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The determination of correlation between stature and foot dimensions in Najafabad population (Iran)

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Abstract

Objectives: Estimation of stature from measurements of different human parts is a significant aspect of forensic medicine and forensic osteology to identify unknown individuals. Stature is dependent on several variables including genetics, race, age, geographical location, and climate conditions, so it is necessary to define a robust relationship for different people to aid in the identification of individuals. The current study was carried out to test a correlation between stature and foot parameters in a population from Najafabad, Iran.

Methods: A total of 206 volunteer adults comprising 106 males and 100 females between the ages of 19 and 38 years were recruited for the study, and measurements of stature, foot length, foot width, medial arch height, lateral malleolus height, medial malleolus height, and navicular height were recorded. Linear regression models were used to estimate stature.

Results: The results indicated a positive correlation between stature and foot measurements. Among all parameters, the left foot length (LFL) and right foot width showed the most (r=0.819) and the least (r=0.551) relationship with stature, respectively. A strong correlation between stature and foot dimensions was identified that could add a further dimension to the identification of individuals from skeletal parts.

Conclusion: The LFL gives the best prediction of stature compared to other foot measurements.

Keywords: Foot Measurements, Forensic Anthropology, Regression Equation, Stature.

Introduction

Forensic osteology is the most popular branch of forensic anthropology[1,2] and is usually used for exploration and assessment of discovered bone fragments to extract relevant information about the individual that may have been a victim of a crime[1,3] or a missing person.[4]

The determination of sex, stature, age, and ethnicity offers a biological profile that can help reduce the list of possible unknown identities or victims.[1,3-6] The data obtained from the body segments of missing person/victim's profile may lead to the identification of the person, when there was an anthropological studies for the related population.[7,8] Furthermore, these data are used for orthopedic and plastic surgery, as well as designing artificial joints and bones for individuals.[9-11] The DNA fingerprinting seems to be a choice method in modern forensic medicine to identify the individuals, but the data are directly dependent on the quality of DNA extraction and the ability of genome amplifying, leading to the different degree of DNA degradation in the tissue.[12] In addition to its cost, it means there are several errors in this technique. Therefore, it is sometimes easier to discover missing people by helpful biological profiles rather than DNA testing. Therefore, special attention should begiven in creating such databases at a global level to aid in the identification with modern ease of travel.[1,3,4]

Among the most helpful parameters, stature is directly related to different body bone parts and is considered to be an important assessment in the identification of unknown individuals.[1,4] Many studies are using the hand, phalanges, lower leg length, arm span, foot dimensions, and foot sizes to calculate the body stature.[1,4,13-16] The correlation between diverse body parts, especially hand and foot size, with height has been utilized in many anthropometric evaluations to calculate stature from bone measurements.[1,16] Compared to the hand, the foot seems to be much more important, as in a mass disaster when most of the body segments are separated, crushed, and/or even burnt, feet often are enclosed in shoes, increasing the probability of using this part of the body in the individual identification.[2-4,13,17] In such situations, using foot parameters provides a suitable predictor of stature for an individual.[4] A wide range of studies has been done on stature estimation among different populations form different geographical regions, and formulation of stature from body segments was found to be unique based on the race, genetic content, geographical region, and climate features.[1,4] This means that a huge global database is needed based on mentioned characteristics, but currently, there is a lack of data from different regions to be used in the individual identification from fragmented human remains.[18] In addition, despite lots of anthropometric studies in the Middle East, there are no specific standards apply for the Iranian/Persian population due to several climate features and various types of ethnic groups.[19]

Objectives

Therefore, the present study was designed to create regression equations for the determination of the stature based on the anthropometric measurement of foot in an Iranian population. Furthermore, the data obtained from this study were compared with other populations.

Methods

A cross-sectional survey of participants within the age group of 19–38 years whose parents and grandparents were from Najafabad City was conducted. All participants were selected by simple sampling available case method and examined for stature and foot measurements. Measurements were taken from 206 randomly selected native adults (106 people were male and the rest were female) of Najafabad, a City of the Isfahan province in Iran.

Only those participants with no physical disabilities or health problems, without complications or injuries on the lower limbs, and no history of surgery to the feet were included in this study.

The study was conducted in separate rooms. All measurements were taken at a fixed time of day and by one person to avoid the interobserver error.

Foot anthropometric parameters including foot length: the maximum distance between the heel and the longest toe, foot width: the distance between the most prominent point on the medial side of the foot and to the most prominent point on the lateral side,[20] medial arch height (MAH): the distance between the highest point on the dorsal of the foot to the floor,[14] medial malleolus height: the distance between the medial malleolus to the floor, lateral malleolus height: the distance between the lateral malleolus to the floor,[21] and navicular height: the height of the most medial point of the navicular from the floor[22] were measured in a relaxed sitting position using calipers. To measure the stature of the participants, they were asked to stand barefoot in an upright position, and stature was measured from the floor to top of the head using a centimeter scale.[20]

Statistical analysis

The primary data were analyzed using IBM SPSS statistics for windows, version 19.0. (Armonk, NY: IBM corp.). Data were expressed as means±standard deviation (SD). Comparisons between groups were performed with analysis of parametric tests. The Pearson's correlation coefficient was used to measure the statistical association between two continuous variables. The linear regression formula was used to assess the relationship between the dependent and independent variables. A $P < 0.05$ was considered statistically significant.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. All studies were approved by the Research Ethics Committee of Kashan University of Medical Sciences (IR.KAUMS. MEDNT.REC.1397.089).

Results

The results of this study indicated that stature is correlated with the foot anthropometric parameters measured in this population except for the right foot width (RFW) (P=0.338) which did not correlate well. Table 1 displays mean, SDs, minimum and maximum values of stature, and left/right foot measurements of the adult population in Najafabad.

The mean age of the participants was 28.02±4.64 years old. More precisely, the mean age of males and females was 27.27±4.86 and 28.81±4.28 years old, respectively, and no significant difference was observed between males and females (P=0.017).

t-test analysis also showed that the anthropometric measurement of the foot was significantly higher for males than that in females and the differences were statistically significant (P<0.0001).

The correlation between stature and quantitate anthropometric data was evaluated, and "r" value was calculated for each variable. Since parameters with "r>0.7" have more correlation, the strongest correlation in both sides was reported between stature and foot length.

After determining the significant variables, stature prediction models were assessed using multiple regression and stepwise method [Table 2].

The models were developed based on the independent variables. The multiple regression analysis was used for models. The relationship between the stature and the independent variables was presented as in Equation 1.

$Y = b_0 + b_1x_1 + b_2x_2 + \cdots + b_px_p + \varepsilon$ (Eq.1)

Where "Y" is the dependent variable, "x" is the predictor variables, "b" is beta coefficient, and "ε" is the random error.

The coefficient of determination (R2) was used to analyze the performance of the model. This parameter represents the difference between the predicted values and the real values. The value of this parameter was calculated using Equation 2. The coefficient R2 shows the correlation between all the independent variables and stature as a dependent variable.

$$R^2 = 1 - \frac{\sum(T_j - Y_j)^2}{\sum {T_j}^2 - \frac{(\sum T_j)^2}{n}} \quad \text{(Eq.2)}$$

Tj and Yj are measured and predicted values, respectively, and n is the number of measurements.

Figure 1 presents the comparison of the measured stature with those predicted by regression models. The values predicted by multiple regression technique were close to the values measured.

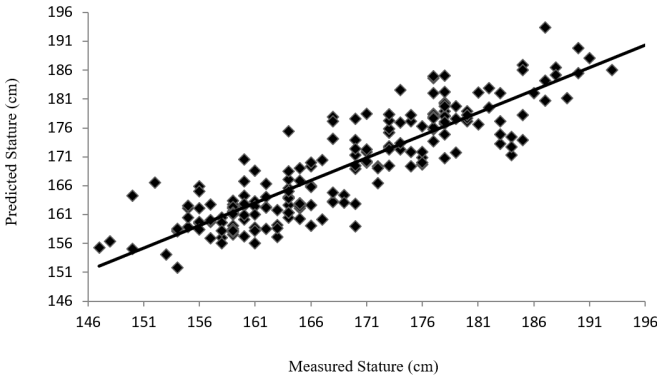

Figure 1. Comparison between the measured and predicted stature using multiple regression

Table 1. Descriptive statistics of anthropometric measurements in Najafabad, Iran

	Mean		SD		Minimum		Maximum	
Measurements (mm)	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
Foot length	246.19	244.71	17.48	17.29	208.00	208.00	290.00	297.50
Foot width	98.86	98.96	10.94	6.02	82.00	84.62	185.20	117.00
Medial Malleolus height	91.21	91.89	9.96	11.09	62.76	13.48	114.70	116.00
Lateral Malleolus height	73.35	74.14	6.53	7.90	59.00	49.46	96.86	98.50
Navicular height	62.16	62.67	10.19	9.85	39.60	35.00	87.36	85.80
Medial arch height	33.10	32.22	8.33	8.06	18.34	18.80	55.12	50.30
Stature	1690		106		1360		1990	
Age	280.2		4.64		190.0		380.0	

Table 2. Regression analysis (stepwise) in the stature prediction model

Independent Variables [a]					
No	**Variables**	**B**	**SE(b)**	**Beta**	**P-value**
1	Right Foot Length	0.265	0.039	0.44	0.000
2	Medial Arch Height	0.306	0.073	0.249	0.000
3	Right Medial Malleolus Height	0.92	0.043	0.101	0.033

[a] Response variable: Stature, R = 0.88, Adjusted R^2 = 0.77

Table 3. Comparison of different foot dimensions in different studies, Mean (mm)

	Sample	Sex	LFL	LFW	LMMH	LLMH	LNH	LMAH	RFL	RFW	RMMH	RLMH	RNH	RMAH	Stature (cm)
Najafabad, Iran	N=206	Male	257.81	102.30	97.73	75.03	69.11	39.83	255.93	101.47	97.63	77.96	68.55	38.49	176.69
	19-38 year	Female	233.74	95.25	84.22	71.54	54.71	25.98	232.94	96.33	85.80	70.12	56.49	25.58	160.71
North India [25]	N=246	Male	247.0	95.0	-	-	-	-	247.2	95.2	-	-	-	-	168.24
	17-20 years	Female	226.0	85.3	-	-			226.5	85.6	-	-	-	-	155.72
North Bengal [26]	N=350	Male	240.1	99.1	-	-	-	-	239.6	98.9	-	-	-	-	162.23
	18-50 years	Female	222.7	89.9	-	-	-		222.3	89.8	-	-	-	-	149.53
Nigeria [13]	N=400	Mal	264.2	90.9	-	-	-	-	283.9	90.2	-	-	-	-	173.73
	22-25 years	Female	247.0	81.1	-	-	-		245.2	82.3	-	-	-	-	160.00
Slovak [27]	N=250	Male	262.5	99.9	-	-	-	-	262.5	99.6	-	-	-	-	179.50
	18-24 years	Female	238.6	89.8	-	-	-	-	238.6	89.9	-	-	-	-	166.38
Turkey [29]	N=249	Male	255.79	95.7	81.16	-	72.10	-	256.01	97.72	79.93	-	72.41	-	174.191
	18-44 years	Female	230.79	85.57	72.38	-	62.69	-	230.46	87.18	72.61	-	64.09	-	161.690
United Kingdom [28]	N=62	Male	268.50	-	-	-	45.03	-	268.25	-	-	-	45.14	-	180.0
	36-39 years	Female	240.07	-	-	-	39.48	-	240.22	-	-	-	40.27	-	165.0
Taiwan [30]	N=3000	Male	259.7	-	-	-		39.5	-	-	-	-	-	-	172.7
	18-60 years	Female	235.8	-	-	-		34.7	-	-	-	-	-	-	160.9

LFL: Left Foot Length. **LFW:** Left Foot Width. **LMMH:** Left Medial Malleolus Height. **LLMH:** Left Lateral Malleolus Height. **LNH:** Left Navicular Height. **LMAH:** Left Medial Arch Height. **RFL:** Right Foot Length. **RFW:** Right Foot Width. **RMMH:** Right Medial Malleolus Height. **RLMH:** Right Lateral Malleolus Height. **RNH:** Right Navicular Height. **RMAH:** Right Medial Arch Height.

Discussion

Personal identification from body parts of the dead is one of the essential tasks of forensic research[23,24] and is an important consideration in forensic medicine.[19] Prediction of the height of an individual is a main outcome of forensic anthropology.[3,24] Due to the fact that each part of the human body has a relationship with stature, this can therefore be estimated from bone dimensions.[12]

There is a need to gather anthropometric data in most countries with a reference database for different peoples to aid in the identification of missing people, victims of crime, and natural or human-made disasters. We therefore made a start by establishing a correlation between height and different parameters of the foot in a Persian/Iranian population using subjects, who were born and brought up in the Najafabad City of Iran, and who were between the ages of 19 and 38 years.

The correlation of foot length with the stature was the most significant, and the correlation of LFL compared to right foot length was significant (r=0.819). Thus, there is a strong and positive relationship between LFL and height. Our data also showed that the foot length in males is longer than that in females and also left foot is longer compared to the right side.

Similar to our study, the mean for foot length among males in North India[25] was longer than females. However, contrary to our study, the right foot had a longer length compared to the left side in both sexes [Table 3]. In addition, people who live in North Bengal[26] [Table 3] showed a longer foot length on the left side rather than the right side. This coincides with our data, in which the feet span in males was longer than females. By contrast, in a study on Slovak females,[27] foot length in the females was found to be similar on both sides [Table 3]. Among the Iranian population as well as other populations, the foot length on the left side was longer than that in the right. The exception in the published literature seems to be male populations in North India and Nigeria. Moreover, our investigation on foot length and its relation to stature showed that British[28] and Slovakian males with longer foot length had higher statures in comparison to Iranian males. Interestingly, Nigerian men with longer foot length had shorter stature than those in Iran[13] [Table 3].

We also found that foot width has a lesser correlation with stature. Our data showed that the foot width for males is wider than that in females, and the correlation of left foot width is more than RFW in both genders. Apart from the sex, Iranians showed greater foot breadth in comparison with other populations [Table 3]. Interestingly, Iranians had the widest foot breadth, whereas Slovaks were the tallest.[27] Furthermore, data from the present and previous studies have generally revealed that the left foot was wider than the right side except for the people of Turkey[29] [Table 3].

The present study indicated that the mean value of navicular height for men was greater than that for women, and this equation was commonly seen among other populations in other studies [Table 3]. When the Iranian stature was compared with that in different countries, the results showed that Turkish men with the longest navicular height had the shortest stature,[29] whereas British men with the shortest navicular height were the tallest) [Table 3]. Achieved data describe a positive correlation between medial and lateral malleolus height and stature. Furthermore, we found that males with longer medial and lateral malleolus height showed higher stature in comparison to females. Although the left medial malleolus height is more relevant (r=0.601).

According to our analyses of the literature, there was not enough anthropometric measurement on medial arch height. One report from Taiwan,[30] similar to our study, reported that MAH for men is greater than that for women. Interestingly, in comparison with our study, the Taiwanese men had a shorter medial arch than that in the Iranian population and also a shorter stature. On the other hand, women in Taiwan with a longer medial arch had the same stature as women in Iran.

Anthropometric data are still the most critical and essential research issue and have played a fundamental role in the vast design fields. These data are also influenced by multiple factors, such as gender, age, culture, nutrition, climate, and social development,[31] so each country must build its own anthropometrics database. This study aimed to obtain a regression formula for estimating stature from foot parameters and compare that with the regression formula of other authors.

Conclusions

We found a strong correlation between stature and all foot dimensions, but the regression analysis showed that the LFL gives the best prediction of stature compared to other measurements. Comparison with other populations, available in published reports, demonstrates the in-population correlations but between-population variabilities. These clearly indicate the need for population- specific metrics that facilitate the identification of persons from isolated body parts. Given increasing rates of global travel and migration, it seems vital that such databases exist and that the current study stimulates the initiation of a national database in Iran as other countries.

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Competing interests

The authors declare that they have no competing interests.

Abbreviations

LFL: Left Foot Length. LFW: Left Foot Width. LMMH: Left Medial Malleolus Height. LLMH: Left Lateral Malleolus Height. LNH: Left Navicular Height. LMAH: Left Medial Arch Height. RFL: Right Foot Length. RFW: Right Foot Width. RMMH: Right Medial Malleolus Height. RLMH: Right Lateral Malleolus Height. RNH: Right Navicular Height. RMAH: Right Medial Arch Height.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Role of the funding source

None.

Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. The study was conducted in accordance with the Declaration of Helsinki. All studies were approved by the Research Ethics Committee of Kashan University of Medical Sciences (IR.KAUMS.MEDNT.REC.1397.089).

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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