Estimation of Body Height by Measuring Foot Dimensions: A Survey on Iranian Adult People

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Abstract

Background: The estimation of body height by measuring foot dimensions can be very important in especial conditions such as forensic medical issues. In the current study, an effort was made to assess the relationship between height and foot bone parameters in a sample of Iranian adult people.

Methods: This cross-sectional study was conducted on 250 healthy medical people (125 male and 125 female) aged 18 to 59 years. Foot parameters including foot length, foot width and size of the toes in both right and left legs were measured by a single measuring tool. Body height of the subjects was also measured in standing erect anatomical position by stadiometer.

Results: A strong correlation was found between the length of right foot and body height (r=0.999, p<0.001) as well as between the length of left foot and body height (r=0.996, p<0.001). An adverse association was indicated between body height and the length of the first (r=-0.180, p=0.004) and second (r=-0.155, p=0.014) toes on the right foot. Also, a similar adverse correlation was found between height and the length of the first toe on the left foot (r=-0.186, p=0.003). A Positive relation between height and foot length was significant in both sex, but direct association between foot width and height was significant only in women not in men. The association was significant between height and first toes only in men.

Conclusion: By measuring foot length, foot width (in women) and length of the first toe (in men), the estimation of body height can be possible.

Keywords: Height; Foot; Dimensions; Iran

Introduction

Growth as a natural process is assessed by measuring parameters from the birthday such as lengthening and thickening of bones as well as other body landmarks making total body stature. Stature is a significant physical identity and shows the height of persons in standing position. Body height measurement is includes the evaluation of dimensions of legs, pelvis, vertebral column and skull [1]. Discovering significant relationship between body height and the length of other bones has been considered for many years leading presentation of some physical formula to estimate height by measuring long bones [2, 3]. This estimation can be very important in especial conditions such as forensic medical issues [4, 5]. Primarily, Rutishauser et al. [6] could find foot length as a reliable predicting factor for estimation of body height. Since then, many attempts were made to discover other predicting factor to determine height with higher accuracy and reliability. The application of foot bones indices can be more valuable because maturation and ossification of these small bones occur earlier than the long bones and thus body height can be predicted earlier by measuring foot parameters than by measuring long bones indices [7]. Individual identification from foot and its segments becomes more significant in cases of mass disasters since there is probability of recovering feet as it is enclosed in shoes [8]. In the current study, an effort was made to assess the relationship between height and foot bone parameters in a sample of Iranian people.

Materials and Method

This cross-sectional study was conducted on 250 consecutive healthy medical people (125 male and 125 female) aged 18 to 59 years who were attending to Rasoul-e-Akram Hospital in Tehran in 2015. The participants belonged to various ethnicities resident in Iran. Foot parameters including foot length, foot width and size of the toes in both right and left foot were measured by a single measuring tool. The foot length was measured using a sliding caliper (Mitutoyo, Japan) capable of measuring to the nearest 0.01 mm. Foot width was measured using a line perpendicular to the projected length axis through the center of the first metatarsal head. Body height of the subjects was also measured in standing erect anatomical

position by stadiometer. All measurement was made by the same person to avoid personal bias.

Results were presented as mean ± standard deviation (SD) for quantitative variables and were summarized by absolute frequencies and percentages for categorical variables. Normality of data was analyzed using the Kolmogorov-Smirnoff test. The correlation between study parameters was assessed using the Pearson's correlation test or non-parametric Spearman's correlation test unadjusted and also adjusted for sex. For the statistical analysis, the statistical software SPSS version 16.0 for windows (SPSS Inc., Chicago, IL) was used. P values of 0.05 or less were considered statistically significant.

Results

The average age of the participants was 39.38 ± 13.12 years (median 41.00 years, ranged 18 to 59 years). The mean body height was in total 170.45 ± 12.93 cm (median 173.00 cm) and the mean body mass index was also 23.42 ± 4.21 kg/m^2 (median 23.00 kg/m^2). The average length of left and right feet was 25.88 ± 1.96 cm (median 26.1 cm) and 25.83 ± 1.95 cm (median 26.2 cm), respectively. **Table 1** shows the averages of the mentioned variables in both sexes.

Table 1 The average of variables according to sex.

	N	Mean	Std. Deviation	Std. Error Mean
Age				
Male	125	39.39	13.132	1.175
Female	125	39.36	13.168	1.178
Total	250	39.38	13.12	
Height				
Male	125	170.65	13.06	1.168
Female	125	170.26	12.848	1.149
Total	250	170.45	12.93	
Right Foot Length				
Male	125	25.857	1.9718	0.1764
Female	125	25.799	1.942	0.1737
Total	250	25.88	1.96	
Left Foot Length				
Male	125	25.779	1.9622	0.1755
Female	125	25.978	1.96	0.1753
Total	250	25.83	1.95	
BMI				
Male	125	23.52	4.1262	0.3691
Female	125	23.32	4.3135	0.3858
Total	250	23.42	4.21	

The mean width of the foot was also 7.84 ± 5.74 cm (median 7.30 cm).

Table 2 The mean length of the toes in study population.

	1st toe	2nd toe	3rd toe	4th toe	5th toe
Total					
Right foot	4.99 ± 0.23	4.68 ± 0.13	5.96 ± 0.56	4.25 ± 0.11	3.22 ± 0.11
Left foot	4.99 ± 0.23	4.66 ± 0.14	5.12 ± 0.09	4.21 ± 0.13	3.22 ± 0.11

As shown in **Table 2**, the mean length of the first to fifth toes on the right foot was 4.99, 4.68, 5.96, 4.25 and 3.22 cm and the mean length of the first to fifth toes on the left foot was 4.99, 4.66, 5.12, 4.21 and 3.23 cm, respectively. A strong correlation was found between the length of right foot and body height (r=0.999, p<0.001) as well as between the length of left foot and body height (r=0.996, p<0.001).

However, no correlation was revealed between height and width of the foot (r=0.074, p=0.245). As presented in **Table 3**, adverse association was indicated between body height and the length of the first (r=-0.180, p=0.004) and second (r=-0.155, p=0.014) toes on the right foot. Also, a similar adverse correlation was found between height and the length of the first toe on the left foot (r=-0.186, p=0.003). Regarding association between height and foot parameters in men and women **(Table 4)**, positive relation between height and foot length was significant in both sexes, but direct association between foot width and height was significant only in women not in men. Regarding association between height and length of the toes, this association was found between height and both right and left first toes only in men, not in women.

Table 3 The correlation between length of the toes and height according to the sex; Pearson correlation (Sig. [2-tailed]).

	1st toe	2nd toe	3rd toe	4th toe	5th toe
Total					
Right foot	-0.18	-0.155	-0.048	-0.025	0.042 (0.508)
	-0.004	-0.014	-0.454	-0.698	
Left foot	-0.186	0.022 (0.725)	0.001 (0.993)	-0.046	-0.055
	-0.003			-0.464	-0.39
Men					
Right foot	-0.229	-0.144	-0.126	0.039 (0.669)	0.007 (0.939)
	-0.01	-0.11	-0.16		
Left foot	-0.281	0.031 (0.729)	-0.143	-0.082	-0.035
	-0.001		-0.11	-0.366	-0.697
Women					
Right foot	-0.13	-0.168	0.088 (0.327)	-0.083	0.077 (0.396)
	-0.148	-0.062		-0.355	
Left foot	-0.091	0.011 (0.903)	0.147 (0.102)	0.000 (0.998)	-0.075
	-0.313				-0.405

Discussion

The Estimation of anthropometric measures can play a role in determining gender, identity, and many other things that are helpful to identify the dead bodies found which are unknown. But the important thing here is that these measurements should be done separately in each population, because the racial and ethnic differences are affective on these measures and reduce the possibility of generalizing. Therefore, given that it has not done similar studies in Iran and due to the importance of the issue, in this study we estimated the height according to the foot measurements in Iranian Population.

Table 4 The correlation between length of the toes and height according to the sex; Pearson correlation (Sig. [2-tailed]).

	Right Foot Length	Left Foot Length	Foot Width
Male	1.000 (0.000)	0.996 (0.000)	0.092 (0.309)
Female	1.000 (0.000)	1.000 (0.000)	0.185 (0.039)

Our attempts led to find the length of foot as a strong predictor for body height, but width of the foot was not valuable for predicting height. Also, regarding association between height and length of toes, only first toe could predict body height only in men not in women. Various researchers could find similar findings in other populations indicating the importance of foot dimensions for predicting body height. In a large study on Chinese children, a very high linear correlation was found between height and foot length with a correlation coefficient ranged 0.96-0.99 for both sexes [9]. In another study by Grivas et al. on school age children, it was revealed a significant correlation between both right and left foot length and either

height or weight leading introduction of a fit formula between these parameters as height (cm)=34.113+3.716x(right foot length (cm))+1.558 (if girl)+2.499x(age(years)) [2]. They similarly showed that foot length estimated the stature and weight of a juvenile, especially after adjusting for age and sex. Another study by Agnihotri et al. showed that right foot length, could explain about 77% variations in body height [10]. Krishan et al. study revealed that the correlation between stature and all the foot measurements was found to be positive and statistically significant (p-value<0.001) and foot length measurements estimate stature with greater accuracy when compared to foot breadth measurements [11]. In another study by Krishan [11], 7 anthropometric measurements were taken separately on both left and right feet of each individual. The outcomes demonstrated that significant (P<0.01) bilateral asymmetry exists in T-1, T-2 and T-5 lengths. All the 7 foot parameters have chosen for the study were found to be positively correlated with stature. The maximum correlation coefficients were revealed by the toe length measurements [12]. The study of Uhrová et al. have shown significant sex differences in hand and foot dimensions as well as in stature (p<0.05). There was a positive and statistically significant correlation between stature and all measurements in both sexes (p<0.01). The uppermost correlation coefficient was found for foot length in men (r=0.71) as well as in women (r=0.63) [13].

An important strengthen of the current study is that most previous studies focused on an especial age variants especially children and thus an estimation between height and foot dimensions in adults was not previously assessed [14]. In this regard, our study could demonstrate high reliability of foot parameters especially foot length to predict height in all age subgroups.

Our findings are very applicable in different forensic medicine issues. In fact, determining the height in patients with severe accidents, burns and in mutilated cases by foot dimensions are so difficult needing more available dimensions. In fact, the use of foot length, foot width in women and also length of the first toe in men can be very helpful in authentication. More important, considering a combination of these parameters can increase the accuracy of identification in legal medicine and thus comparing use of each parameter alone or in combination with each other should be assessed in further studies. Also, it should be considered that the obtained correlations may be different in various populations and ethnicities emphasizing ethnical-based analyses of association between height and foot parameters.

According to previous studies the physical stature decline by aging. Fernihough showed that reduction in height is an important phenomenon among populations. Also, the rate of reduction is higher in female than male [15]. In addition, Health Status of the Elderly Population can effect on this reduction. In another study by Bagga, he evaluated the height reduction in women age ranged from 30 to 70, he also demonstrated the reduction on age 60-69 [16]. Although the results of previous studies are controversial about the exact age of the height reduction, the authors recommend paying attention to the age range in future studies to prevent the probable effect of age on the height.

Body morphological and height changes seems influence by many internal and external factors, including the mechanical effects of use and wear and physical stress during the life of a person, different cultures and life style which should considered in height evaluation [16].

Conclusion

In summary, by measuring foot length, foot width (in women) and length of the first toe (in men), the estimation of body height can be possible, however this possibility was only tested in our population and should be assessed in further populations to achieve a global accurate formula.

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