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Original Article

Estimation of Stature from Hand Measurements and Handprints in a Sample of Saudi Population

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Abstract

Stature estimation is a commonly used method in forensic identification analysis. The tracks and remnants available at crime scene or catastrophes can give extensive information concerning the biological profiles of unknown persons. However, the investigator should take into account the constitutional peculiarities of the population where the evidence was found due to the high specificity of such data. The present work aimed at studying the ethnic peculiarities of the Saudi Arabian population and to estimate stature using the measurements of hands and handprints. A total of 200 native Saudi subjects of both genders within the age group of 17 to 26 years were included in the study. The height of each participant was measured and correlated with hand length, palm length, and the hand breadth measured on both sides. Descriptive statistical analysis, paired samples T-test, Pearson correlation analysis, and regression analysis were performed. Obtained regression equations have a 1-4 cm deviation when used for the stature estimation in the population from which the data have been obtained. The accurate estimation rate of the formulae is >95%.

Keywords: Stature, Hand, Handprints, Saudi Population

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تقدير طول القامة لعينة من المجتمع السعودي من خلال قياسات اليد وأبعاد بصمتها

المستخلص

يستخدم تقدير طول القامة عادة لتحديد هوية الجاني من أكثر الأساليب شيوعاً والمستخدمة في التحديد الجنائي للهوية، حيث يمكن للآثار والبقايا المتاحة في مسرح الجريمة أو موقع الكارثة أن تعطي بيانات ومعلومات شاملة بشأن التعريف البيولوجي للأفراد مجهولي الهوية. ويجب على الباحث أو الخبير الأخذ في عين الاعتبار خصوصية وطابع المكان الذى تم العثور فيه على الأدلة نظراً للأهمية العالية لهذه البيانات. ويهدف هذا البحث إلى دراسة الخصائص العرقية لسكان المملكة العربية السعودية وتقدير طول القامة باستخدام قياسات اليد وحدودها وأبعاد بصمتها، ولتحقيق هذا الهدف أجريت الدراسة على 200 مشترك من الجنسين من الفئة العمرية ما بين 17 و 26 عاماً، وتم قياس طول كل مشترك وربطه بكل من قياسات طول اليد وطول الكف وعرض اليد في كلا اليدين اليمنى و اليسرى. واستخدم التحليل الإحصائي الوصفي للبيانات واختبار - ت T - test للبيانات ومعامل ارتباط بيرسون

Pearson correlation و تحليل الانحدار الإحصائي. ووفقاً لعلاقات (معادلات) الانحدار التي تم الحصول عليها باستخدام معدل الانحدار وجد أن هناك معدل انحراف ما بين 1 الى 4 سم عند استخدامها في تحديد طول القامة لعينات مجتمع الدراسة التي جمعت البيانات منها، وكان معدل دقة التقدير للعلاقة التي تم الحصول عليها أكبر من 95% .

الكلمات المفتاحية: طول القامة، اليد، بصمة اليد، المجتمع السعودي

1. Introduction

The primary aim of forensic investigation of human remains is determination of the biological profile of a victim, which includes gender, age, stature, and ethnicity [1].

Along with the other parameters, stature is one of the basic characteristics that helps to recognize an individual in cases of mass destruction or even in the absence of main body parts.

The dimensional relationship between body segments allows the reconstruction of its original stature and is widely used in modern forensic practice [2, 3]. Analysis of recently conducted studies shows that stature can be effectively estimated from the length of separated long bones of the upper and lower limbs [4, 5], from the length and breadth of the foot and footprints [6-8], as well as from the linear dimensions of the hand and handprints [9-11].

The specific relations between the dimensions of various body parts can also be used to identify victims or body remains even in the absence of complete evidence. Handprints are the most common physical evidence left at crime scenes. Obtaining a unique pattern of fingerprints is considered the key in identifying the criminal [12], but they may not always be available. However, as handprints are made by the most prominent parts of the hand and reflect the real size of the hand, they may be used for the prediction of the gender and stature of the person who deposited them [11, 13].

A problem in forensic investigation is that individual physiques and body proportions vary from one ethnic group to another, as they are highly influenced by nutrition and the life style of the community [14]. The ethnic factor carries great importance in solving the identification task, and it must be taken into account by forensic anthropologists and archeologists. It is forensic anthropology that helps to specify and relate the findings to a certain ethnic group or geographical area, assisting the progress of investigation [15-16].

The ethnic difference in hand dimensions to stature proportion have already been analyzed in the population of Western Australia [11], central India [17], North and South India [18-20], Slovakia [21], Turkey [22], Egypt [23], Nigeria [24], China [25], Thailand [26], and the Gujarat region [27].

The primary objective of the present research is to study the ethnic peculiarities of the relationship between stature and hand measurements in native Saudis and to estimate stature using the measurements of hands and handprints in this population.

2. Subjects and Methods

2.1 Subjects

The study was carried out at Tabuk University in accordance with the standard ethics laid down by the Tabuk University Ethical Committee for Human Experimentations. Tabuk University is situated in the city of Tabuk, a historic city in the northwestern region of Saudi Arabia. A sample of 100 males and 100 females was collected among right-handed students within the age group from 18 to 26 years. Only participants without visible pathology or history of any surgical procedures on the hand were included in our study. Preference was given to the individuals whose parents and grandparents have being living in the Northern part of Saudi Arabia to characterize ethnic peculiarities of this part of the country.

2.2 Methods

2.2.1 Stature measurement

Stature was measured by a standard stadiometer (Seca 216 Stadiometer, Scales Galore, USA). The individual was asked to stand barefoot on the horizontal flat base in an erect position with their back in contact with the vertical board of the stadiometer and head oriented in the eye–ear–eye plane (Frankfurt plane). Then the measurement was taken in centimeters as the distance between the heel and the highest point on the head (vertex) by bringing the sliding bar to the vertex.

2.2.2 Hand measurements

Hand measurements were taken in centimeters to the nearest millimeter by a sliding caliper in accordance with the conventional technique [28-29]. Intra-observer error was determined to be within accepted standards for all measurements ($R > 0.9$; r TEM < 5%) [30]. The palm was placed in a supinate position with fingers extended and close to each other. The long axis of the forearm was kept parallel to the axis of the hand. Then, the following linear dimensions were measured on both hands (Figure-1a):

- Hand length (HL) - distance between the distal crease of the wrist joint and the tip of the 3rd finger;
- Palm length (PL) - distance from the mid-point of the distal transverse crease of the wrist to the point of contact between the proximal flexion crease of the middle and fourth fingers;
- Hand breadth (HB) - distance between the most remote points on the heads of the 2nd and 5th metacarpal bones.

Each measurement was repeated thrice, and the mean value was recorded in order to minimize inter-observer errors.

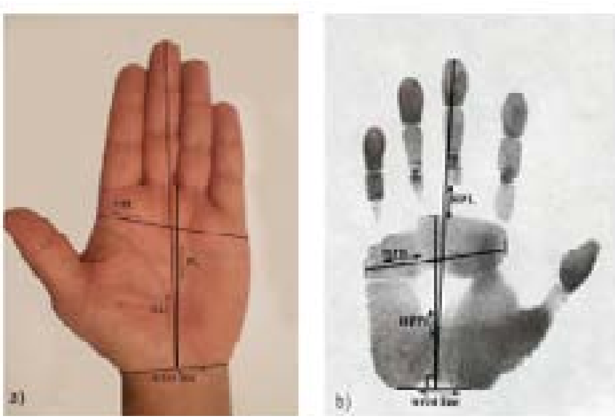

Figure 1-a: *Hand measurements: hand breadth (HB), hand length (HL), palm length (PL); and* **1-b:** *Handprint measurements: handprint breadth (HPB), handprint length (HPL), handprint palm length (PPL).*

2.2.3 Handprints acquisition and measurement

The handprints were taken from the relaxed hand with the extended fingers and the thumb apart using an inkless shoe print kit (Jacksonville, US). The subject was requested to place the hand prone on an inkless shoe print pad with a little pressure and then onto shoe print paper. The same procedure was repeated for the opposite hand. The linear dimensions of the handprint such as handprint breadth (HPB), handprint length (HPL), and handprint palm length (HPPL) were measured between the most projected parts of the handprints (Figure-1b). The wrist line was designated as a perpendicular to the palm axis line passing through the most proximal prints of the thenar and hypothenar due to inability to localize the distal transverse crease of the wrist.

2.2.4 Statistical analysis

The obtained data were computed and analyzed with SPSS 11.0 software. After the calculation of descriptive statistics, sex-specific and bilateral differences of hand measurements were evaluated using a paired samples t-test. Significance of correlation between the stature and the dimensions of the hand was analyzed using the Pearson correlation coefficient. The hand dimensions showing substantial correlation with stature were incorporated into a regression model to calculate constant "a" and regression coefficient "b" for the following estimation of stature as ST=a+bx, where "x" is a known "independent variable" that is one of the hand dimensions. A series of stepwise regression analyses were performed to determine a regression equation for the estimation of stature from various measurements of hands and handprints. The model with the highest value of coefficient of determination, " R2 " , was considered as the most appropriate one for determining stature. The standard error of estimate (SEE) was calculated by calculating the difference between measured stature and stature estimated with the regression equation.

3. Results

The descriptive statistical analysis of the data showed that the mean male stature in native Saudis from Tabuk equaled 171.5 cm with the maximum and minimum 178.5 and 159.5 cm, respectively. The mean female height varied from 148.0 to 171.5 cm with the mean 159.3 cm. Table-1 shows the descriptive statistics and comparison of identical measurements of hand, handprints, and stature in Saudi male and female individuals. According to our results, the stature and dimensions of the hand, measured directly on the hands as well as on the handprints, were significantly higher in males than in females. The Pearson correlation analysis revealed positive relations between stature and all hand measurements in males and females. The substantial correlation was found with the length parameters of the hand such as HL and HPL ($p < 0.001$) (Table-2). However, the analysis showed weak and statistically insignificant relations between stature and breadth parameters of the hand, especially in the male group. The bilateral asymmetry for length parameters was not strongly pronounced (Table-3). Only the hand breadth in the male study group was higher on the right than on the left, up to 3 mm ($p < 0.001$). That is why this parameter was excluded from the following calculations.

The length measurements of hands and handprints were evaluated by linear regression analysis for each gender group. Table-4 indicates obtained regression equations, R,

Table 1- *Descriptive statistics and comparison for identical measurements of hand, handprints, and stature in Saudi male and female individuals*

Measurements (cm)	Males			Females			T-test value	Sig.	MD	SED
	Mean	SD	SEM	Mean	SD	SEM				
HB	8.390	0.5182	0.0946	7.404	0.4028	0.0462	10.440	0.312	0.9861	0.0945
PL	10.140	0.550	0.1004	9.629	0.4592	0.0527	4.875	0.047*	0.5111	0.1048
HL	18.103	1.0190	0.1860	17.057	0.7243	0.0831	5.940	0.013*	1.0468	0.1762
HPB	7.630	0.5802	0.1059	7.034	0.3235	0.0371	6.714	0.000*	0.5958	0.887
HPPL	9.033	0.5241	0.0957	8.671	0.5238	0.0601	3.207	0.003*	0.3623	0.1130
HPL	17.333	0.8248	0.0150	16.311	0.7620	0.0874	6.081	0.023*	1.0228	0.1741
Stature	171.52	5.1044	0.5381	159.309	6.3574	0.4387	16.125	0.001	12.2107	0.7573

SD, standard deviation; Sig, significance level; MD, mean of difference; SED, standard error difference; HB,hand breadth; PL – palm length; HL – hand length; HPB – handprint hand breadth; HPPL – handprint palm length; HPL – handprint hand length.

** Difference is statistically significant at p < 0.05.*

Table 2- *Pearson's correlation (r) between the stature and various dimensions of the hand and handprints*

	Males	Females	T-test value	Sig.	MD	SED
Males	0.341*	0.750**	0.577**	0.017	0.751**	0.488**
Females	0.401**	0.639**	0.595**	0.306**	0.566**	0.347**

***. Correlation is significant at the 0.05 level (1-tailed).**

****. Correlation is significant at the 0.01 level (1-tailed).**

HB - hand breadth; PL – palm length; HL – hand length; HPB – handprint hand breadth; HPPL – handprint palm length; HPL – handprint hand length.

R2, adjust R2, and SEE values.

The correlation coefficient (R) showing the relationship between stature and hand measurements in the present study generally coincides with the corresponding value of the Pearson's correlation.

It is evident that the R value is higher for the manual measurement of HL and HPL (R = 0.750 and 0.751, respectively) in the male group. Similarly, the most strongly correlated variable in the female group appears to be HL measured manually (R = 0.639), compared to the handprints (R = 0.566). So, the breadth measured on the hands and handprints was of minor importance in both groups.

According to the value of the coefficient of determination (R2), which represents the proportion of variation in stature explained by hand measurements in our research, it is evident that the best model for determining stature is the one taking into consideration HL and HPL in males (54% and 56% respectively) and HL in females (40.8%).

The change in explanation rate (adjust R2) in the male group (100 subjects) was the highest for HL (49.8 ± 3.39 %). In the female group (100 subjects), these rates varied from 40.5 ± 4.9 % for HL to 11.6 ± 5.97% for HPPL (the data in Table-4).

The obtained regression equations were checked for their accuracy. The minimum, maximum, and the mean of each length parameter were substituted in the regression

Table 3- *Paired samples T- test data of bilateral difference in the measurements of hands and handprints in males and females*

Analyzed pairs		Paired Differences					T-test value	Sig. (2-tailed)
		Mean	SD	SEM	95% Confidence Interval of the Difference			
					Lower	Upper		
HB	Males	0.0326	0.1146	0.0121	0.0084	0.0567	3.683	0.001
	Females	0.0763	0.1283	0.0208	0.0342	0.1185	2.668	0.009
HL	Males	-0.2562	0.3615	0.0383	-0.3323	-0.1800	-6.686	0.000
	Females	0.0605	0.2982	0.0484	-0.0375	0.1586	1.251	0.219
PL	Males	-0.1888	0.2777	0.0294	-0.2473	-0.1303	-6.412	0.000
	Females	-0.0053	0.3328	0.0540	-0.1147	0.1041	-0.097	0.923
HPB	Males	0.1146	0.3084	0.0327	0.0496	0.1796	3.506	0.001
	Females	-0.0158	0.3018	0.0490	-0.115	0.0834	-0.322	0.749
HPL	Males	-0.0562	0.3735	0.0396	-0.1349	0.0225	-1.419	0.159
	Females	-0.0421	0.3599	0.0584	-0.1604	0.0762	-0.721	0.475
HPPL	Males	-0.0371	0.5277	0.0559	-0.1482	0.0741	-0.663	0.509
	Females	-0.0053	0.3271	0.0531	-0.1128	0.1023	-0.099	0.922

SD-Standard deviation; SEM-Standard error of the mean; HB - hand breadth; PL – palm length; HL – hand length; HPB – handprint hand breadth; HPPL – handprint palm length; HPL – handprint hand length.

Table 4- *Linear regression equations for the estimation of stature from measurements of hands and handprints in males and females*

Measurements (cm)	Regression equations for males	R	R2	adj. R2	SEE
HL	ST=3.708*HL+104.428	0.750	0.540	0.498	±3.36
PL	ST=5.412*PL+116.640	0.577	0.332	0.459	±4.19
HPL	ST=4.7*HPL+90.058	0.751	0.564	0.241	±3.39
HPPL	ST=4.804*HPPL+128.126	0.488	0.238	0.329	±4.48
Measurements (cm)	**Regression equations for females**	**R**	**R2**	**adj. R2**	**SEE**
HL	ST=5.514*HL+65.15	0.639	0.408	0.405	±4.90
PL	ST=8.09*PL+81.39	0.595	0.354	0.351	±5.12
HPL	ST=4.67*HPL+82.89	0.566	0.320	0.317	±5.25
HPPL	ST=4.26*HPPL+122.03	0.347	0.120	0.116	±5.97

R - correlation coefficient; R2 - coefficient of determination; adjust R2 - change explanation rate; SEE - standard error of estimate; ST – stature; HB - hand breadth; PL – palm length; HL – hand length; HPB – handprint hand breadth; HPPL – handprint palm length; HPL – handprint hand length; adj. R2 - adjusted R2

Table 5- *Comparison of actual stature (cm) and estimated stature (cm) from various hand dimensions*

Measurements (cm)	Estimated stature for males			Estimated stature for females		
	min	**max**	**mean**	**min**	**max**	**mean**
HL	162.27	177.10	171.54	152.82	170.46	160.59
PL	166.43	177.79	171.51	148.53	167.95	159.28
HPL	161.96	179.82	171.5	152.94	169.28	159.15
HPPL	166.55	176.6	171.5	154.04	163.77	158.96
Actual stature	159.5	178.5	171.5	148.0	171.5	159.3

HB - hand breadth; PL – palm length; HL – hand length; HPB – handprint hand breadth; HPPL – handprint palm length; HPL – handprint hand length.

equations, and statures were calculated. Comparison of the estimated stature with the actual stature measurements showed their close coincidence; this is especially evident for the mean values (criteria in Table-5).

4. Discussion

The present research is a pioneering study designed to reveal certain ethnic-related anatomical peculiarities of the Saudi Arabian male and female population that can be used for forensic identification of individuals. The members of this community represent an anthropologically and genetically homogeneous population. Thus, our findings are helpful to identify an individual involved or injured in a crime when hand impressions are available. It is well-known that conventional investigation of forensic and archaeological human remains is based on estimation of bio-demographic parameters including stature, age, weight, and gender. Stature is considered as the main characteristic for identification of an unknown person and is usually evaluated based on the lengths of the limb bones. However, stature is a specific characteristic which depends on a number of factors such as gender, genetic make-up, racial and geographical origin, social stratum and physical activity. The primary objective of the present research is to study the ethnic peculiarities of the relationship between the stature and hand measurements in native Saudis and to estimate stature using the measurements of hands and handprints in this population.

Analysis of the literature and comparison of stature obtained by researchers in other countries with our results shows a close coincidence of body height of Saudi Arabians with Chinese and Egyptian populations, while people from Slovakia and Australia are considerably taller. On the other hand, the inhabitants of India and Bangladesh are the shortest (Table-6).

Earlier studies have shown that hand measurements tend to differ among ethnic groups [24, 27]. Therefore, we have compared our results with analogous data obtained in other populations. The hand measurements obtained in the Saudi Arabian population are similar to those in the Chi-

Table 6- *Comparison of human body stature (St), and hand dimensions (cm) in males (M) and females (F) in different geographical regions (Mean ± SD)*

		KSA [Present study]	Australia [11]	China [25]	Slovakia [21]	India [20]	Turkey [22]	Egypt [23]	Nigeria [24]	Bangladesh [6]
HL	M	171.5 ± 5.10	178.5 ± 7.05	170.4 ± 4.82	179.5 ± 6.46	173.6 ± 5.0	172.4 ± 6.86	172.8 ± 7.2	174.79 ± 0.86	162.23 ± 5.69
	F	159.3 ± 6.36	163.7 ± 7.14	159.7 ± 5.22	166.3 ± 6.18	156.2 ±7.1	162.0 ± 6.41	158.9 ± 5.37	167.3 ± 1.04	149.53 ± 5.37
PL	M	8.39 ± 0.51	9.07 ± 0.485	8.34 ± 0.92	8.49 ± 0.43	8.17 ± 0.04	8.29 ±0.484	8.22 ± 0.45	9.73 ± 0.01	-
	F	7.40 ± 0.4	7.88 ± 0.455	7.16 ±0.55	7.58 ± 0.36	7.26 ± 0.1	7.57 ±0.388	7.43 ± 0.4	9.00 ± 0.07	-
HPL	M	18.10 ± 1.02	19.5 ± 0.925	18.3 ± 0.875	18.7 ± 0.905	18.4 ± 0.08	19.2± 0.932	19.93 ±0.875	20.62 ± 0.13	-
	F	17.05 ± 0.72	17.6 ± 0.820	16.9 ± 0.955	17.2 ± 0.755	16.74 ± 0.11	17.9 ±0.697	18.26 ±0.77	19.85 ± 0.18	-

ST – stature; HB - hand breadth; PL – palm length.

nese, with the exception of female hand length, which was slightly longer in our studied population. Table-6 indicates the differences in hand size in Australians, Egyptians, and Nigerians, whose hands are much longer and wider in comparison with our study group.

In this study, Saudi adult males showed significantly larger hand dimensions ($p < 0.001$) than Saudi females. According to our results of the paired T-test, the most sexually dimorphic parameter in studied population was the hand breadth followed by the palm length. These findings are consistent with previous studies conducted in different populations of Asia [18-20, 25], Europe [5, 21], and Turkey [22].

The bilateral variation was statistically significant only for the hand breadth in the male group ($p < 0.001$). This confirms the results of Piti Laulathaphol, who has investigated the Thai population [26]. However, researchers in Australia, Egypt, and India have revealed significant asymmetry of hand breadth in females as well ($p < 0.05$) [11, 18, 23].

Our study obtained a highly positive and statistically significant correlation of body height with hand and palm lengths measured directly on hands and handprints in both sexes, suggesting a linear and close relationship between stature and these measurements (Table-2). The lower value of the correlation coefficient for the measurement of hand breadth indicates that the length parameters are more valuable for the stature estimation, which is concordant with the previous studies [21, 23, 25]. However, the results of Tang et al. demonstrated another tendency in their regression models SEE for estimation of stature from hand breadth (2.95 - 3.05 cm), which was significantly lower than the same one for hand length (5.63 - 5.64 cm), albeit showing less correlation of stature with hand breath (R=36.8) than with hand length (R = 66.4) [25].

In the present study, the mean SEE calculated in the regression model for stature estimation from hand length measurements is smaller as compared to the other measurements of the hand (3.36 cm in males and 4.9 cm in females. The same degree of high accuracy in the regression models for the estimation of stature from hand length was also reached by Laulathaphol et al. (3.29 - 3.60 cm) and Sanli et al. (3.50 - 4.59 cm) [26, 31]. On the other hand, the higher SEE value in the regression models calculated by Habib et al. (4.77 - 7.27 cm), Ishaak et al. (4.74 - 5.17 cm), and Uhrova et al. (5.01 - 5.06 cm) could be related to wide diversity in their sampled populations [10-11, 21].

Analysis of employed statistical techniques for the estimation of stature from various measurements of hands showed that the regression analysis is the most accurate method for estimating stature, and it may be used in different ways. The majority of researchers simultaneously applied several regression analysis models such as linear, stepwise, and multiple [11, 21, 25]. However, comparison between the settings of regression models exposed highly controversial results. Some authors reported that multiple regressions gave a more accurate estimation of stature showing less error of estimate [10, 19, 22], while others reported an approximately equivalent degree of prediction accuracy in all foresaid models [11, 20, 25].

In the present research, authors proceeded from the assumption that the multiple regression analysis is appropriate where both hands and feet measurements are included in the stature estimation process; applying this method to research based only on measurement of hands with insignificant asymmetry and weak hand breadth correlation with stature was considered as unreasonable (criteria in Table-2 and Table-3).

The formulae derived from our linear regression analysis have a 1-4 cm deviation when used for the stature estimation in our studied population (data in Table-5). The accurate estimation rate of the formulae is >95%. We believe that they are the equations of choice for stature estimation in cases of handprint disclosure at a crime scene or for identification of dismembered bodies where only hands were found.

5. Conclusion

The presented method of stature reconstruction, based on correlation of body height with hand and palm lengths measured directly on hands and handprints, is highly efficient and gives statistically significant results in both sexes. This study revealed that length measurements of the hand are much more reliable for stature estimation than the breadth measurements. It has to be noted that the formulas obtained in the present study are specific to the study population in this research; therefore, application of these formulas to other populations might produce incorrect results.

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