standard deviations were obtained for stature and all measurements of both ears in males and females. Correlation between stature and different measurements was tested using Pearson's correlation. Student-*t*-test was done to establish that a significant sexual difference was present. Linear regression analysis was performed to derive an equation to predict stature in Upper Egypt population.

Results

In this study, there was a significant sexual difference in stature and insignificant sexual difference in all ear measurements except right and left EL, left EW, left LL and right TW. There was a statistically significant difference in all measurements of both ears except EL in males and EL, LL and CW in females (Table 1).

There was a significant strong positive correlation between all measured parameters of right and left ears and stature in both sexes (Table 2). Linear regression analysis was done in this study to predict the stature of both sexes from external ears measurements.

By linear regression analysis, stature can be estimated from this equation:

Person's stature = constant + (slopping of unstandardized coefficient x ear measurement). By simple linear regression analysis, the most predictable variable in estimation of stature in males from right ear measurements was EL (R= 0.963 & R^2 = 0.928) followed by CL (R= 0.945 & R^2 = 0.944) and finally EW (R= 0.930 & R^2 = 0.865). While, in left ear, the most accurate variable that can predict stature was EL (R= 0.956 & R^2 = 0.915) followed by CW (R= 0.955 & R^2 = 0.913) and finally CL (R= 0.945 & R^2 = 0.893) (Table 3).

In females, the most predictable variables of stature from right ear parameters were EW (R= 0.925 & R^2 = 0.855), followed by EL (R= 0.898 & R^2 = 0.806) and lastly LW (R= 0.893 & R^2 =0.797). While, in left ear, the most accurate variable that can predict stat-

Figure 1. Photograph of the Right Ear of a Female Subject showed the Measured Parameters as Follow: Ear Length (A-B), Ear Width (C-D), Conchal Length (E-F), Conchal Width (G-H), Lobule Length (F-B), Lobule Width (I-J), Tragus Length (G-F), Tragus Width (K-L).

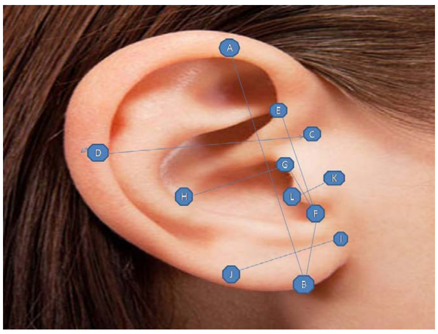

Table 1. Descriptive Statistics of the Measurements of External Ears Along with Stature in Both Sexes Using *t* - Test.

	Male (n=120)		P value	Female (n=80)		P value	P value between Different sex	
	RT side	LT side		RT side	LT side		RT side	LT side
EL Range Mean ± SD	(51.8-74.4) 65.41±5.89	(51.8-73.4) 65.72±5.49	0.665	(51.8-74.4) 63±6.83	(51.8-74) 62.15±6.7	0.427	0.011*	<0.001*
EW Range Mean ± SD	(31-43.2) 36.76±2.97	(31.3-43) 38.48±2.72	<0.001*	(31-43.2) 36.01±3.09	(31.3-43.3) 37.42±2.97	0.004*	0.087	0.012*
LL Range Mean ± SD	(13-27) 19.68±3.76	(15.3-26.6) 21.14±3.01	0.001*	(13-27) 19.09±4.01	(14.8-26.6) 19.58±3.16	0.397	0.293	0.001*
LW Range Mean ± SD	(13-25.6) 19.03±3.06	(15-26.2) 20.77±3.03	<0.001*	(13-25.6) 18.8±3.33	(15-26.2) 20.45±3.09	0.001*	0.612	0.483
CL Range Mean ± SD	(20.2-37.8) 29.79±4.71	(22-39.8) 32.91±4.62	<0.001*	(20.2-39.7) 29.15±5.72	(20.99-43.6) 32.28±6.04	0.001*	0.388	0.433
CW Range Mean ± SD	(11.2-27.8) 20.73±3.94	(12-31.3) 23.67±5.39	<0.001*	(11.2-33.5) 21.56±5.51	(12-31.3) 22.77±6.14	0.192	0.246	0.292
TL Range Mean ± SD	(6-17.6) 11.82±2.95	(8.7-18.6) 13.49±2.66	<0.001*	(6-19.6) 11.94±3.42	(8.7-18.6) 13.36±2.77	0.004*	0.792	0.725
TW Range Mean ± SD	(1.2-9.2) 4.49±2.3	(3.9-11.8) 7.13±2.19	<0.001*	(1.2-11.9) 5.42±3.53	(3.9-12) 7.41±2.48	<0.001*	0.039*	0.414
Stature Range Mean ± SD	(149-185) 167.83±8.38			(147-185) 164.2±9.91			0.006*	

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width, SD: Standard Deviation

*P value is significant when P < 0.05.

Table 2. Correlation between Different Parameters of Both Ears & Stature in Males & Females.

Male	Stature	
	r	P value
Right EL	0.963	<0.001*
Right EW	0.930	<0.001*
Right LL	0.806	<0.001*
Right LW	0.916	<0.001*
Right CL	0.972	<0.001*
Right CW	0.907	<0.001*
Right TL	0.872	<0.001*
Right TW	0.833	<0.001*
Left EL	0.956	<0.001*
Left EW	0.829	<0.001*
Left LL	0.782	<0.001*
Left LW	0.850	<0.001*
Left CL	0.945	<0.001*
Left CW	0.955	<0.001*
Left TL	0.883	<0.001*
Left TW	0.824	<0.001*
Female	Stature	
	r	P value
Right EL	0.898	<0.001*
Right EW	0.925	<0.001*
Right LL	0.664	<0.001*
Right LW	0.893	<0.001*
Right CL	0.849	<0.001*
Right CW	0.690	<0.001*
Right TL	0.838	<0.001*
Right TW	0.629	<0.001*
Left EL	0.863	<0.001*
Left EW	0.825	<0.001*
Left LL	0.337	<0.001*
Left LW	0.797	<0.001*
Left CL	0.862	<0.001*
Left CW	0.878	<0.001*
Left TL	0.857	<0.001*
Left TW	0.720	<0.001*

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width

*correlation is significant if P < 0.05.

Table 3. Simple Linear Regression Analysis of Measurements of Both Ears to Predict the Stature in Males & Females.

Male Model	B	SEM	R	R^2	SEE	P value	Regression equation
Right EL Constant	1.37 78.21	0.03 2.31	0.963	0.928	2.26	< 0.001*	S= 78.21+ (1.37 x Right EL)
Right EW Constant	2.62 71.48	0.09 3.51	0.93	0.865	3.08	< 0.001*	S= 71.48 + (2.62 x Right EW)
Right LL Constant	1.79 132.51	0.12 2.43	0.806	0.65	4.98	< 0.001*	S= 132.51 + (1.79 x Right LL)
Right LW Constant	2.5 120.22	0.1 1.94	0.916	0.839	3.37	< 0.001*	S= 120.22 + (2.5 x Right LW)
Right CL Constant	1.73 116.27	0.03 1.16	0.945	0.944	1.98	< 0.001*	S= 116.27 + (1.73 x Right CL)
Right CW Constant	1.92 127.88	0.08 1.74	0.907	0.822	3.55	< 0.001*	S= 127.88 + (1.92 x Right CW)
Right TL Constant	2.47 138.61	0.12 1.55	0.872	0.76	4.12	< 0.001*	S= 138.61 + (2.47 x Right TL)
Right TW Constant	3.03 154.21	0.18 0.93	0.833	0.695	4.65	< 0.001*	S= 154.21 + (3.03 x Right TW)
Left EL Constant	1.46 71.88	0.04 2.71	0.956	0.915	2.45	< 0.001*	S= 71.88 + (1.46 x Left EL)
Left EW Constant	2.55 69.69	0.15 6.1	0.829	0.688	4.7	< 0.001*	S= 69.69 + (2.55 x Left EW)
Left LL Constant	2.17 121.83	0.16 3.41	0.782	0.612	5.24	< 0.001*	S= 121.83 + (2.17 x Left LL)
Left LW Constant	2.35 118.99	0.13 2.81	0.85	0.723	4.42	< 0.001*	S= 118.99 + (2.35 x Left LW)
Left CL Constant	1.71 111.42	0.05 1.81	0.945	0.893	2.75	< 0.001*	S= 111.42 + (1.71 x Left CL)
Left CW Constant	1.48 132.68	0.04 1.02	0.955	0.913	2.48	< 0.001*	S= 132.68 + (1.48 x Left CW)
Left TL Constant	2.78 130.31	0.13 1.86	0.883	0.781	0.394	< 0.001*	S= 130.31+ (2.78 x Left TL)
Left TW Constant	3.15 145.36	0.19 1.48	0.824	0.679	4.76	< 0.001*	S= 145.36 + (3.15 x Left TW)
Female Model	**B**	**SEM**	**R**	**R^2**	**SEE**	**P value**	**Regression equation**
Right EL Constant	1.3 82.14	0.07 4.58	0.898	0.806	4.39	< 0.001*	S= 82.14 + (1.3x RT EL)
Right EW Constant	2.96 57.6	0.13 4.9	0.925	0.855	3.79	< 0.001*	S= 57.6+ (2.96 x RT EW)
Right LL Constant	1.64 132.86	0.21 4.08	0.664	0.440	7.45	< 0.001*	S= 132.86 + (1.64 x RT LL)
Right LW Constant	2.65 114.34	0.15 2.89	0.893	0.797	4.49	< 0.001*	S= 114.34+ (2.65 x RT LW)
Right CL Constant	1.46 121.37	0.1 3.07	0.849	0.720	5.27	< 0.001*	S= 121.37+ (1.46 x RT CL)
Right CW Constant	1.24 137.42	0.14 3.27	0.690	0.476	7.21	< 0.001*	S= 137.42+ (1.24 x RT CW)
Right TL Constant	2.42 135.27	0.17 2.22	0.838	0.702	5.44	< 0.001*	S= 135.27+ (2.42 x RT TL)
Right TW Constant	1.76 154.61	0.24 1.59	0.629	0.396	7.74	< 0.001*	S= 154.61+ (1.76 x RT TW)
Left EL Constant	1.27 84.89	0.08 5.28	0.863	0.745	5.03	< 0.001*	S= 84.89 + (1.27 x LT EL)
Left EW Constant	2.74 61.43	0.21 7.99	0.825	0.681	5.63	< 0.001*	S= 61.43 + (2.74 x LT EW)
Left LL Constant	1.05 143.5	0.33 6.62	0.337	0.114	9.38	< 0.001*	S= 143.5 + (1.05 x LT LL)
Left LW Constant	2.54 112.05	0.21 4.53	0.797	0.634	6.02	< 0.001*	S= 112.05 + (2.54 x LT LW)
Left CL Constant	1.41 118.54	0.09 3.08	0.862	0.744	0.504	< 0.001*	S= 118.54 + (1.41x LT CL)
Left CW Constant	1.41 131.94	0.08 2.05	0.878	0.771	4.76	< 0.001*	S= 131.94 + (1.41 x LT CW)
Left TL Constant	3.06 123.31	0.21 2.84	0.857	0.734	5.14	< 0.001*	S= 123.31 + (3.06 x LT TL)
Left TW Constant	2.87 142.91	0.31 2.45	0.72	0.518	6.92	< 0.001*	S= 142.91 + (2.87 x LT TW)

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width
*Correlation is significant if $P < 0.05$.
S: person's stature

ure was CW (R= 0.878 & R^2 = 0.771) followed by EL (R= 0.863 & R^2 = 0.745) and finally CL (R= 0.862 & R^2 = 0.744) (Table 3).

By multiple linear regression analysis, combination of all measurements in both ears was occurred. In the right ear in males, R= 0.997 and R^2 =0.994. While, in the left ear, R= 0.994 and R^2 = 0.987. In females, R= 0.996 and R^2 = 0.991 in the right ear, in the left ear, R= 0.991 and R^2 = 0.982 (Table 4).

By stepwise linear regression analysis, 6 models can be used to predict stature in males from right ear measurements. The most predictable model in stature estimation was that contained combination of (CL, EL, TW, LW, LL and EW) (R= 0.997 and R^2 = 0.993) (Table 5). While, in the left ear of males, 7 models can be used and the model that can estimate stature accurately was that contained combination of (EL, TW, EW, CW, LL, LW and CL) (R= 0.994 and R^2 = 0.986) (Table 6).

Three models were used to predict stature from right ear measurements by stepwise linear regression analysis in females. The model that can highly predict stature accurately was that contained combination of (EW, LL and EL) (R= 0.993 and R^2 = 0.986). While, in left ear five models were used. The model that contained combination of (EL, LW, TL and TW) was the most predictable model in stature estimation (R= 0.990 and R^2 = 0.981) (Table 7).

Standard error of estimate (SEE) was demonstrated in all tables of linear regression analysis. IT was calculated separately for each regression formula for estimation of stature. The SEE tends to predict the deviation of estimated stature from the actual stature. It is clear from table 8, that the mean estimated stature was close to the actual stature in both sexes from measurements of both ears. This indicates that the measuring technique in this study is satisfactory.

Table 4. Multiple Linear Regression Analysis of Measurements of Both Ears to Predict the Stature in Males & Females.

Male Model	B	SEM	R	R^2	SEE	P value	Regression equation
Right EL	1.55	0.1	0.997	0.994	0.65	< 0.001*	S= 65.41
Right EW	1.75	0.29				< 0.001*	+ (1.55 x RT EL)
Right LL	-1.24	0.23				< 0.001*	+ (1.75 x RT EW)
Right LW	-0.67	0.12				< 0.001*	+ (-1.24 x RT LL)
Right CL	-1.61	0.17				< 0.001*	+ (-0.67 x RT LW)
Right CW	1.71	0.36				< 0.001*	+ (-1.61 x RT CL)
Right TL	-3.04	0.69				< 0.001*	+ (1.71 x RT CW)
Right TW	4.89	0.47				< 0.001*	+ (-3.04x RT TL)
Constant	65.41	5.74					+ (4.89 x RT TW)
Left EL	1.61	0.08	0.994	0.987	0.98	< 0.001*	S= 101.13
Left EW	-1.78	0.18				< 0.001*	+ (1.61x LT EL)
Left LL	1.18	0.28				< 0.001*	+ (-1.78x LT EW)
Left LW	-2.31	0.37				< 0.001*	+ (1.18x LT LL)
Left CL	1.29	0.44				0.005*	+ (-2.31x LT LW)
Left CW	-1.21	0.35				0.001*	+ (1.29 x LT CL)
Left TL	0.25	0.38				0.506	+ (-1.21 x LT CW)
Left TW	3.05	0.41				< 0.001*	+ (0.25 x LT TL)
Constant	101.13	5.78				< 0.001*	+ (3.05 x LT TW)
Female Model	**B**	**SEM**	**R**	**R^2**	**SEE**	**P value**	**Regression equation**
Right EL	0.27	0.1	0.996	0.991	0.96	0.008*	S= 41.82
Right EW	3.17	0.32				< 0.001*	+ (0.27 x RT EL)
Right LL	-1.69	0.06				< 0.001*	+ (3.17 x RT EW)
Right LW	0.25	0.13				0.055	+ (-1.69 x RT LL)
Right CL	0.15	0.18				0.423	+ (0.25 x RT LW)
Right CW	0.14	0.12				0.243	+ (0.15 x RT CL)
Right TL	1.41	0.33				< 0.001*	+ (0.14 x RT CW)
Right TW	-1.14	0.17				< 0.001*	+ (1.41 x RT TL)
Constant	41.82	6.38					+ (-1.14 x RT TW)
Left EL	0.94	0.07	0.991	0.982	1.38	< 0.001*	S= 87.89
Left EW	0.08	0.18				0.629	+ (0.94x LT EL)
Left LL	-0.03	0.09				0.685	+ (0.08 x LT EW)
Left LW	-1.51	0.27				< 0.001*	+ (-0.03x LT LL)
Left CL	0.01	0.09				0.941	+ (-1.51x LT LW)
Left CW	0.18	0.1				0.069	+ (0.01 x LT CL)
Left TL	3.84	0.38				< 0.001*	+ (0.18 x LT CW)
Left TW	-1.31	0.27				< 0.001*	+ (3.84 x LT TL)
Constant	87.89	2.95					+ (-1.31x LT TW)

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width

*correlation is significant if $P < 0.05$.

S: person's stature.

Table 5. Multiple Stepwise Linear Regression Analysis of Right Ear Parameters to Predict the Stature in Males.

Model	B	SEM	R	R^2	SEE	P value	Regression equation
Right CL Constant	1.73 116.27	0.03 1.16	0.972	0.945	1.98	< 0.001*	S= 116.27 + (1.73x Right CL)
Right CL Right EL Constant	1.02 0.59 98.34	0.9 0.7 2.51	0.981	0.963	1.62	< 0.001* < 0.001*	S= 98.34 + (1.02x Right CL) + (0.59 x Right EL)
Right CL Right EL Right TW Constant	-1.23 1.7 2.24 83.38	0.14 0.7 0.13 1.62	0.995	0.989	0.87	< 0.001* < 0.001* < 0.001*	S= 83.38 + (-1.23 x Right CL) + (1.7 x Right EL) + (2.24 x Right TW)
Right CL Right EL Right TW Right LW Constant	-1.5 1.92 3.02 -0.56 83.51	0.15 0.09 0.23 0.14 1.52	0.995	0.991	0.82	< 0.001* < 0.001* < 0.001* < 0.001*	S= 83.51 + (-1.5 x Right CL) + (1.92 x Right EL) + (3.02 x Right TW) + (-0.56x Right LW)
Right CL Right EL Right TW Right LW Right LL Constant	-1.5 1.91 3.71 -0.5 -0.44 89.41	0.14 0.08 0.29 0.14 0.13 2.24	0.996	0.992	0.78	< 0.001* < 0.001* < 0.001* < 0.001* < 0.001*	S= 89.41 + (-1.5 x Right CL) + (1.91x Right EL) + (3.71x Right TW) + (-0.5x Right LW) + (-0.44x Right LL)
Right CL Right EL Right TW Right LW Right LL Right EW Constant	-1.29 1.68 3.22 -0.58 -0.68 0.8 76.95	0.13 0.09 0.28 0.12 0.13 0.16 3.23	0.997	0.993	0.71	< 0.001* < 0.001* < 0.001* < 0.001* < 0.001* < 0.001*	S= 76.95 + (-1.29 x Right CL) + (1.68 x Right EL) + (3.22 x Right TW) + (-0.58x Right LW) + (-0.68x Right LL) + (0.8 x Right EW)

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width
*correlation is significant if $P < 0.05$.
S: person's stature

Table 6. Multiple Stepwise Linear Regression Analysis of Left Ear Parameters to Predict the Stature in Males.

Model	B	SEM	R	R^2	SEE	P value	Regression Equation
Left EL Constant	1.46 71.88	0.04 2.71	0.956	0.915	2.45	< 0.001*	S= 71.88 + (1.46x Left EL)
Left EL Left TW Constant	1.12 1.25 85.16	0.03 0.07 1.71	0.987	0.974	1.37	< 0.001* < 0.001*	S= 85.16 + (1.12x Left EL) + (1.25x Left TW)
Left EL Left TW Left EW Constant	1.17 1.89 -0.62 101.06	0.03 0.16 0.13 3.87	0.989	0.978	1.27	< 0.001* < 0.001* < 0.001*	S= 101.06 + (1.17x Left EL) + (1.89 x Left TW) + (-0.62x Left EW)
Left EL Left TW Left EW Left CW Constant	1.35 2.11 -0.62 -0.26 93.58	0.07 0.17 0.13 0.09 4.69	0.989	0.979	1.23	< .001* < .001* < .001* 0.008*	S= 93.58 + (1.35x Left EL) + (2.11x Left TW) + (-0.62x Left EW) + (-0.26 x Left CW)
Left EL Left TW Left EW Left CW Left LL Constant	1.65 1.66 -1.03 -0.59 1.06 88.56	0.09 0.18 0.18 0.11 0.22 4.42	0.991	0.982	1.13	< 0.001* < 0.001* < 0.001* < 0.001* < 0.001*	S= 88.56 + (1.65x left EL) + (1.66x Left TW) + (-1.03x Left EW) + (-0.59 x Left CW) + (1.06x Left LL)
Left EL Left TW Left EW Left CW Left LL Left LW Constant	1.58 2.78 -1.58 -0.24 1.95 -1.87 108.39	0.08 0.26 0.17 0.11 0.25 0.34 5.35	0.993	0.985	1.01	< 0.001* < 0.001* < 0.001* 0.042* < 0.001* < 0.001*	S= 108.39 + (1.58 x Left EL) + (2.78 x Left TW) + (-1.58 x Left EW) + (-0.24 x Left CW) + (1.95 x Left LL) + (-1.87 x Left LW)
Left EL Left TW Left EW Left CW Left LL Left LW Left CL Constant	1.63 3.24 -1.77 -1.13 1.9 -2.33 1.21 101.54	0.08 0.3 0.18 0.33 0.24 0.37 0.42 5.74	0.994	0.986	0.98	< 0.001* < 0.001* < 0.001* 0.001* < 0.001* < 0.001* 0.006*	S= 101.54 + (1.63x Left EL) + (3.24 x Left TW) + (-1.77 x Left EW) + (-1.13 x Left CW) + (1.9x Left LL) + (-2.33 x Left LW) + (1.21 x Left CL)

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width
*correlation is significant if $P < 0.05$. S: person's stature

Table 7. Multiple stepwise linear regression analysis of measurements of both ears to predict the stature in females.

Model	B	SEM	R	R^2	SEE	P value	Regression equation
Right EW Constant	2.96 57.6	0.13 4.99	0.925	0.855	3.79	< 0.001*	S= 57.6 + (2.96 x Right EW)
Right EW Right LL Constant	5.05 -1.82 17.06	0.13 0.11 3.26	0.985	0.97	1.72	< 0.001* < 0.001*	S= 17.06 + (5.05 x Right EW) + (-1.82 x Right LL)
Right EW Right LL Right EL Constant	4.17 -1.66 0.36 22.59	0.13 0.07 0.04 2.36	0.993	0.986	1.21	< 0.001* < 0.001* < 0.001*	S= 22.59 + (4.17 x Right EW) + (-1.66 x Right LL) + (0.36 x Right EL)
Left CW **Constant**	1.41 131.94	0.08 2.05	0.878	0.771	4.76	< 0.001*	S= 131.94 + (1.41 x Left CW)
Left CW **Left EL** **Constant**	0.88 0.74 98.01	0.07 0.06 3.28	0.956	0.913	2.95	< 0.001* < 0.001*	S= 98.01 + (0.88 x Left CW) + (0.74 x Left EL)
Left CW **Left EL** **Left TL** **Constant**	0.49 0.72 0.99 94.85	0.12 0.06 0.25 3.12	0.963	0.928	2.71	< 0.001* < 0.001* < 0.001*	S= 94.85 + (0.49 x Left CW) + (0.72 x Left EL) + (0.99 x Left TL)
Left EL **Left LW** **Left TL** **Constant**	1.13 -2.41 3.8 92.01	0.04 0.17 0.15 1.66	0.988	0.976	1.56	< 0.001* < 0.001* < 0.001*	S= 92.01 + (1.13 x Left EL) + (-2.41 x Left LW) + (3.8 x Left TL)
Left EL **Left LW** **Left TL** **Left TW** **Constant**	1.03 -1.82 4.34 -1.15 88.02	0.04 0.2 0.25 0.18 1.73	0.990	0.981	1.4	< 0.001* < 0.001* < 0.001* < 0.001*	S= 88.02 + (1.03 x Left EL) + (-1.82 x Left LW) + (4.34 x Left TL) + (-1.15 x Left TW)

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width
*correlation is significant if $P < 0.05$.
S: person's stature

Table 8. Comparison between Actual Stature and Estimated Stature from Measurements of Both Ears in Males and Females.

	Male		Female	
	RT side	**LT side**	**RT side**	**LT side**
Estimated stature by EL Range Mean ± SD	 (149.19-180.15) 167.85±8.07	 (147.51-179.04) 167.82±8.01	 (149.61-179.04) 164.3±8.89	 (150.99-179.32) 164.2±8.55
Estimated stature by EW Range Mean ± SD	 (152.73-184.71) 167.80±7.79	 (149.51-179.34) 166.89±6.95	 (149.36-185.48) 164.1±9.16	 (147.37-180.32) 165.2±8.17
Estimated stature by LL Range Mean ± SD	 (155.84-180.96) 166.86±6.75	 (155.11-179.69) 166.83±6.55	 (154.19-177.17) 165.2±6.57	 (159.14-171.61) 164.5±3.34
Estimated stature by LW Range Mean ± SD	 (152.73-184.25) 166.83±7.67	 (154.26-180.6) 166.78±7.12	 (148.81-182.22) 164.1±8.84	 (150.28-178.82) 164.6±7.89
Estimated stature by CL Range Mean ± SD	 (151.22-181.67) 167.81±8.14	 (149.13-179.64) 167.72±7.92	 (151.04-179.68) 164.7±8.41	 (148.22-180.21) 164.5±8.54
Estimated stature by CW Range Mean ± SD	 (149.46-181.43) 167.93±7.59	 (150.5-179.15) 167.81±8.01	 (151.32-179.01) 164.6±6.83	 (148.93-176.26) 164.1±8.7
Estimated stature by TL Range Mean ± SD	 (153.44-182.12) 167.81±7.31	 (154.49-182.01) 167.8±7.41	 (149.81-182.75) 164.1±8.3	 (149.93-180.23) 164.6±8.49
Estimated stature by TW Range Mean ± SD	 (157.84-182.11) 167.81±6.98	 (157.64-182.53) 167.82±6.91	 (156.73-175.63) 164.4±6.23	 (154.11-177.37) 164.3±7.12
Actual Stature Range Mean ± SD	 (149-185) 167.83±8.38		 (147-185) 164.2±9.91	

EL: Ear Length, EW: Ear Width, LL: Lobule Length, LW: Lobule Width, CL: Conchal Length, CW: Conchal Width, TL: Tragus Length, TW: Tragus Width.

Discussion

Human identification is of a great importance in many anthropological cases and traumatic events. Within the medicolegal field, the objective of the forensic anthropologist when working with recovered skeletal remains is the determination of sex, stature, age and race. Estimation of stature is an important tool in forensic examination especially in unknown highly decomposed, fragmentary and mutilated human remains [7].

Stature is being one of the criteria of personal identification that helps in narrowing down the investigation process and thus provides useful clues to the investigation agencies. It becomes very difficult for a forensic anthropologist when isolated remains of head, face, or skull are brought for forensic examination, as the standards available in this direction are scanty. Therefore, facial measurements (e.g. nose, mouth and ear measurements) act as a useful tool in the absence of the other evidences for stature estimation [11].

There are many functions of external ear. It receives sound waves for hearing and supporting eye glasses. Also, it is an important aesthetic defining feature of the human face. Overall, facial beauty arises from symmetric and harmonious proportions of its defining features [12].

There are many benefits of using the ear dimensions as a data source for individual identification. The ear has characteristic ear parts; the location of these parts, their directions, angles; their size and relation within the ear are distinct and unique to humans. So, ear measurements can be used as a modality for personal identification [13].

Studies of external ear morphometry have been significantly used in many purposes like plastic surgery [14-17], determination of racial variation [18] and designing of ear related products [19]. The use of external ear measurements in stature estimation is limited. Therefore, the objective of this study was to estimate stature Upper Egypt population using external ear morphometry and derive a linear regression equation to predict stature.

The results of this present study demonstrated that there was a statistically insignificant sexual difference in all ear measurements except right and left EL, left EW, left LL and right TW. Coinciding with these results, Cagatay and Erol [17] concluded that there was a significant sexual difference in right and left EL, EW, LW and LL.

Deopa et al., [2] conducted a study included anthropometric measurements of external ear of medical students in Uttarakhand region. Their study revealed the presence of insignificant sexual difference in all measured parameters of both ears. Their study is not in agreement of our study. In the study of Oludiran and Omotoso [20], there was a significant sexual difference in EL, EW and lobule parameters of both ears and this is not in concordance with our findings except in EL of both ears, left EW and left LL which are significantly sexually different.

This study revealed that there was a strong significant positive correlation between all measurements of both ears and stature in both sexes. These results agree with the results of Magaji et al., [21]. Their study revealed that there was a statistically significant correlation between EL and EW of both ears and stature. Also, our results are in concordance with the results of Lynn et al., [22, 23]. Their study on ear print revealed that there was a possible correlation between some auricle dimensions and stature. .

Prediction of stature from external ear measurements in this study was done by the use of linear regression analysis. By simple linear regression analysis, the highly predictable variables of stature from right ear measurements in males were EL, CL and EW. While, from left ears measurements, the variables were EL, CW and CL. In females, the most highly predictable variables of right ear were EW, EL and LW. On the other hand, the highly predictable variables of left ear were CW, El and CL.

In stepwise linear regression analysis, the model that can highly statistically significantly predict stature in males from right ear measurements was the combination of (CL, EL, TW, LW, LL and EW). While, in left ear the model was the combination of the following parameters (EL, TW, EW, CW, LL, LW and CL). In females, the most predictable model of stature from right ear measurements was combination of (EW, LL and EL). In left ear, the model was that contained combination of (EL, LW, TW and TL).

Only a single study [21] involving the use of simple linear regression formula for estimation of stature from external ear measurements could be found by the authors. This study revealed that left EW (R^2= 0.086) was the most predictable variable to estimate stature, this is followed by right EL (R^2= 0.082) and finally left EL (R^2 = 0.074) and their results are not in concordance with our results.

When we compare our study with those of others, we find that there is a difference in the values of ear measurements and these differences could be a result of many factors such as race, age, genetic variables, individual constitution, environmental factors, and human error in both ear measurements and stature estimation.

Conclusion & Recommendations

In conclusion, this study has demonstrated that the ear morphometry is an additional important tool in the estimation of stature by using simple statistical method. The regression equations generated from external ear measurements can be a supplementary approach for the estimation of stature when extremities are not available. Also, the regression formulae derived in this study will be of potential use in clinical, medicolegal and anthropological studies.

It is recommended to do further researches to cover the assessment of the effect of age and population race on the regression coefficients during estimation of stature from ear morphometry.

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