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Predictive role of hand and foot dimensions in stature estimation

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Abstract: Stature estimation is a commonly used parameter in identification searched by medico-legal experts and forensic anthropologists. To estimate stature; measurements of hand length (HL), hand breadth (HB), wrist breath (WB), foot length (FL), foot breadth (FB) and ankle breadth (AB) were used in this study. It was aimed to predict most useful variables and to perform formulas originated from those variables significantly correlated to stature. Measurements were obtained from 356 volunteers. The best correlation value among 6 searched variables were detected in foot dimensions as FL variable for males r=0.696 and for females r=0.496 and in hand dimensions as HL variable for males r=0.578 and for females r=0.309, respectively. The least estimation error in stature prediction was achieved with using all variables in defined regression equations. Lengths measurements belong to hand and foot dimensions were more useful parameters than breadth measurements of those in stature estimation.

Key Words: Forensic science; forensic anthropology; identification; stature estimation; foot dimensions; hand dimensions

Stature estimation of an individual from the skeletal material or the mutilated or parts of limbs has obvious significance in the forensic identification analysis. These let us know and discuss about many accidents (airplanes, trains etc.) mass disasters and murder cases [1-3]. Also, in aspect of forensics; it is crucial in description of suspects from palms and foot prints in crime scenes [4-6]. Not only in forensic sciences but also in many other study disciplines such as anatomy, podiatry, medicine and anthropology [7].

For stature estimation researches, different nutrition types and physical activities may cause variations in populations. Many studies are successfully performed on this topic despite a wide range of ethnics and races through the populations.

Most of the studies about stature estimation are concentrated on upper and lower extremities. [8-10]. Among them, there were a few studies focusing on hand and foot dimensions for estimation of stature. Also these few studies are only about either hand or foot measurements in prediction of relation to stature [11-13]. In this study, it was aimed to evaluate the predictive role of hand and foot dimensions in stature estimation.

Materials and Methods

This research was composed of anatomically healthy adults living in Turkey, who of a middle-class social economy. For the present study 224 males and 132 females totally 356 volunteers having the age ranges of 20-51 years were studied. Informed consents were obtained from each individual. For standard measurements, the dimensions were

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taken with an anthropometer in millimeters using standard anthropometric instruments such as sliding and spreading calipers, steel tape and scale.

A preliminary study on prediction of existence for bilateral differences was carried out if there was a difference or not. This difference was tested on 20 subjects and the result was statistically not showed out a significancy (p>0.01) with paired t-test. Statistical insignificancies in bilateral differences were shown by some studies [5, 6, 14]. Thus all measurements of volunteers' extremities were taken from the right side by first author (A. Ozaslan). Obtaining the data and analyzing statistics were in millimeters.

The subjects were asked to remove their shoes and socks. They were oriented in the standard anatomic position with the head on the Frankfort Horizontal Plane. Stature, three dimensions of hand (Figure 1) and three dimensions of foot (Figure 2) were measured following the International Biological Program Protocol [15, 16].

Stature was taken from the vertex to the floor obeying the anatomic position and Frankfort Plane.

Hand breadth (HB) is measured from base of 5th to 2nd metacarpus using a sliding caliper.

Hand length (HL) is measured from mid-point below radial and ulnar tuberosity to tip of middle finger using a standard measuring tape.

Wrist breadth (WB) is taken across the styloid processes (oblique to the long axis of the arm) with pressure to compress to tissue using a sliding caliper.

Foot breadth (FB) is the distance between the lateral and medial sides at the metatarsal region using a sliding caliper.

Foot length (FL) is the maximum distance between the most anterior and posterior projecting part of the foot with an anthropometer.

Ankle breadth (AB) is taken across the malleoli with pressure to compress the tissues using a sliding caliper.

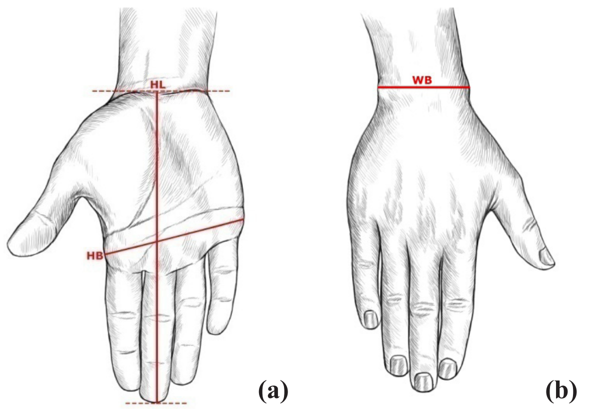

Figure 1. A diagram showing various landmarks and measurements of hand(a) and wrist(b)

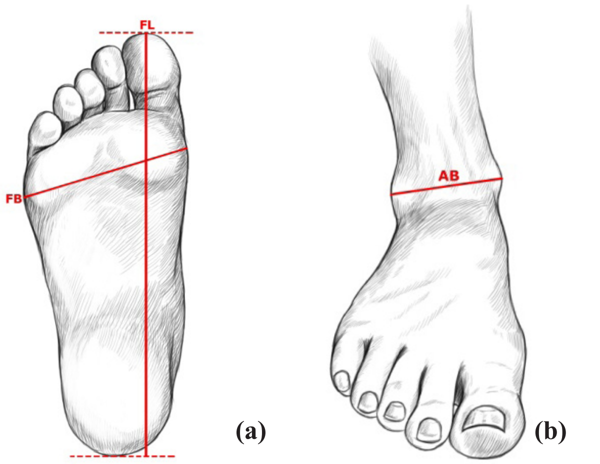

Figure 2. A diagram showing various landmarks and measurements of foot (a) and ankle (b)

The measurements obtained were statistically analyzed using SPSS 14.0. The analyses included means, standard deviations and ranges. Analysis of the differences in stature, HB, HL, WB, FB, FL, AB between Turkish male and female individuals was done by paired t-test. Karl Pearson's correlation coefficients are derived between six variables and stature. Single and multiple linear regressions were done to estimate stature from hand and foot dimensions. The statistical analyses including whole data set of HB, HL, WB, FB, FL and AB were also applied

for both sexes.

To determine inter-observer error ratios in point of six variables and stature, measurements were repeated by second author of the study (B. Karadayi) in 20 individuals and data were evaluated with paired t-test.

Results

Descriptive statistical data and t-test data about variables of stature, hand and foot measurements on study of 356 volunteers were shown in Table 1. It was observed in taken measurements that actual stature of males and females were between 1546-1975 mm and 1462-1848 mm, respectively. Sex differences were detected for all variables at p< 0.001 values.

A more significant correlation for males according to females was detected between all variables and stature in this study. The best correlation coefficient was determined in males for stature estimation as follows; in hand dimensions for hand length (HL) it was R= 0.578 and in foot dimensions for foot length (FL) that was R= 0. 696. Also in females; hand length presented the best correlation between hand dimensions and stature

Table 1. Descriptive statistics for stature and dimensions (mm) of hand and foot in males and females

Variables	Male (n=224)				Female (n=132)				t-Test
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	t-value
Stature	1546	1975	1724.37	68.65	1462	1848	1620.10	64.19	14.175*
HL	163	215	192.34	9.32	160	200	179.60	6.97	13.193*
HB	61	97	82.95	4.84	68	86	75.74	3.88	14.539*
WB	48	69	57.28	3.78	45	61	51.34	2.72	15.768*
FL	218	293	250.86	13.56	206	268	228.86	10.74	15.917*
FB	63	117	93.69	7.43	70	102	86.11	5.86	10.013*
AB	58	90	72.95	4.74	59	88	66.89	4.18	12.158*

* p-value <0.001

(R= 0.309) and foot length presented the best correlation between foot dimensions and stature (R= 0.496).The weakest correlation in stature estimation were in hand breadth in males (R= 0.173) and wrist breadth in females (R= 0.117) (Table 2). A better relation was found between stature and hand / foot dimensions due to hand and foot breadths for both sexes.

Table 2. Correlations between stature and hand and foot dimensions

Variables	Male (n=224)		Female (n=132)	
	R	R-Square	R	R-Square
HL	0.578	0.335	0.309	0.096
HB	0.173	0.030	0.257	0.066
WB	0.199	0.040	0.117	0.014
FL	0.696	0.484	0.496	0.246
FB	0.317	0.100	0.168	0.028
AB	0.281	0.079	0.249	0.062

When single linear regression equations for all variables were defined; it was possible to be done that the least error in stature estimation by using foot lengths' measurements for males and females. Standard error estimations (SEE) were 49.40 mm for males and 55.95 mm for females (Table 3).

The best estimation in multiple linear regression formulas for stature estimation in both males and females living in Turkey were gained from equations originated from all variables (males SEE:46.52 mm; females SEE: 52.19 mm) (Table 4).

Table 3. Single linear regression formulas for stature (mm) from hand and foot dimensions

Sex	Variables	Equations	S.E.E.(mm)
Male	HL	S=922.01+4.15(HL)	54.63
	HB	S=1520.76+2.45(HB)	67.76
	WB	S=1517.50+3.61(WB)	67.42
	FL	S=840.88+3.52(FL)	49.40
	FB	S=1450.19+2.93(FB)	65.26
	AB	S=1428.10+4.06(AB)	66.04
Female	HL	S=1116.56+2.80(HL)	60.32
	HB	S=1298.32+4.25(HB)	62.27
	WB	S=1478.80+2.75(WB)	63.99
	FL	S=941.95+2.96(FL)	55.95
	FB	S=1461.86+1.84(FB)	63.52
	AB	S=1364.68+3.82(AB)	62.41

S: stature, SEE: Standard Error Estimation

Table 5 presents a comparison of actual stature and stature estimation from dimensions of hand and foot using linear regression equations. The widest range in both sexes was observed in the foot length used equation. Close values were detected in mean estimated statures among every variables and that closeness was also seen between actual and mean estimated stature.

Measurements repeated on randomly selected 20 subjects for detecting inter observer error incidences; was determined as p>0.01 for FB

Table 4. Multiple linear regression formulas for stature (mm) from hand and foot dimensions

Sex	Variables	Equations	S.E.E.(mm)
Male	HL, HB, WB, FL, FB, AB	S=754.44+2.44(HL)-1.73(HB)-1.88(WB)+2.88(FL)-0.16(FB)+0.57(AB)	46.52
	HL,HB,FL,FB	S=746.16+2.31(HL)-2.13(HB)+2.85(FL)-0.08(FB)	46.65
	HL, HB, WB	S=977.60+4.44(HL)-0.91(HB)-0.63(WB)	54.63
	FL, FB, AB	S=822.33+3.51(FL)-0.29(FB)+0.66(AB)	49.55
	HL, FL	S=668.04+2.01(HL)+2.67(FL)	47.44
Female	HL, HB, WB, FL, FB, AB	S=518.09+1.41(HL)+2.48(HB)-2.69(WB)+2.99(FL)-0.69(FB)+2.64(AB)	52.19
	HL,HB,FL,FB	S=509.44+1.52(HL)+2.59(HB)+2.98(FL)-0.04(FB)	52.74
	HL, HB, WB	S=971.63+2.38(HL)+3.26(HB)-0.51(WB)	59.62
	FL, FB, AB	S=825.15+2.99(FL)-1.02(FB)+2.94(AB)	55.06
	HL, FL	S=606.20+1.93(HL)+2.93(FL)	53.20

Table 5. Comparison of actual stature (mm) and estimated stature (mm) from hand and foot dimensions

Estimated stature using regression equations for	Males		Females	
	Estimated Stature (Range)	Mean Estimated Stature	Estimated Stature (Range).	Mean Estimated Stature
HL	1597.7-1813.3	1719.4	1565.0-1677.1	1619.9
HB	1670.5-1758.8	1724.4	1587.2-1663.7	1620.1
WB	1690.8-1766.7	1724.4	1602.6-1646.6	1620.1
FL	1608.6-1872.7	1724.3	1552.3-1736.0	1620.1
FB	1634.6-1792.6	1724.4	1590.5-1649.3	1620.1
AB	1663.7-1793.6	1724.4	1590.0-1700.7	1620.1
Actual Stature	1546.0-1975.0	1724.4	1462.0-1848.0	1620.1

variable within measurements and $p>0.05$ for the other variables. It is concluded that all these resulting variables were statistically insignificant (Table 6).

Discussion

Methods used in long bone measurements for stature estimation are shown as resulting minimum errors with many studies [17-19]. Not only like long bones measurements but also hand and foot dimensions are predicted as useful parameters in stature estimation. In this study, it was aimed to indicate the most useful variables in stature estimation from 6 variables including hand and foot dimensions and to use those variables that are significantly correlated to stature in order to do the best close estimation to actual stature.

Another aim is to establish new data to use in stature estimation for adults living in Turkey and also to improve the present data.

Hormonal, genetic and environmental factors are effective in occurring of physical characteristics between sexes [20, 21]. In some studies, it was shown that sex difference is related to age of puberty; age of puberty being 2 years later in males as compared with females gives them extra time for growth [5, 6, 22]. In addition, it is known that there is a relation between Y chromosome and stature [23]. In this study; stature and the other measured anthropometric variables showed sex differences, too. Except HB all the other variables

Table 6. Inter-observer error calculated in 7 anthropometric measurements using paired t-test (n=20).

Variables	Mean Difference	Standard Deviation	%95 Confident Interval of the Difference		t-value	P-value
			Lower	Upper		
Stature	-1.125	3.757	-3.127	0.877	-1.198	p>0.05
HL	-0.563	3.010	-2.167	1.042	-0.747	p>0.05
HB	0.500	1.633	-0.370	1.370	1.225	p>0.05
WB	0.375	1.408	-0.375	1.125	1.065	p>0.05
FL	0.688	2.414	-0.599	1.974	1.139	p>0.05
FB	1.688	2.651	0.275	3.100	2.546	p>0.01
AB	-0.250	1.983	-1.307	0.807	-0.504	p>0.05

of this study are better related to stature in men than women.

Evaluated 6 anthropometrical variables of this study, the best correlation was detected in FL (males r=0.696; females r=0.496) and HL (males r= 0.578; females r= 0.309) within both sexes. Also in Krishan and Sharma study in which 4 variables of 6 parameters of this study showed a good correlation between foot length and stature (FL, FB, HL, HB) like this study. Thus, accordance was detected between this study and Krishan and Sharma's study [6].

In this study among hand dimensions, HL had the best correlation with stature. A weak correlation was stated between HB and stature. HL's relation with stature in men was accordance with Chilkhakar et al, Krishan and Sharma and Agnihotri et al but lower than Sanli et al ve Habib and Kamal's studies [6, 24-27]. In women; it was found that HL's correlation with stature was lower than Sanli et al, Krishan and Sharma, Sunil et al, Habib and Kamal, Agnihotri et al's studies [6, 25-28]. For both sexes it was observed that HB's correlation with stature was lower than Krishan and Sharma and Chilkhakar et al's studies [6, 24].

In this study, it was seen that in men FL's correlation with stature was in accordance with Zeybek et al, Sanli et al and Nachiket et al's studies [26, 29, 30]. For women; there was also accordance with Ozden et al and Krishan and Sharma's studies [6, 31]. This similarity was correlated to the reason that these mentioned studies also carried out in Turkish population like this study. Besides, it was seen that FL's relation with stature' similarity existed between adults living in Turkey and for adults living in some regions of India.

When it is focused on the relation of FB's with stature; correlation values of men were in accordance with Zeybek et al's and Krischan and Sharma's studies but for women with Zeybek et al's only [6, 29]. Accordance of values with Zeybek et al's might originate from carrying out mentioned study also for Turkish population.

A few studies were encountered in literatures for WB's and AB's correlation with stature. These two variables showed out weak correlation with stature in this study. Present study, correlation with stature of WB's was lower than Chumlea et al's correlation value [32]. When multiple regression equations for stature estimation with WB and AB used with the other variables, a minimal contribution to stature estimation was observed.

SEE is a good parameter in order to show the relation between real value and estimated value. To estimate the stature in single linear regression equations defined for 6 variables SEE ranges were between ±49.40 and ±67.76 for males and between ±55.95 and ±63.99 for females. When Krishan and Sharma's study performed for Indian population was compared to this study, it was seen that estimated stature have similar SEE values for men but lower SEE values for women of that study [6]. In Kanchan et al, Krishan and Sharma and Sanli et al's studies they also made minimum errors in linear regression equations for relation of FL with stature as this study [5, 7, 26].

The minimal estimation errors were shown to be for hand lengths in hand dimensions and foot lengths in foot dimensions as in the previous studies. Error proportions of the multiple regression equations which are built up with hand and foot dimensions of the current study were higher than Krishan and Sharma's [6]. This result might be commented as an indicator of more variations in Turkish population than Indians. The mean value estimates are close to mean actual stature. This is due to the fact that regression equations are calculated from measures of central tendency.

Stature estimation could be calculated with minimum error in the situation of obtaining all the variables of this study. It is possible to estimate stature either hand measurements or foot measurements are obtained. It was detected that length measurements are much more reliable than breadth measurements. Obtained formulas are specific to that study populations therefore application of these by the other populations might cause incorrect results. Thus necessity in creation of specific equations peculiar to populations should be taken into account by researchers.

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