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ESTIMATION OF HEIGHT FROM LENGTH OF ULNA AND LENGTH OF FIBULA IN INDIAN AND IRAQI POPULATION

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Abstract

Objective: To develop regression model for height prediction using age, length of ulna and fibula in Indian and Iraqi populations.
Methods: Apparently healthy 103 Indians (48 Male and 55 Female) and 93 Iraqi (40 male and 53 female) aged 18 to 32 years were enrolled for the study. Length of right ulna, length of right fibula and height were recorded using standard anthropometric instruments. Models were developed for height prediction separately for males and females in Indian as well as Iraqi population using length of fibula, length of ulna and both.
Results: Mean height was similar in Indian and Iraqi males whereas, Iraqi females were significantly taller than Indian females ($p<0.05$). Multiple regression analysis revealed length of fibula, length of ulna and geographical population groups (Indian/Iraqi) as significant predictors of height for male ($R^2=0.473$) and female ($R^2=0.729$) ($p<0.01$). Model developed with length of both fibula and ulna provided accurate and reliable means in estimating height over ulna or fibula alone ($r=0.73$ to 0.87; $p<0.001$).
Conclusions: Model based on length of both fibula and ulna was better predictor of height in Indian and Iraqi populations in both sexes. The regression formula proposed in the study will be useful in height prediction to clinicians, anthropologists and forensic scientists etc.

Keywords: Height Prediction Model, India, Iraq, Ulna, Fibula

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INTRODUCTION

Height is fundamental to assess growth, nutrition and calculating body surface area (Gauld *et al*., 2004). The established relationship between stature and dimensions of various body parts, preludes an area of interest to anatomists, anthropologists and to forensic experts. Many studies have estimated stature from percutaneous body measurements which are race, age, sex dependent (Agnihotri *et al*., 2009). It is known fact that the different population groups exhibit variation in their body proportions as a result of which correlation of length of one bone to stature not only varies from population to population but also between sexes (Nath *et al*., 2007). Various long bones have been employed for stature estimation using variety of methodologies (Athawale, 1963; Shroff and Vare, 1979). Many formulae like multiply by a given factor and then add a fixed factor have been proposed. Accuracy of these formulae remains concern as formulae developed for one population do not always give accurate results for other population (Nath *et al*., 2007; Ozaslan *et al*., 2006; Duyar *et al*., 2006; Duyar and Pelin, 2010). Thus, warrants the need for race- age- sex specific stature estimation formulae.

Among various bones, measuring length of fibula and ulna is comparatively easy. The forearm bone, ulna is one of the long bones in the body that is often used for body height estimation and it has proximally a tip of olecranon process and distally the styloid process which are easily palpable. On the other hand, fibula lateral bone of the leg is also one of the long bones in the body in contrast to the femur which is less likely to suffer osteoporotic fractures or not affected by deformities of the knee or ankle joint. In addition, it does not require a 90-degree position of the knee and ankle joint and can be easily measured from the lateral side (Auyeung *et al*., 2009). The fibula has easily identifiable surface landmarks i.e. the head and tip of lateral malleolar process, making the measurement easy. A study conducted by Auyeung *et al.,* (2009) in older Chinese population demonstrated the accuracy and precision of stature estimation by length of fibula and ulna. Duyar and Pelin (2010) have developed formula for height estimation based on the length of ulna. They have applied 14 other formulae reported in literature and indicated that the population-specific equation gave the most accurate results. Athawale (1963) in an Indian study estimated height of individuals in Maharashtra, using formula developed for Western population.

However, this estimation involved 5-8% error and the author further developed two formulae to predict height separately for males and females of age between 25-30 years using length of radius and ulna. Nath *et al*. (2007) have developed population and age specific regression formulae based on length of fibula and other parameters. Results show that length of fibula exhibit maximum differences between the sexes followed by length of tibia and length of femur. Moreover, individuals belonging to the similar genetic composition but inhabiting different or similar geographical locations vary in their body proportions as a consequence of which the multiplication factor (i.e. Stature/ Bone length ratio) differs. This is a clear indication that secular trends also play an important role in this aspect and the multiplication factors formulated on a population needs to be revised at least once in a decade to have greater accuracy in the predicted stature among the living populations. In this context, the present study primarily is focused on developing and examining equations to predict height from measurement of length of fibula and ulna in two geographically different populations i.e. Indian and Iraqi population.

MATERIALS AND METHODS

Study sample

Apparently healthy 196 adults belonging to two different geographic populations, i.e. Indian and Iraqi were enrolled for the study. Total there were 103 (48 Male and 55 Female) students from Medical College of Bharati Vidyapeeth Deemed University, Pune India and 93 Iraqi (40 male and 53 female) students form Medical College of Basra, Basra University, Basra, Iraq. All the participants of the study were in the age range of 18 to 32 years.

Techniques for taking measurements

Length of right ulna, length of right fibula and height were recorded for each participant using standard anthropometric instruments. All the measurements were taken by the same person three times and then the mean was recorded for each participant. Length of ulna was measured using spreading caliper as the distance between tip of olecranon process to tip of styloid process of same side. Position given to the subject with the flexed elbow and hand touching the other shoulder (palm of hand spread over the opposite shoulder). Length of fibula was measured as the distance between head of fibula to lower most point of lateral malleolus. Measurements were taken with the individual sitting on the chair with semi flexed knee joint, instrument using spreading caliper. Height was measured as a vertical distance between vertex to floor using stadiometer. The subject was in erect posture, standing barefooted on floor with both feet in close contact with each other and back and hips touching the wall.

Statistical analysis

All variables were tested for normality by the Kolmogorov-Smirnov test. Age, height, length of fibula and length of ulna were normally distributed. All analysis was done separately for men and women. Statistical analysis was done using the software SPSS 16.0 for Windows (SPSS, Chicago, IL, USA). Mean height of Indian and Iraqi participants was compared using independent sample t test. Multiple linear regression analysis was performed to explore relationship of height with age, geographically different populations (Indian/Iraqi), length of fibula and length of ulna. Three separate regression models were constructed to estimate height using; i) only length of ulna, ii) only length of fibula and iii) length of ulna as well as fibula.

RESULTS

Table 1 presents average height of the Indian and Iraqi participants. Mean height was similar in Indian and Iraqi males ($p>0.1$) whereas, mean height of Iraqi females was significantly higher than Indian females ($p<0.05$).

Table 1. Mean height (cm) of Indian and Iraqi participants

Parameters	Indian (n=103)	Iraqi (n=93)
Male	172.0 ± 4.2	171.5 ± 5.6
Female	157.9 ± 5.3	160.3 ± 4.6*

Values significant as p< 0.05; ns; non-significant; *p<0.05

Predictors of height in male and female populations groups

To explore relative importance of age, geographical population and length of fibula and length of ulna on height of male and female participants, multiple linear regression analysis was performed by taking height as dependent variable and age, geographically different populations (Indian/Iraqi), length of fibula and length of ulna as explanatory variables (Table 2). The regression models were statistically significant for male ($R^2= 0.473$, $p< 0.01$) and female ($R^2= 0.729$, $p< 0.01$) (Table 2). The analysis revealed that length of fibula, length of ulna and geographical population groups (Indian/ Iraqi) as significant predictors of height ($p<0.05$). However, the effect of age on height was non-significant ($p>0.05$).

Effect of difference in geographical locations (Indian/Iraqi) was assessed by using interaction terms in each linear regression analysis for male and female. The variable on geographical population groups (Indian/ Iraqi) was significant predictor of height in the both the models of males and females ($p<0.05$) which indicated that the pattern of the relationship between height and the length of the bone was not similar between the Indian and Iraqi populations. Therefore, separate prediction equations were constructed for the Indian and Iraqi groups.

Estimation of height using length of fibula and length of ulna

Regression analysis is performed for each of the two bones; fibula and ulna, as well as for a combination of fibula and ulna. Following three models were developed to predict height using different independent variable; Model 1: Length of Fibula, Model 2: Length of Ulna, Model 3: Length of Fibula and Ulna. Each of these three models was run separately for four populations; 1) Indian male, 2) Indian female 3) Iraqi Male and 4) Iraqi female. Summary of 12 different models is given in Table 3 to 4. Height can be estimated using the equation given in the Table 5.

Table 2. Multiple linear regression model for male participants

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2
		B	Std. Error	Beta			
Males	(Constant)	86.208	11.472	-	7.514	0.000	0.47
	Length of Fibula (cm)	1.331	0.349	0.474	3.813	0.000	
	Length of Ulna (cm)	1.315	0.509	0.307	2.581	0.012	
	Age (years)	-0.258	0.175	-0.143	-1.476	0.144	
	Indian/Iraqi	2.462	1.044	0.240	2.359	0.021	
Females	(Constant)	56.102	8.321	-	6.743	0.000	0.72
	Length of Fibula (cm)	1.540	0.212	0.565	7.275	0.000	
	Length of Ulna (cm)	1.387	0.351	0.305	3.954	0.000	
	Age (years)	0.602	0.328	0.102	1.834	0.170	
	Indian/Iraqi	2.501	0.576	0.244	4.342	0.000	

Dependent Variable: Height (cm) Predictors: (Constant), Length of Fibula (cm), Length of Ulna (cm), Age (years), Geographical population group (Indian/ Iraqi).

Table 3. Multiple linear models for Indian Population

	Models	Constant	B coefficient	SE	R^2	P value
Males	Model 1:					
	Length of Fibula	70.5	2.60	0.39	0.507	0.000
	Model 2:					
	Length of Ulna	100.2	2.59	0.49	0.394	0.000
	Model 3 (both):	63.3			0.559	
	Length of Fibula		1.92	0.48		0.000
	Length of Ulna		1.22	0.54		0.030
Females	Model 1:					
	Length of Fibula	71.2	2.49	0.20	0.732	0.000
	Model 2:					0.000
	Length of Ulna	71.2	3.49	0.44	0.537	
	Model 3:					
	Length of Fibula	67.7	1.84	0.33	0.758	0.000
	Length of Ulna		1.05	0.50		0.043

Table 4. Multiple linear models for Iraqi Population

	Models	Constant	B coefficient	SE	R^2	P value
Males	Model 1:					
	Length of Fibula	112.1	1.57	0.36	0.347	0.000
	Model 2:					
	Length of Ulna	96.23	2.77	0.63	0.350	0.000
	Model 3 (both):					
	Length of Fibula	93.57	0.67	0.40	0.534	0.001
	Length of Ulna		1.95	0.70		0.009
Females	Model 1:					
	Length of Fibula	97.68	1.82	0.23	0.541	0.000
	Model 2:					
	Length of Ulna	81.0	3.18	0.45	0.491	0.000
	Model 3:	75.7			0.625	
	Length of Fibula		1.20	0.28		0.000
	Length of Ulna		1.74	0.52		0.002

Table 5. Multiple Linear Regression equation for height estimation from length of fibula and length of ulna

Population subgroups	Model 1[a]	Model 2[b]	Model 3[c]
Indian Male	70.599+2.604 FL	100.235+2.598 UL	63.314+1.920 FL+1.225 UL
Iraqi Male	112.103+1.575 FL	96.238+2.774 UL	93.576+0.674 FL+1.951 UL
Indian Female	71.202+2.497 FL	71.260+3.494 UL	67.730+1.844 FL+1.055 UL
Iraqi Female	97.687+1.822 FL	81.005+3.189 UL	75.721+1.201 FL+1.743 UL

a.Height= Constant + B of fibula
b.Height= Constant + B of ulna
c.Height= Constant + B of fibula + B of ulna

Table 6. Standard error of estimation and correlation coefficient of the equations for height estimation from length of fibula and length of ulna

Population subgroups	Model 1		Model 2		Model 3	
	SEE	r	SEE	r	SEE	R
Indian Male	3.3341	0.712	3.6964	0.628	3.1886	0.748
Iraqi Male	4.6395	0.589	4.6296	0.591	3.4565	0.730
Indian Female	2.7982	0.855	3.6769	0.733	2.5821	0.871
Iraqi Female	3.1688	0.736	3.3383	0.701	2.8950	0.790

SEE: Standard error of estimate; r= correlation coefficient

Data presented in Table 6 are Mean Standard error of estimation (MSEE) and correlation coefficient of equation with height. For Model 1, standard error of estimation range from 2.7 to 4.6 cm and correlation coefficient from 0.58 to 0.85. Range of standard error of estimation and correlation coefficient for Model 2 was 3.3 to 4.6 cm and 0.59 to 0.73 whereas for Model 3 it was 2.5 to 3.1 cm and 0.73 to 0.87, respectively. Equation which has small standard error of estimation and correlates highly with height would provide more accurate estimation of height as compared to the one that has relatively high error of estimation and low correlation. When the three models were arranged in descending order of standard errors of estimation and correlation coefficients; Model 3 ranked highest followed by Model 1 and Model 2. This indicates that height prediction equations based on length of both fibula and ulna was best among all three models. However, height estimation based on length of fibula was better than length of ulna.

DISCUSSION

The present research hypothesized that Indian population differ significant from Iraqi population in terms of height therefore separate height prediction equations are required for these population groups. To test these hypothesis data were collected on height, length of fibula and length of ulna and prediction models were developed. The comparison between Indian and Iraqi populations with respect of the skeleton is scarcely reported in the literature. Average height in India and Iraqi groups, when compared using t-test statistic indicated that the average height was similar in males but Iraqi female were significantly taller that Indian females.

This study proposed a gender and geographical location (Indian and Iraqi) specific linear regression models to predict height of an individual. Several studies have provided height prediction equations for different population groups using length of ulna and length of fibula. A study was conducted by Nath *et al*. (2007) in Indian population with similar age group as our study reported average height 167.6 cm and length of fibula 38.5 cm. Participants of our study were 4.34 cm taller and length of fibula was longer by 0.5 cm. MSEE (3.71 cm) and correlation coefficient (0.758) of this study was comparable to our study (MESS; 3.33 cm and correlation coefficient; 0.712). Yet, small difference of 0.3 was observed in multiplication factor in the two equations.

Many studies have used length of ulna to predict height (Barbosa *et al*., 2012; Duyar *et al*., 2006 and 2010). MSEE and correlation coefficient reported in these studies ranged from 0.5 to 8 cm and 0.6 to 0.9, respectively. Our values of MSEE (3 to 4 cm) and r (0.5 to 0.8) fall in the reported range of these studies. Study conducted by Duyar *et al*. (2006 and 2010) in Turkish adults (age 18-45 years) male reported similar correlation but the MSEE of their equation (8.3 cm and 5.6 cm) was almost double than the MSEE (3.6 cm) observed in present study. A study carried out in English and Portuguese elderly population also reported the same correlation coefficient 0.6 to 0.7 as we have observed but here also their MSEE was higher than the present study (Barbosa *et al*., 2012).

The height prediction equations were (84.5+3.2 U) and (92.0 +2.9 U) for English and Portuguese population which were comparable with present study equations for length of ulna. This comparison demonstrated better prediction of height by our models. Similar to our model 3 (length of fibula and ulna) a study conducted in Chinese elderly population used both length of fibula and ulna for height prediction along with age comparison of these equation indicated similar correlation coefficient of these models but MSEE of our models were higher (Auyeung *et al*., 2009). Another study carried out by Agnihotri and his group (2009) used tibia and ulna bone to predict height of adult population. They have given three models using length of ulna and tibia separately and one with addition of length of tibia and ulna. They found that model developed using addition of tibia and ulna was better than other two models. Similarly, in the present study model using both bones fibula and ulna gave better estimation of height compared to models developed using either fibula or ulna. Comparison of our three models suggested that equation developed using length of fibula and length of ulna together was more accurate and precise in predicting height. This confirms the fact that it is possible to improve the ability to predict height by using data on two of the bones.

Conclusion

Overall results conclude geographical population groups, length of fibula and length of ulna as significant predictors of height for both male and female populations. However, effect of age was non-significant. This finding proves the necessity of having separate formulae for Indian and Iraqi population groups. Three different formulae (based on length of fibula only, length of ulna only, and length of both fibula and ulna) were calculated for each of the four population groups; Indian Male/Female and Iraqi Male/Female. Ranking of these formulae based on standard error of estimation and correlation coefficient indicated that prediction of height by model with a combination of length of both fibula and ulna was better followed by length of fibula only and then length of ulna only in both Indian and Iraqi populations in both sexes. Thus, the present study showed that length of both ulna and fibula was important for estimating height in Indian and Iraqi populations. Separate and independent linear regression equations derived for the particular sex and populations groups should be used for better and accurate results.

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