The Determination of Correlation Between Stature and Foot Dimensions in Iranian Population

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The determination of correlation between stature and foot dimensions in Iranian population

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1. Abstract

Background: Estimation of stature from measurements of different human parts is significantly considered in forensic medicine to identity unknown individuals. Since stature data is dependent on different causes such as age, race, genetics, geographical location and climate condition so it is needed to find a relationship among different people. This study was carried out to evaluate stature from foot parameters in Najafabad, a city in Iran.

Method: A total number of 206 volunteer adults comprising 106 males and 100 females between the ages of 19 - 38 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.

Results: Linear regression models were used to estimate stature. The results indicated a positive correlation between stature and foot measurements. Among all parameters, left foot length and right foot width showed the most ($r=0.819$) and the least ($r=0.551$) relationship with stature, respectively.

Conclusion: A strong correlation between stature and all foot dimensions were found.

Key words: foot measurements, stature, forensic anthropology, regression equation

2. Background

Forensic osteology is the most popular branch of forensic anthropology and is (1, 2) usually used for exploration and assessment of discovered bone fragments to extract relevant information about victims (1, 3) and missing people(4).

Determination of sex, stature, age and ethnicity (1) offers a biological profile that can help reduce the list of possible unknown identities or victims(1, 3, 4). If a match is made with the victim's profile, it may lead to discover identity. What is planned is the susceptible to amplification and depends on the degree of DNA degradation (5). It means that it is easier to discover missing people by helping biological profiles rather than DNA testing. Therefore, special attention should be given in creating databases all over the world (1, 3, 4).

Among these 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 regress on body stature(1, 4, 6-9).

The association between divers body parts specially hand and foot with height has persuaded so many anthropometric to regress stature from bone measurements (1, 9). Compared to hand, foot seems to be much more important since, in a mass disaster when most of the body is separated and crushed, there is a probability of the recovery of feet often enclosed in shoes (2-4, 6, 10). In such a situation, using feet parameters provides a good estimation of the stature of a person(4).

However, extensive works have been done on stature estimation among people living in different places but stature varies with race, genetics of a person, geographical location and climate condition (1, 4). And that is why there is still not enough databases from different regions to identify fragmented human remains (11). Additionally, despite lots of anthropometric studies in the Middle East, there is not a specific standard for Iranian population (12).

So, the present study was designed to create a regression equation for the determination of the relationship between stature and foot measurement in Iran.

3. Materials and Methods

In this study, measurement was performed on randomly selected 206 native adults of Najafabad, a city of Isfahan province in Iran (Fig.1).

Among these samples, 106 people were male and the rest were female. According to ethics approved by Kashan University of Medical Sciences committee subjects were examined for stature and foot measurements.

3.1 Inclusion Criteria: Only those participants within the age group of 19-38 years whose parents and grandparents were from Najafabad 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.

3.2 Methods of Collection of Data: The study was conducted in separate rooms. All measurements were taken at a fixed time of day and by one person in order to avoid the inter-observe error.

Foot anthropometric parameters were measured in a relaxed sitting position by using caliper. 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 centimeter-scale(13).

3.3 Land marks and techniques involved in collecting measurements:

Foot length: The maximum distance between the heel and the longest toe (10, 13) (Fig2.a).

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 (4, 13) (Fig2.b).

Medial arch height: The distance between the highest point on the dorsal of the foot to the floor (14) (Fig2.c).

Medial malleolus height: The distance between the medial malleolus to the floor (15) (Fig3.a).

Lateral malleolus height: The distance between the lateral malleolus to the floor (15)(Fig3.b).

Navicular height: The height of the most medial point of the navicular from the floor (14) (Fig3.c).

4.Results

Table 1 displays mean, standard deviations, minimum and maximum values of stature and left/right foot measurements of the adult population in Najafabad.

Table 1. Descriptive statistics of anthropometric measurements in Iranian population.

Measurements(mm)	Mean		SD		Minimum		Maximum	
	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	

The mean age of the subjects 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 ($p=0.017$) (Table2).

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 ($p < 0.0001$) (Table2).

Table 2. Comparing the anthropometric measurement of lower limb between male and females in Iranian population.

	Sex				
	Male		Female		P-value
	Mean	SD	Mean	SD	
Stature(cm)	176.69	7.92	160.71	5.73	<0.0001
Age	27.27	4.86	28.81	4.28	0.017
LFL(mm)	257.81	14.61	233.74	10.23	<0.0001
LFW(mm)	102.30	12.31	95.25	7.85	<0.0001

LMMH(mm)	97.73	8.26	84.22	6.17	<0.0001
LLMH(mm)	75.03	7.06	71.54	5.39	<0.0001
LNH(mm)	69.11	8.06	54.71	6.15	<0.0001
LMAH(mm)	39.83	6.09	25.98	2.16	<0.0001
RFL(mm)	255.93	14.89	232.94	10.46	<0.0001
RFW(mm)	101.47	6.10	96.33	4.68	<0.0001
RMMH(mm)	97.63	11.71	85.80	6.04	<0.0001
RLMH(mm)	77.96	7.72	70.12	5.83	<0.0001
RNH(mm)	68.55	8.23	56.49	7.30	<0.0001

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.

According to table 3, the correlation between stature and quantitate anthropometric data was evaluated and "*r*" 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.

Table3. Correlation between stature and quantitate anthropometric data in Iranian population.

		LFL	LFW	LMMH	LMH	LNH	LMAH
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Stature(mm)	r	0.819	0.389	0.601	0.375	0.611	0.675
	P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
		RFL	RFW	RMMH	RMH	RNH	RMAH
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Stature(mm)	r	0.834	0.551	0.543	0.499	0.476	0.647
	P-value	<0.0001	0.338	<0.0001	<0.0001	<0.0001	<0.0001

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.

After determining the significant variables, stature prediction models were assessed using multiple regression and stepwise method (Table4).

Table 4. 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 R² = 0.77

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 Eq. 1.

$$Y = b_0 + b_1x_1 + b_2x_2 + \dots + b_px_p + \varepsilon \text{ (Eq.1)}$$

Where "Y" is the predicted value of the dependent variable, "x" is the predictor variables, "b" is the slope (beta coefficient), and "ε" is the random error.

4.1 Model Assessment Criteria

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 Eq.2. The coefficient R² shows the correlation between all the independent variables and stature as a dependent variable.

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

T_j and Y_j are measured and predicted values respectively and n is the number of measurements.

Figure 4 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.

Table 5. Comparison of different dimensions of measured foot in different studies

5. Discussion

Personal identification from body parts of the dead is one of the essential tasks of forensic research (16, 17) and is prominently considered in forensic medicine (12). In addition, the prediction of the height of an individual is a main aspect of forensic anthropology (3, 17). Due to the fact that every part of human has a constant relationship with stature, it can be estimated from bone dimensions (5).

Therefore, owing to the necessity of gathering anthropometric databases in Iran, an attempt was made to find a correlation between height and different parameters of the foot in Iran. Subjects, who were born and grown up in the Najafabad city of Iran, were chosen from the ages of 19 to 38.

Generally, the results of this study indicated that the stature is correlated to the studied various foot anthropometric parameters except for right foot width ($P=0.338$).

5.1 Relationship between Foot length and stature

Among these parameters, the correlation of foot length with the stature was more than the other parameters and the correlation of Left Foot Length (LFL) compared to Right Foot Length (RFL) was significant ($r=.819$). 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 (4), the mean for foot length among males in North India was longer than females. But contrary to our study, the right foot had a longer length compared to the left side in both sexes (Table 5).

In addition, people who live in North Bengal (18) (Table 5) showed a longer foot length on the left side rather than the right side. This coincides our data in which the feet span in males was longer than females.

In a study on Slovak's females (19), it was shown that the foot length in females in both sides are similar which is in contrast to our study (Table 5).

Among the Iranian population as well as other ones being investigated in this study, the foot length in left side was longer than that in right except for North Indian and Nigerian men.

Our investigation about foot length and its relation to stature showed that British and
Slovakian males with longer foot length had higher stature in comparison to Iranian males.
Interestingly, the Nigerian men (6) with longer foot length had shorter stature than those in
Iranian (Table 5).

5.2 Relationship between Foot Width and Stature

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 (LFW) is more than Right
Foot Width (RFW) in each gender separately.

Similar to other studies, our study showed that men have a longer foot breadth than women.
Apart from the sex, the Iranians showed greater foot breadth in comparison with other ones.
(Table 5).

Interestingly, the Iranians had the widest foot breadth while it was the Slovakian who were
the tallest (19). Furthermore, data from the present and previous studies have generally
revealed that the left foot width was wider than the right side except for the people of Turkey
(Table 5).

5.3 Relationship between Navicular Height and Stature

The present study indicated that the mean value of Navicular height for men was greater than
that for females and this equation was commonly seen among other populations in other
studies (Table 5).

When the Iranian stature was compared with that in different countries, the results showed
that the Turkish men (20) with the longest Navicular height had the shortest stature; on the
other hand, the British (21) with the shortest navicular height showed to be the tallest.

5.4 Relationship between Medial and Lateral Malleolus Height and Stature

Our results indicated a positive correlation between Medial and Lateral malleolus height and
stature. Furthermore, it represented that males with the longer medial and lateral malleolus
height showed higher stature in comparison to females. Although the left medial malleolus
height is more relevant ($r=0.601$).

5.5 Relationship between Medial Arch Height and Stature

According to our research, there was not enough anthropometric measurement on medial arch height. One of these reports was from Taiwan(22) in which, similar to our work, they have reported that Medial Arch Height (MAH) for men is longer than that for women. Interestingly, in comparison with our study, the Taiwanese men had a shorter medial arch than that in the Iranian and also the shorter stature. On the other hand, women in Taiwan with the longer medial arch had the same stature as women in Iran.

Conclusion: we found a strong correlation between stature and all foot dimensions but the regression analysis showed that the left foot length gives a better prediction of stature compared to the rest measurements.

6. Declarations statement

Ethics approval and consent to participate: All methods were confirmed by ethical committee of Kashan University of Medical sciences (IR.KAUMS.MEDNT.REC.1397.089).

Competing interests: There was no conflict of interest

Data Availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding: There was no funding.

Authors' contributions: a.b, designed and performed the experiments. C, analyzed the data. d.e, wrote the manuscript. *, supervised all parts.

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Fig1. Location map of Najafabad, the study area in Iran.

Fig2. a: Foot length: The maximum distance between the heel and the longest toe. **b. 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. **c. Medial arch height:** The distance between the highest point on

the dorsal of the foot to the floor.

Fig3. a. Medial malleolus height: The distance between the medial malleolus to the floor. b. Lateral malleolus height: The distance between the lateral malleolus to the floor. c. Navicular height: The height of the most medial point of the navicular from the floor.	299
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Figure 1

Location map of Najafabad, the study area in Iran.

Figure 2

a: Foot length: The maximum distance between the heel and the longest toe. b. 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. c. Medial arch height: The distance between the highest point on the dorsal of the foot to the floor.

Figure 3

a. Medial malleolus height: The distance between the medial malleolus to the floor. b. Lateral malleolus height: The distance between the lateral malleolus to the floor. c. Navicular height: The height of the most medial point of the navicular from the floor.

Figure 4

Comparison between the measured and predicted stature using multiple regression.

Supplementary Files

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