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Research article

The comparison stature estimation from forearm, hand length and foot length between Iranian and Pakistani medical students

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Abstract: *Objectives:* An important task of the forensic anthropologist in unidentified human remains cases is establishing the identity of the deceased. A forensic anthropologist typically examines the remains in such a case to determine the biological characteristics of the deceased, such as their age, sex, height, and ethnicity, to narrow down the search for the missing. The purpose of this study was the comparison stature estimation from foot, forearm and hand length between Iranian and Pakistani students. *Methods:* Our measurement procedure involved measuring the foot, forearm and hand lengths of 160 Iranian and 200 Pakistani students. A random sampling of 18 to 22-year-olds was used to carry out the survey. Cluster sampling was used to select the subjects for the present descriptive and analytic study. In order to measure the anthropometrics, we used metal and plastic tape, a goniometer, a caliper, and a scale. Foot forearm and hand measurements were taken separately. *Results:* The mean ± SD of the stature were 178.228 ± 6.319 cm and 167.610 ± 7.580 cm in Pakistani males and females, respectively, and in Iranian males and females were 180.446 ± 5.569 cm and 164.435 ± 5.072 cm, respectively. In both Pakistani and Iranian populations, the regression model is meaningful (P = 0.000), except for Pakistani male students' foot length (P = 0.107) and Iranian female students' hand length (P = 0.102). *Conclusion:* We found that the foot, forearms, and hand length are correlated with height. Therefore, they can be used for estimating stature.

Keywords: anthropology; Iranian; foot length; forearm length; hand length; Pakistanis; stature

1. Introduction

Anthropology is the science that studies what makes humans. Physical Anthropology is a branch of anthropology that investigates the skeletal characteristics of the human body in more detail [1]. Anthropometry is derived from the Greek words "Anthropos" (human) and "metron" (measure) [2]. Anthropometry has been a valuable tool in studying human variations over the years. Anthropometry knowledge has proven to be useful in studying human variations [3]. Physical anthropology is primarily concerned with external measurements (Anthropometry) and descriptions (Morphology) of the human body [4]. These measurements are helpful in the analysis and classification of fossil remains and the study of living populations and can determine current variations between different populations [5]. Scientists use human variations to make accurate diagnoses and treatments for diseases and classify people based on race and ethnicity [6]. This is due to various factors, including genetic mutations and the law of natural selection. Some of the factors associated with anthropometric variations in various populations include genetic influences, environmental conditions, and nutritional status [7]. Stature, age, race, gender parameters, and human body skeleton features are among the major parameters studied in anthropology [8–10].

Because of the factors such as sexual dimorphism, topography, climate, geographical location, and diet, modern humans exhibit a wide range of physical differences [11]. The physical differences between different races, tribes, and ethnicities have significant implications for a person's health and identification [12]; hence, it is necessary to establish the health and physical identification measures of each population. In addition to age, race and gender Stature is an important factor for identifying the dimensions of different parts of the body [13,14]. It can be affected by some factors such as Genetic and environmental factors [15,16]. Predicting biological characteristics of individuals using different parts of the body, can confirm the results of forensic identifications [17]. In this way, anthropological studies on body parts are widely used to identify victims in criminal cases, terrorist attacks, and natural disasters [14]. Anatomical methods based on whole-body reconstruction cannot be used to estimate stature. We must select the body part that is documentable in order to determine the structure [18]. However, stature estimation can be performed using mathematical methods, and linear regression equations can be used to find the relationship between different parts of the body and the stature [19]. Estimating stature based on gender, age, and ethnicity are critical in identifying decomposed or mutilated bodies [20]. Many studies used upper and lower limb bones for estimating stature; such as the metatarsal [21], foot [22,23], tibia [24],femur [25], ulna [26], upper arm [27], hand finger [23,28] and phalanges lengths [29]. Some studies made use of bony parts, while others made use of radiological techniques [30]. Iranian and Pakistan are neighboring countries with many similarities. In both countries, there are many students studying in another country. In light of these facts, this study can be scientifically valuable in investigating the anthropological differences between students of these neighbors. The purpose of our study is to compare the stature estimates of Iranian and Pakistani students based on their forearm, hand, and foot lengths.

2. Methods and materials

160 Iranian and 200 Pakistani medical students aged 18–22 (Iranian students mean age: 19.08 and Pakistani students mean age: 19.32) were included in this analytical-descriptive study, and samples were drawn randomly. Subjects with fractures within the forearm, hand, and foot were excluded. All members of the measurement team were trained in anatomy and body landmarks. The superficial forearm, hand and foot sizes of 360 samples were determined using indirect measurement methods. Components such as stature, non-dominant forearm, hand, and foot length were measured. The stature measurement was taken in centimeters from the highest point of the head to the heel. The apparent size of the non-dominant forearm was measured from the tip of the olecranon to the point between the radius and ulnar styloid. AFJ, MAA, and HR were experimenters involved in measuring procedures according to our landmarks and procedures. National Health and Nutrition Examination Survey (NHANES) anthropometry procedures manual were used to determine the point-to-point distance on the human surface under the supervision of an expert anatomist [31]. TA supervised all the measurement steps as an expert anatomist. The hand's length was measured between the midpoint of the radius and ulnar styloid and the tip of the middle finger. The foot length was measured from the rearmost point of the heel to the end of the longest toe (Table 1). Plastic meters and scales were used in the measurement (Figures 1, 2 and 3).

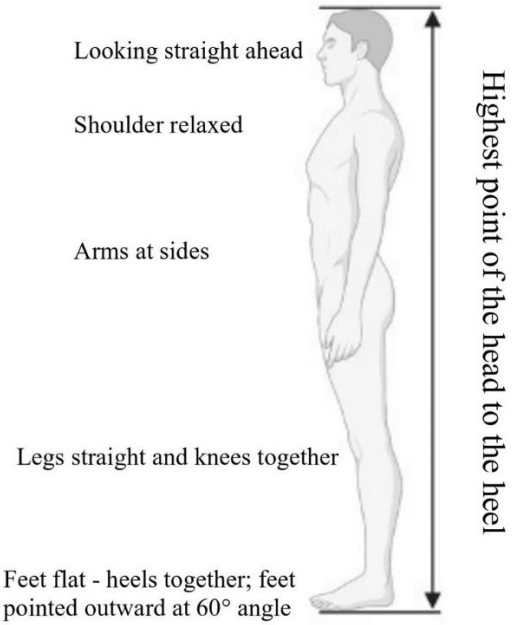

Figure 1. Stature for measurement.

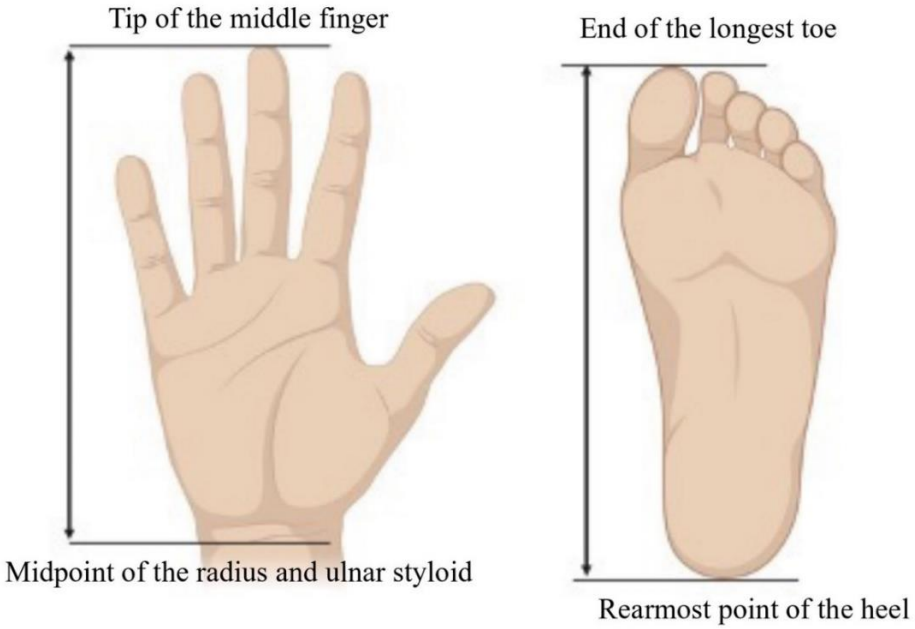

Figure 2. Hand and Foot length for measurement.

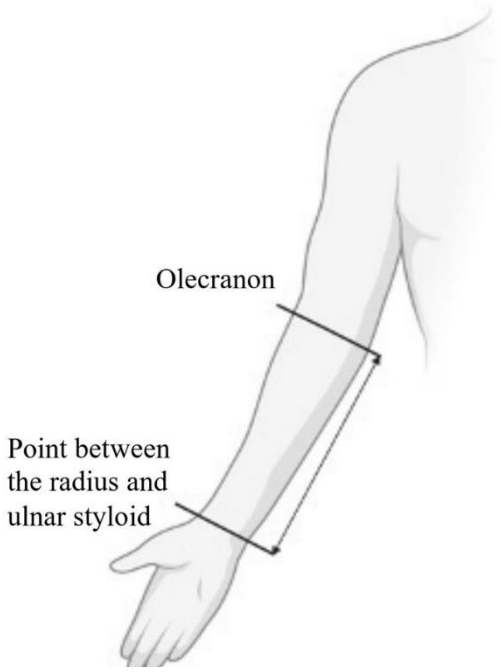

Figure 3. Forearm length for measurement.

Table 1. Definition of hand, forearm and foot measurement in this study.

Body parts	Dimension	Definition
Hand	Hand length	Midpoint of the radius and ulnar styloid and tip of the middle finger
Forearm	Forearm length	Tip of the olecranon to the point between the radius and ulnar styloid
Foot	Foot length	The rearmost point of the heel to the end of the longest toe
Stature	Stature	Highest point of the head to the heel

3. Statistical analysis

SPSS 22.0 software was used for statistical analysis. The association of parameters was assessed by Pearson's correlation coefficient r. Regression equations were computed to examine the relationship between the stature with the forearm, hand and foot length. The P values less than 0.05 were considered statistically significant.

4. Results

In this study, the mean hand length, forearm length, and foot length in Pakistani students were 18.085 ± 1.151 cm, 26.930 ± 1.759, and 25.702 ± 1.731 cm, respectively (Table 2). According to Table 2, the average hand length in Pakistani males 18.637 ± 1.009 cm and the average hand length in Pakistani females was 17.534 ± 1.016 cm. The mean hand length in Pakistani males was significantly higher than in Pakistani females (P = 0.000, Table 3). The mean forearm length in Pakistani males and females was 27.904 ± 1.331 cm and 25.956 ± 1.592, respectively, which was statistically significant (P = 0.000, Table 3). Also, the average foot length in Pakistani males is 26.668 ± 1.158 cm and in Pakistani females is 24.737 ± 1.673 cm, which shows that the average foot length in Pakistani men is higher than in Pakistani women (P = 0.000, Table 3).

In this study, the stature of Pakistani male and female students was also measured and the results showed that the average stature of all samples was 172,919 ± 8,762 cm, while the average stature of Pakistani male and female students was 178.228 ± 6.319 and 167.610 ± 7.580, respectively. The difference between the two sex groups was significant (P = 0.000, Table 3). Also all Iranian student samples are listed in Table 2 by their means of stature, hand, forearm, and foot length. In addition to the other parameters, Table 3 compares the stature of Iranian male and female students. Statistically, all parameters also showed significant differences between the genders (P = 0.000) in Iranian students.

Table 2. Comparison of mean of stature and other parameters for total subjects.

	Population	
	Pakistanis (200)	Iranian (160)
Parameters	Mean ± SD	Mean ± SD
Stature	172.919 ± 8.762	172.440 ± 9.627
Hand Length	18.085 ± 1.151	18.387 ± 1.979
Forearm Length	26.930 ± 1.759	26.328 ± 1.941
Foot Length	25.702 ± 1.731	25.170 ± 1.864

Table 3. Comparison of mean of stature and other parameters between males and females.

	Pakistani (200)			Iranian (160)		
Parameters	Mean ± SD Pakistani Male (100)	Pakistani Female (100)	P-value	Mean ± SD Iranian Male (80)	Iranian Female (80)	P-value
Stature	178.228 ± 6.319	167.610 ± 7.580	0.000	180.446 ± 5.569	164.435 ± 5.072	0.000
Hand Length	18.637 ± 1.009	17.534 ± 1.016	0.000	19.418 ± 0.888	17.356 ± 2.223	0.000
Forearm Length	27.904 ± 1.331	25.956 ± 1.592	0.000	27.751 ± 1.294	24.906 ± 1.347	0.000
Foot Length	26.668±1.158	24.737 ± 1.673	0.000	26.566 ± 1.337	23.775 ± 1.123	0.000

Based on the results of this study, there is a relationship between stature and other parameters that is statistically significant. Pearson correlation (r) between stature and hand length, forearm length, and foot length in all Pakistani male and female samples are 0.592, 0.639, and 0.538, respectively. Based on the results of this study, forearm length can predict the stature parameter better than hand and foot length in Pakistani samples (P = 0.000, Table 4). Also, in all Iranian student's stature and other parameters showed a significant correlation (P = 0.000) (Table 4).

The results showed that the Pearson correlation coefficient (r) between stature and hand length in Pakistani male students was 0.499 and in Pakistani female students was 0.377 and this relationship was significant in both sex groups (P = 0.000, Table 4). Also, the Pearson correlation coefficient (r) between stature and forearm length in Pakistani male and female students was 0.565 and 0.383, respectively, which is statistically significant (P = 0.000, Table 5). Pearson correlation (r) between stature and foot length was 0.162 among Pakistani male students, which is not significant (P = 0.107, Table 5) while Pearson correlation (r) between Pakistani female students was 0.384 and this relationship is statistically significant (P = 0.000, Table 5). There was a clear correlation between Iranian male and female students' stature and all other parameters (P = 0.000), with the exception of Iranian female students' hand length (P = 0.102) (Table 5). The regression model is meaningful in both genders in Pakistani and Iranian populations (P = 0.000) (Tables 6, 7 and 8), with the exception of Pakistani male students' foot length (P = 0.107) and Iranian female students' hand length (P = 0.102) (Tables 6, 7 and 8). When stature and forearm length were used as independent variables in the linear regression, the regression model was significant for the entire study population (P = 0.000) (Table 7).

Also, the relationship between stature and hand length, forearm length, and foot length in all male and female specimens and separately in each sex group, is shown in scatter graphs (Figures 4, 5, and 6).

Table 4. Correlation between stature and other parameters in total subjects.

	Pakistani (200)		Iranian (160)	
Variables	Pearson correlation (r)	P-value	Pearson correlation (r)	P-value
Stature	1	-	1	-
Hand Length	0.592	0.000	0.560	0.000
Forearm Length	0.639	0.000	0.813	0.000
Foot Length	0.538	0.000	0.849	0.000

Table 5. Correlation between stature and other parameters in between males and females.

	Pakistani (200)				Iranian (180)			
	Pakistani Male (100)		Pakistani Female (100)		Iranian Male (90)		Iranian Female (90)	
Variables	Pearson correlation (r)	P-value	Pearson correlation (r)	P-value	Pearson correlation (r)	P-value	Pearson correlation (r)	P-value
Stature	1	-	1	-	1	-	1	-
Hand Length	0.499	0.000	0.377	0.000	0.546	0.000	0.184	0.102 NS
Forearm Length	0.565	0.000	0.383	0.000	0.619	0.000	0.449	0.000
Foot Length	0.162	0.107	0.384	0.000	0.576	0.000	0.657	0.000

Table 6. Linear regression analysis for study population with stature as dependent variable and hand length as independent variable.

	Pakistani			Iranian		
	Male (100)	Female (100)	Total (200)	Male (90)	Female (90)	Total (180)
Regression equation	S = 120.040 + 3.122 (HL)	S = 118.296 + 2.812 (HL)	S = 91.506 + 4.502 (HL)	S = 113.975 + 3.423 (HL)	S = 157.147 + 0.420 (HL)	S = 122.327 + 2.725 (HL)
R	0.499	0.377	0.592	0.546	0.184	0.560
R^2	0.249	0.142	0.350	0.298	0.034	0.314
Adjusted R^2	0.241	0.133	0.347	0.289	0.021	0.310
SEE	0.548	0.698	0.436	0.595	0.254	0.320
B	120.040	118.296	91.506	113.975	157.147	122.327
	3.122	2.812	4.502	3.423	0.420	2.725
P-value	0.000	0.000	0.000	0.000	0.102 NS	0.000

Note: S: Stature, HL: Hand Length, R: Pearson's correlation, R^2: Coefficient of Determination, SEE: Standard Error of the Estimate, B: Unstandardized Coefficients.

Table 7. Linear regression analysis for study population with stature as dependent variable and forearm length as independent variable.

	Pakistani			Iranian		
	Male (100)	Female (100)	Total (200)	Male (80)	Female (80)	Total (160)
Regression equation	S = 103.389 + 2.682 (FL)	S = 120.356 + 1.821 (FL)	S = 87.194 + 3.183 (FL)	S = 106.489 + 2.665 (FL)	S = 122.302 + 1.692 (FL)	S = 66.268 + 4.033 (FL)
R	0.565	0.383	0.639	0.619	0.449	0.813
R^2	0.319	0.146	0.409	0.383	0.202	0.661
Adjusted R^2	0.312	0.138	0.406	0.375	0.192	0.659
SEE	0.396	0.444	0.272	0.383	0.381	0.230
B	103.389	120.356	87.194	106.489	122.302	66.268
	2.682	1.821	3.183	2.665	1.692	4.033
P-value	0.000	0.000	0.000	0.000	0.000	0.000

Note: S: Stature, FL: forearm Length, R: Pearson's correlation, R^2: Coefficient of Determination, SEE: Standard Error of the Estimate, B: Unstandardized Coefficients.

Table 8. Linear regression analysis for study population with stature as dependent variable and foot length as independent variable.

	Pakistani			Iranian		
	Male (100)	Female (100)	Total (200)	Male (80)	Female (80)	Total (160)
Regression equation	S = 154.621 + 0.885 (FtL)	S = 124.608 + 1.738 (FtL)	S = 102.917 + 2.724 (FtL)	S = 116.735 + 2.398 (FtL)	S = 93.946 + 2.965 (FtL)	S = 62.137 + 4.382 (FtL)
R	0.162	0.384	0.538	0.576	0.657	0.849
R^2	0.026	0.147	0.290	0.332	0.431	0.720
Adjusted R^2	0.016	0.139	0.286	0.323	0.424	0.719
SEE	0.544	0.422	0.303	0.385	0.385	0.217
B	154.621	124.608	102.917	116.735	93.946	62.137
	0.885	1.738	2.724	2.398	2.965	4.382
P-value	0.107	0.000	0.000	0.000	0.000	0.000

Note: S: Stature, FtL: Foot Length, R: Pearson's correlation, R^2: Coefficient of Determination, SEE: Standard Error of the Estimate, B: Unstandardized Coefficients.

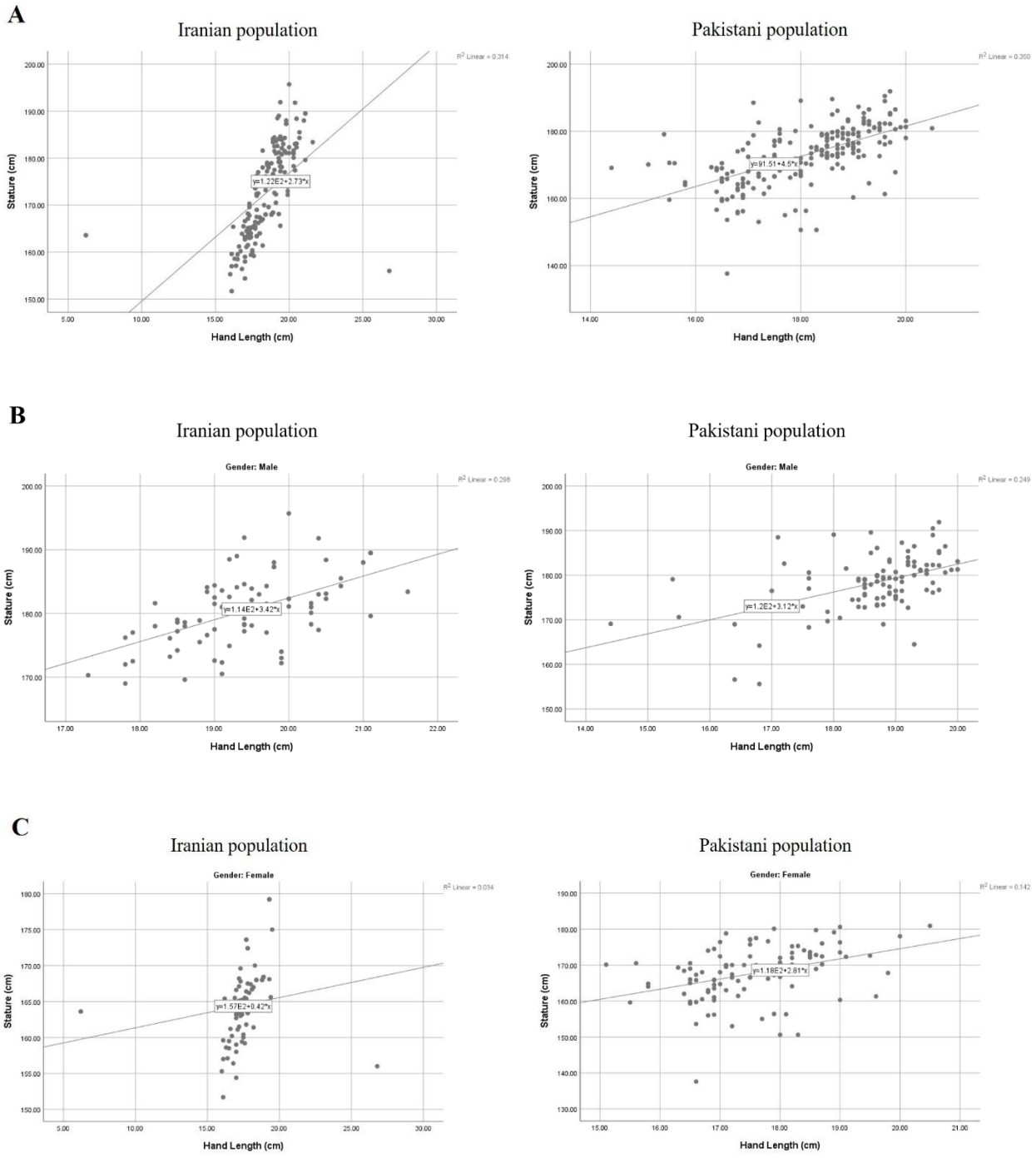

Figure 4. Correlation between stature (cm) with (A) hand length (cm) in total subjects, (B) male hand length (cm) and (C) female hand length (cm).

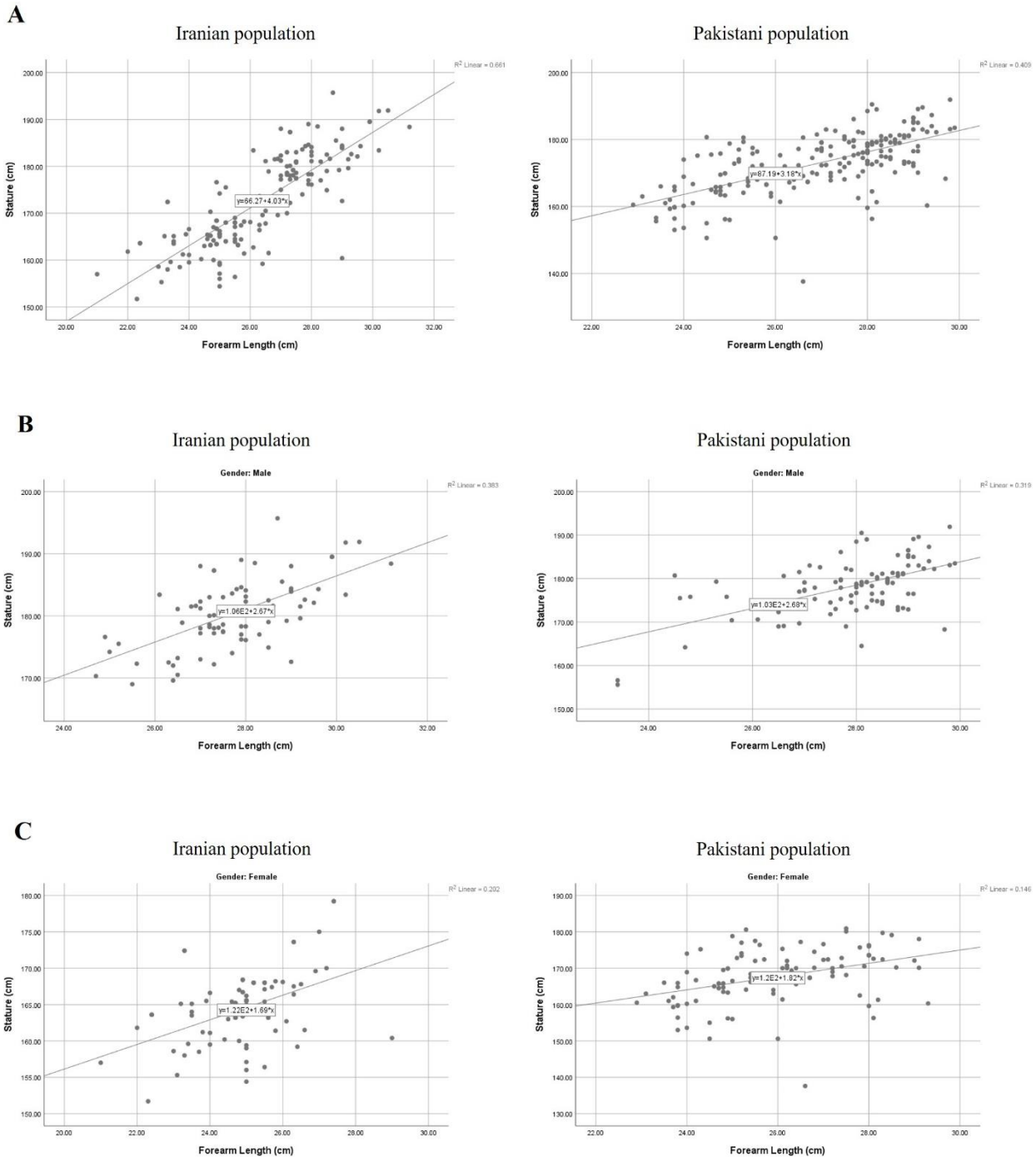

Figure 5. Correlation between stature (cm) with (A) forearm length (cm) in total subjects, (B) male forearm length (cm) and (C) female forearm length (cm).

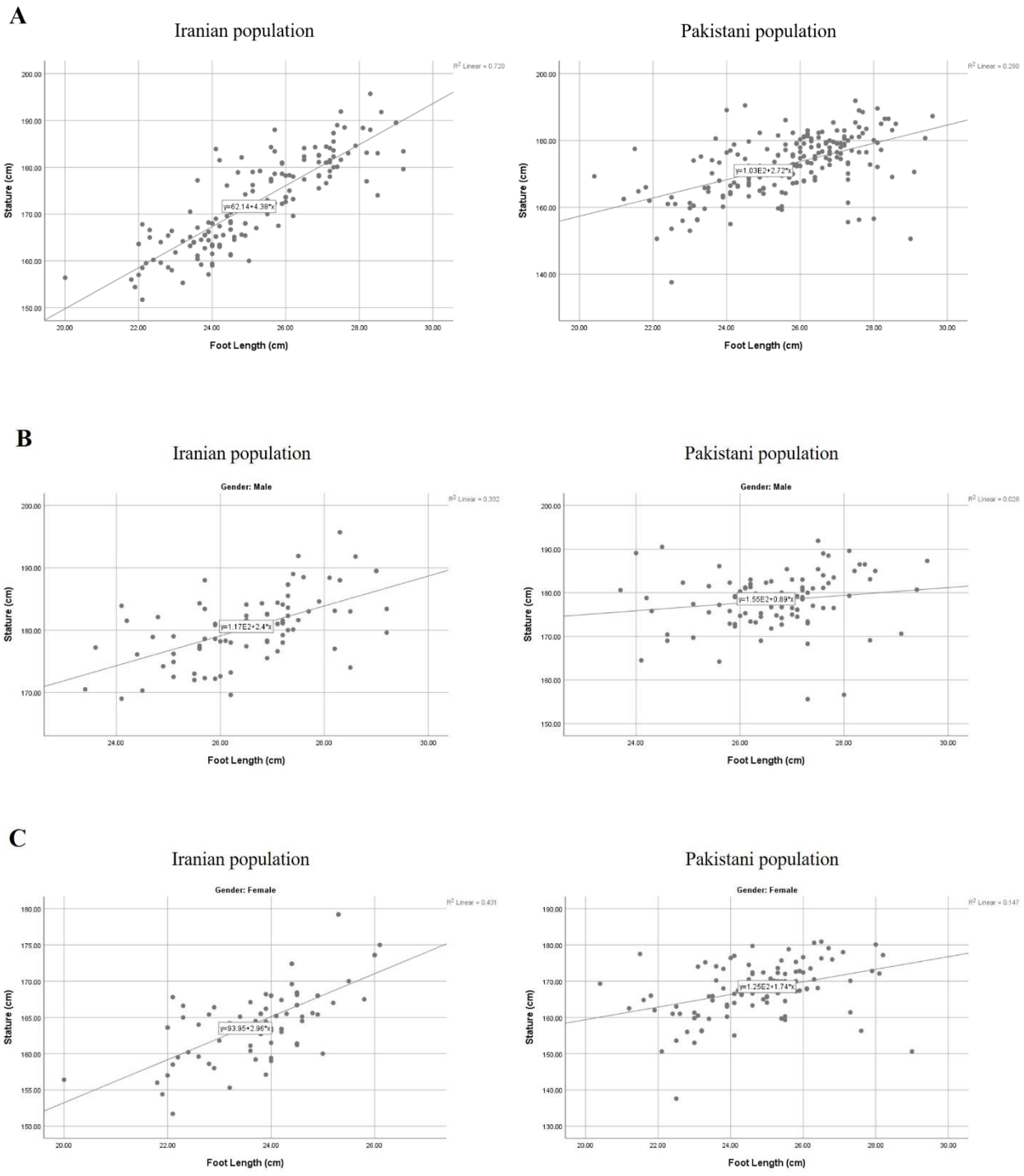

Figure 6. Correlation between stature (cm) with (A) foot length (cm) in total subjects, (B) male foot length (cm) and (C) female foot length (cm).

5. Discussion

Identification of the cadaver is a major challenge in forensic medicine, and stature estimation is an effective factor in anthropometry [32]. In a mass disaster, war, or definite murder situation where parts of the dead body have been severed or mutilated, only a small part of a human remains, Individual identification must be carried out in such a case [33]. A total of 160 Iranians and 200 Pakistanis were randomly selected for the study from among medical students without abnormal skeletal characteristics. This suggests a balanced distribution of ages between the sexes could help create a population with a normal distribution. According to our findings, Iranian and Pakistani male students are higher than female counterparts in their respective populations. which is consistent with the findings of Ilayperuma et al in Sri Lankan [34] and Srivastava et al. in Egyptian population [35] and also with our last study in Iranian student population [1]. In Pakistani population the males and females had a mean stature of 178.228 ± 6.319 and 167.610 ± 7.580 respectively. In Iranian population the males and females had a mean stature of 180.446 ± 5.569 and 164.435 ± 5.072 respectively. The difference in stature between the sexes was statistically significant (P = 0.000). Iranian male student statures are higher than Pakistani male students, but this is not true for female students, so Pakistani female students stature are higher than Iranian female students. As shown in the previous study, stature estimation could be done using the regressions in the Malaysian population. Linear regression is supposed to be a good method for estimating the relationship between stature and body fragments [36]. Our study found a significant positive correlation between hand length and stature, as well as a moderate positive correlation between forearm and foot length with stature.

An anthropological study of a Turkish adult population found statistically significant correlations between stature and hand length for both genders, which is consistent with our findings [37]. We discovered significant differences in forearm, hand and foot length between the male and female groups. A study carried out for estimating the stature from forearm and hand length in Iranian pupolation by Akhlaghi. et al and they found that the forearm lengths has a poor correlation with stature [38]. Also the forearm length was used to predict stature in north Indians by Singh et al. [39]. Furthermore, our results showed that the forearm length in males was higher than females and sexual dimorphism was evident. Our results is consistent with that of Akhlaghi et al. [38].

Correlation coefficient (r) of 0.499 in Pakistani males and 0.377 in Pakistani females for the length of the hand. In Iranian population, correlation coefficient (r) for the length of the hand was 0.546 and 0.184 in males and females respectively; However, the correlation coefficient is higher in males, as reported by Sanli et al. [37] and opposite to reports by Ileperuma et al. [34], and 0.162 in Pakistani males and 0.384 in Pakistani females for the length of the foot; and 0.576 in males and 0.657 in females for the length of the foot in Iranian population. According to the study conducted on stature and forearm, hand, and foot measurement sizes of Iranian and Pakistani students, males were significantly larger than females in each of these regions. This is consistent with finding other races [40–42]. The genetic difference in height between males and females and the earlier maturity associated with the cessation of growth in girls may explain why there are gender differences [43]. As a consequence, it appears sex-specific regression equations must be used when estimating stature from body part measurements [44,45]. An analysis of hand and foot length with stature in the Slovak population showed that foot length in both males and females have the largest correlation with stature [44]. Also,

compared to the dimensions of the upper extremities, the dimensions of the lower extremities correspond more than the other parts with stature in previous studies [46,47].

6. Conclusions

The results of this study are used in forensic medicine and corpse identification and anthropology of two neighboring countries, Iran and Pakistan. The ergonomic design of devices is made better and more efficient if racial differences are considered. A work task, a work movement, and a work activity interact with one another. In addition to the workstation components, furniture, and other equipment, the environment also affects and influences them. All of these factors must contribute to the well-being of the individual and the work output he or she produces. It is possible to design better ergonomics for Iranian and Pakistani students by using the results of this study to estimate body size and stature.

7. Limitation and future direction

This study has several limitations, including limited sample size. A larger sample size was not possible due to the increased costs of the project and the difficulty gathering data from the participants. In order to make use of the results in the future, further research is necessary to evaluate and validate them. If this limitation could be overcome, studies with machine learning algorithms may provide acceptable results in future studies. Also In recent studies, different anatomical features of the foot have been used to estimate height using three-dimensional scanning, which can be a new step for further studies [48,49].

Acknowledgement

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Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Ebrahimi B, Madadi S, Noori L, et al. (2020) The stature estimation from students' forearm and hand length in Iran. *J Contemp Med Sci* 6: 213–217. https://doi.org/10.22317/jcms.v6i5.830
2. Ross JM (2011) Using anthropometrics in designing for enhanced crew performance. *Ship Sci Technol* 5: 41–56. https://doi.org/10.25043/19098642.50
3. Utkualp N, Ercan I (2015) Anthropometric measurements usage in medical sciences. *BioMed Res Int* 2015. https://doi.org/10.1155/2015/404261

4. Singh SP, Mehta P (2009) *Human body measurements: concepts and applications*. Available from: https://www.phindia.com/Books/BookDetail/9788120338630/human-body-measurements-singh-mehta
5. Nicholson E, Harvati K (2006) Quantitative analysis of human mandibular shape using three-dimensional geometric morphometrics. *Am J Phys Anthropol: Off Publ Am Assoc Phys Anthropologists* 131: 368–383. https://doi.org/10.1002/ajpa.20425
6. Chakravarti A (2015) Perspectives on human variation through the lens of diversity and race. *CSH Perspect Biol* 7: a023358. https://doi.org/10.1101/cshperspect.a023358
7. Sánchez-García S, García-Peña C, Duque-López MX, et al. (2007) Anthropometric measures and nutritional status in a healthy elderly population. *BMC Public Health* 7: 1–9. https://doi.org/10.1186/1471-2458-7-2
8. Gocha TP, Vercellotti G, McCormick LE, et al. (2013) Formulae for estimating skeletal height in modern South-East Asians. *J Forensic Sci* 58: 1279–1283. https://doi.org/10.1111/1556-4029.12231
9. Navid S, Mokhtari T, Alizamir T, et al. (2014) Determination of stature from upper arm length in medical students. *Anat Sci J* 11: 135–140.
10. Akhlaghi M, Bakhtavar K, Bakhshandeh H, et al. (2017) Sex determination based on radiographic examination of metatarsal bones in Iranian population. *Int J Med Tox Forensic* 7: 203–208. https://doi.org/10.22037/ijmtfm.v7i4(Autumn).17059
11. Elton S (2008) The environmental context of human evolutionary history in Eurasia and Africa. *J Anat* 212: 377–393. https://doi.org/10.1111/j.1469-7580.2008.00872.x
12. Schmeling A, Reisinger W, Loreck D, et al. (2000) Effects of ethnicity on skeletal maturation: consequences for forensic age estimations. *Int J Legal Med* 113: 253–258. https://doi.org/10.1007/s004149900102
13. Krishan K, Kanchan T, Menezes RG, et al. (2012) Forensic anthropology casework—essential methodological considerations in stature estimation. *J Forensic Nurs* 8: 45–50. https://doi.org/10.1111/j.1939-3938.2011.01122.x
14. Blau S, Briggs CA (2011) The role of forensic anthropology in Disaster Victim Identification (DVI). *Forensic Sci Int* 205: 29–35. https://doi.org/10.1016/j.forsciint.2010.07.038
15. Dubois L, Ohm Kyvik K, Girard M, et al. (2012) Genetic and environmental contributions to weight, height, and BMI from birth to 19 years of age: an international study of over 12,000 twin pairs. *PLOS One* 7: e30153. https://doi.org/10.1371/journal.pone.0030153
16. Garmendia AM, Sánchez-Mejorada G, Gómez-Valdés JA (2018) Stature estimation formulae for Mexican contemporary population: a sample based study of long bones. *J Forensic Leg Med* 54: 87–90. https://doi.org/10.1016/j.jflm.2017.12.019
17. Fournier NA, Ross AH (2016) Sex, ancestral, and pattern type variation of fingerprint minutiae: a forensic perspective on anthropological dermatoglyphics. *Am J Phys Anthropol* 160: 625–632. https://doi.org/10.1002/ajpa.22869
18. Maijanen H (2009) Testing anatomical methods for stature estimation on individuals from the WM Bass donated skeletal collection. *J Forensic Sci* 54: 746–752. https://doi.org/10.1111/j.1556-4029.2009.01053.x

19. Verma R, Krishan K, Rani D, et al. (2020) Stature estimation in forensic examinations using regression analysis: a likelihood ratio perspective. *Forensic Sci Int: Rep* 2: 100069. https://doi.org/10.1016/j.fsir.2020.100069
20. Chandra A, Chandna P, Deswal S, et al. (2015) Stature prediction model based on hand anthropometry. *Int J Biomed Biol Eng* 9: 201–207.
21. Bidmos MA (2008) Metatarsals in the estimation of stature in South Africans. *J Forensic Leg Med* 15: 505–509. https://doi.org/10.1016/j.jflm.2008.05.007
22. Rani M, Tyagi AK, Ranga VK, et al. (2011) Stature estimates from foot dimensions. *J Punjab Acad Forensic Med Toxicoly* 11: 26–30.
23. Mohamadon E, Alias A, Abu Bakar SN, et al. (2020) Predictive role of hand and foot dimensions for stature estimation in the Malaysian population. *Aust J Forensic Sci* 52: 178–193. https://doi.org/10.1080/00450618.2018.1510028
24. Chibba K, Bidmos MA (2007) Using tibia fragments from South Africans of European descent to estimate maximum tibia length and stature. *Forensic Sci Int* 169: 145–151. https://doi.org/10.1016/j.forsciint.2006.08.011
25. Brits DM, Bidmos MA, Manger PR (2017) Stature estimation from the femur and tibia in Black South African sub-adults. *Forensic Sci Int* 270: 277.e1–277.e10. https://doi.org/10.1016/j.forsciint.2016.10.013
26. Torimitsu S, Makino Y, Saitoh H, et al. (2014) Stature estimation based on radial and ulnar lengths using three-dimensional images from multidetector computed tomography in a Japanese population. *Leg Med* 16: 181–186. https://doi.org/10.1016/j.legalmed.2014.03.001
27. Chandran S, Manipady S, Shetty M, et al. (2016) Estimation of stature by percutaneous measurement of upper arm length among native adult population of Dakshina Kannada district. *Indian J Forensic Med Toxicol* 10. https://doi.org/10.5958/0973-9130.2016.00071.2
28. Ibrahim MAB, Khalifa AM, Hagras AM, et al. (2016) Sex determination from hand dimensions and index/ring finger length ratio in North Saudi population: medico-legal view. *Egypt J Forensic Sci* 6: 435–444. https://doi.org/10.1016/j.ejfs.2016.11.002
29. Agrawal J, Raichandani L, Kataria SK, et al. (2013) Estimation of stature from hand length and length of phalanges. *J Evol Med Dent Sci* 2: 9651–9657. https://doi.org/10.14260/jemds/1672
30. Rodríguez S, Miguéns X, Rodríguez-Calvo MS, et al. (2013) Estimating adult stature from radiographically determined metatarsal length in a Spanish population. *Forensic Sci Int* 226: 297. e1–297. e4. https://doi.org/10.1016/j.forsciint.2012.12.006
31. CDC (2017) National Health and Nutrition Examination Survey (NHANES): Anthropometry Procedures Manual. Available from: https://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf
32. Duyar I, Pelin C, Zagyapan R (2006) A new method of stature estimation for forensic anthropological application. *Anthropological Sci* 114: 23–27. https://doi.org/10.1537/ase.041217
33. Barbaro A (2017) *Manual of Forensic Science: An International Survey*, Boca Raton: CRC Press.
34. Ilayperuma I, Nanayakkara G, Palahepitiya N (2009) Prediction of personal stature based on the hand length. *Galle Med J* 14: 15–18. https://doi.org/10.4038/gmj.v14i1.1165

35. Zaher JF, El-Ameen NFM, Seedhom AE (2011) Stature estimation using anthropometric measurements from computed tomography of metacarpal bones among Egyptian population. *Egypt J Forensic Sci* 1: 103–108. https://doi.org/10.1016/j.ejfs.2011.03.002
36. Gul H, Nizami SM, Khan MA (2020) Estimation of body stature using the percutaneous length of ulna of an individual. *Cureus* 12. https://doi.org/10.7759/cureus.6599
37. Sanli SG, Kizilkanat ED, Boyan N, et al. (2005) Stature estimation based on hand length and foot length. *Clin Anat: Off J Am Assoc Clini Anatomists Br Assoc Clin Anatomists* 18: 589–596. https://doi.org/10.1002/ca.20146
38. Akhlaghi M, Hajibeygi M, Zamani N, et al. (2012) Estimation of stature from upper limb anthropometry in Iranian population. *J Forensic Leg Med* 19: 280–284. https://doi.org/10.1016/j.jflm.2011.12.034
39. Singh S, Nair SK, Anjankar V, et al. (2013) Regression equation for estimation of femur length in central Indians from inter-trochanteric crest. *J Indian Acad Forensic Med* 35: 223–226.
40. Ahmed AA (2013) Estimation of stature using lower limb measurements in Sudanese Arabs. *J Forensic Leg Med* 20: 483–488. https://doi.org/10.1016/j.jflm.2013.03.019
41. Cordeiro C, Munoz-Barus JI, Wasterlain S, et al. (2009) Predicting adult stature from metatarsal length in a Portuguese population. *Forensic Sci Int* 193: 131. e1–131. e4. https://doi.org/10.1016/j.forsciint.2009.09.017
42. Wilbur AK (1998) The utility of hand and foot bones for the determination of sex and the estimation of stature in a prehistoric population from west-central Illinois. *Int J Osteoarchaeol* 8: 180–191. https://doi.org/10.1002/(SICI)1099-1212(199805/06)8:3<180::AID-OA421>3.0.CO;2-D
43. Papalia D, Olds S, Feldman R (2021) Human Development, 14th Edition, New York: McGraw Hill. Available from: https://www.mheducation.com/highered/product/experience-human-development-papalia-martorell/M9781260726602.html
44. Uhrová P, Beňuš R, Masnicová S, et al. (2015) Estimation of stature using hand and foot dimensions in Slovak adults. *Leg Med* 17: 92–97. https://doi.org/10.1016/j.legalmed.2014.10.005
45. Ogan CA, Babatunde LB, Salawu AA, et al. (2020) Predictive models for sex and stature estimation using foot anthropometric dimensions among indigenes of cross river state. *J Anat Sci* 11: 135–143.
46. Fessler DMT, Haley KJ, Lal RD (2005) Sexual dimorphism in foot length proportionate to stature. *Ann Hum Biol* 32: 44–59. https://doi.org/10.1080/03014460400027581
47. Özaslan A, İşcan MY, Özaslan İ, et al. (2003) Estimation of stature from body parts. *Forensic Sci Int* 132: 40–45. https://doi.org/10.1016/S0379-0738(02)00425-5
48. Lee YC (2021) Stature estimation using foot dimensions via 3D scanning in Taiwanese male adults. *Sci Justice* 61: 669–677. https://doi.org/10.1016/j.scijus.2021.08.007
49. Hsieh MC, Zhu A, Lee YC (2022) Stature estimation from various three-dimensional anthropometric foot measurements of Taiwanese female population. *Leg Med* 54: 102000. https://doi.org/10.1016/j.legalmed.2021.102000