USE OF HAND AND ITS CORRESPONDING PRINT DIMENSIONS IN STATURE ESTIMATION

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ABSTRACT

Background: Personal identification is one of the most important challenges that may face forensic scientists, especially in cases of incomplete, mutilated or even fragmented remains. Stature is one of the primary identification parameters. Previous studies were performed to estimate stature from hand and its corresponding print dimensions using different regression models. These studies highlight the importance of the presence of population-specific standards. The current study **aims** to develop predictive regression equations that could be used for stature estimation using anthropometric hands and their corresponding print dimensions. One hundred and fifty adult participants were enrolled in the study (75 male & 75 female). Statures were measured, and seven dimensions of each hand and its corresponding print were also measured for each participant. **Results:** All measurements of the male group were significantly higher. Bilateral significant differences were found in some hands and their corresponding print dimensions in both sexes. According to Karl Pearson's correlation coefficient, all measurements were significantly correlated to stature; "right-hand length" showed the strongest correlation with stature in both sexes, while "right handprint length" in females and "left handprint length" in males showed the strongest correlation with stature. Simple linear regression analysis showed that both hand and handprint lengths in both sides for both sexes had the lowest standard error of estimate, ensuring their lowest prediction error in stature estimation. **Conclusion:** hand and its corresponding print dimensions can be used in adult stature estimation. Further studies of people of other geographical regions in Egypt are recommended to get a biological-specific Egyptian standard**.**

Keywords: Anthropometric measurements, Hand, Handprint, Stature, Prediction.

INTRODUCTION

Identification is one of the most important challenges that may face forensic scientists, especially in cases of incomplete, mutilated, or even fragmented remains **(Pininski and Brits 2014)**. Medico-legal investigation of the body remains aims to determine its age, gender, stature, and ethnicity to build up its biological profile, which in turn narrows down the matching profiles **(Pickering and Bachman 2009)**. Stature is one of the main identification parameters; it has a biological relationship with different body parts; this promotes the use of skeletal remains in its estimation **(Giurazza et al., 2012; Waghmare et al., 2010)**.

Using hand and its corresponding print dimensions is considered to some extent, a new approach for stature estimation. There are wide differences between different populations regarding anthropometric measurements and their correlation with stature. This might be attributed to environmental and genetic factors. Hence, the formula that can be applied for one population may not be reliable for another population **(Kanchan et al., 2010)**. This highlighted the need for establishing population-specific standards; and led to the great interest in conducting studies on different populations using some hand/handprint dimensions for stature estimation **(Ahemad and Purkait 2011; Ahmed 2013)**. Although few studies have been conducted in Egypt (**Habib and Kamal 2010; Paulis 2015, Sharaf El-Din et al. 2016)**, it is essential to highlight that the Egyptian population exceeds 90 million; they have wide population diversity due to wide variation in geographical regions and their specific characteristics; also due to variations in socio-economic, cultural, and environmental factors. Furthermore, a novel method modified from that of **Ishak, and his colleagues** was applied in the current research in measuring hand and its corresponding print dimensions **(Ishak et al., 2012)**. Additionally, more parameters were also used other than those used in previous studies. Based on the reasons, the current study was carried out to develop predictive regression equations that could be used for stature estimation using anthropometric hands and its corresponding print dimensions in adult Egyptians.

PARTICIPANTS & METHODS

This descriptive cross-sectional study was conducted on 150 volunteers (75 males & 75 females); they were recruited from students, employees, and workers of the Faculty of Medicine, Ismailia, Egypt. Their ages range from 18 to 65 years old. Individuals with a history of physical deformity, hand trauma, or hand surgery that could affect hand dimensions were excluded from the study, as were those with foot/backbone deformity, a history of trauma, or surgical procedures that could affect height.

Written informed consent was taken from each participant after obtaining approval from the Institutional Review Board.

Stature (distance between the vertex and the floor) was measured. Each participant was standing in an erect position; barefooted; arms beside their corresponding thighs, heels in contact with each other & shoulders, buttocks, and heels were in contact with the wall. The head was positioned in the horizontal plane of Frankfort, with the headboard pressed against the vertex **(Akhlaghi et al., 2012)**. The "CanoScan LiDE 110" flatbed scanner was used to obtain images for both hands, where the palmar surface of the hand was placed upon the scanner, with all fingers extended and adherent to each other, keeping the long axis of the hand parallel to that of the forearm. These images were converted to handprints, which in turn converted to grey-scale (with adjustments of contrast and brightness by using Photoshop software package-SC6 edition) to obtain the most accurate handprints' images **(Ishak et al. 2012)**.

Seven measurements were taken of both sides' hands and their corresponding prints using the Photoshop software package's measuring tool, and all measurements were recorded in centimeters (cm). Hand and its corresponding print dimensions were taken according to the following definitions (Fig. 1, 2).

Hand length (HL): "Distance from mid-point of the wrist distal transverse crease to middle finger's tip" (Akhlaghi et al. 2012; Habib and Kamal 2010; Ishak et al. 2012).

Handbreadth (HB): "Distance between the most outside projections of heads of both 2nd and 5th metacarpals" (Ishak et al., 2012; Krishan and Sharma, 2007).

Palm length (PL): "Distance from mid-point of the wrist distal transverse crease and middle finger proximal flexion crease" **(Ishak et al., 2012; Kanchan and Rastogi 2009)**.

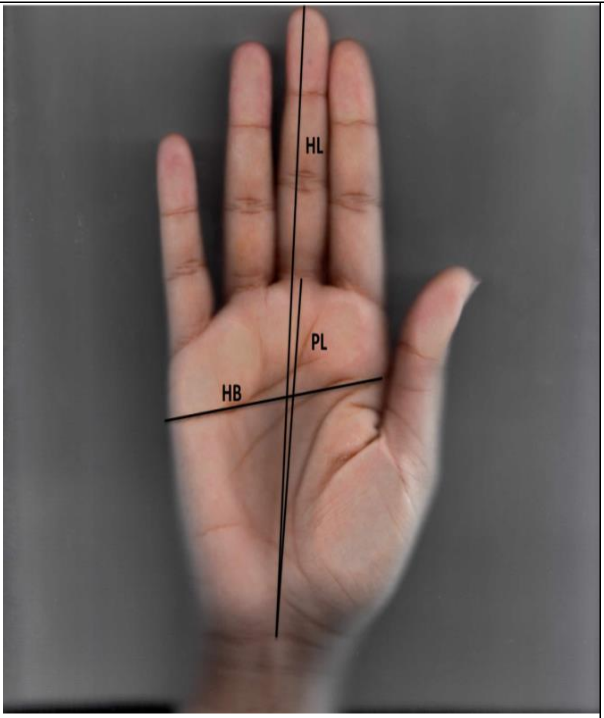

Figure (1): Hand measurement **(HL**:hand length, **PL**: palm length, **HB**: hand breadth) 'Quoted from work station'

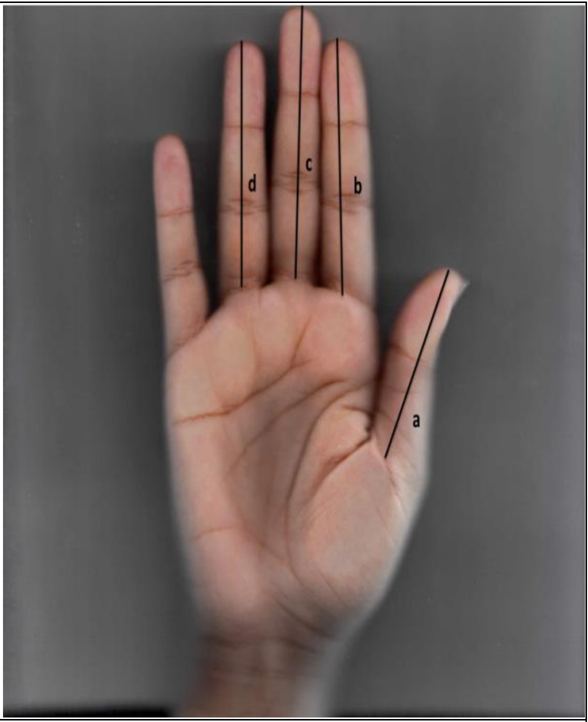

Figure (2): Fingers lengths [**a**: Thumb (1D); **b**: Index (2D); **c**: Middle finger (3D); **d**: Ring finger (4D)] 'Quoted from work station'

Figure (1): Fingerprints measurements [a: Thumb finger (1D); b: Index finger (2D); c: Middle finger (3D); d: Ring finger (4D)]. 'Quoted from workstation'

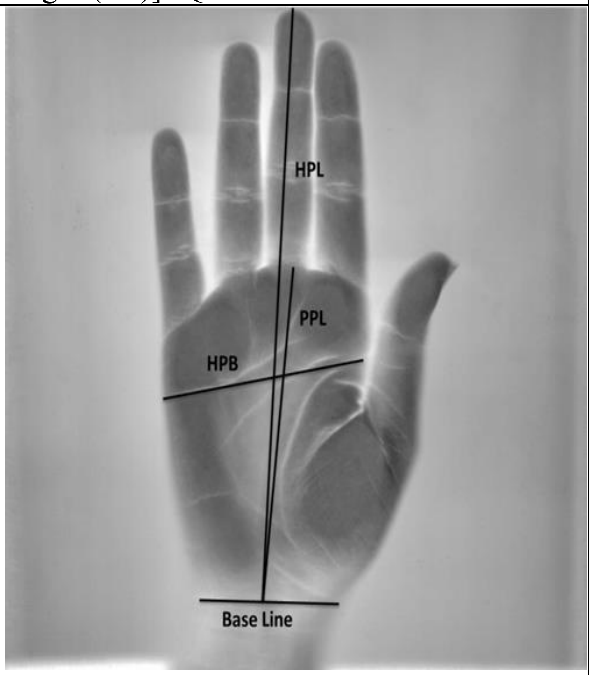

Figure (4): Handprint dimensions (HPL:Hand print length, PPL: Palm print length, HPB: Hand print breadth)'Quoted from work station'

Thumb (1D); Index (2D); Middle (3D); Ring (4D) finger length: "Distance from each finger proximal flexion crease and its corresponding tip" **(Akhlaghi et al. 2012; Ishak et al. 2012)**.

Handprint dimensions were the same as those of hand dimensions, except for handprint length and breadth. (Fig.3, 4)

Handprint length (HPL): "Distance between the palm baseline (transverse line of the most inferior point of the palm) to middle finger's tip."

Handprint breadth (HPB): "Distance between the lateral projection of palm print at the 2nd metacarpal and the medial projection of palm print at the distal transverse crease" **(Ishak et al., 2012)**.

All measurements were performed by using the same tool to avoid technical errors and by the same researcher to avoid inter-observer bias. Measurements of ten participants were obtained on three different days (two days intervals) to calculate the absolute technical error of measurement (TEM) and relative technical error of measurement (rTEM) (Sharaf El-Din et al. 2016). The coefficient of reliability (R) was calculated. "R" values were higher than the cut-off value of 0.95 for all measurements; this Intra-observer error was within the acceptable standards (R > 0.9; rTEM < 5%) **(Ahmed 2013; Ulijaszek and Kerr 1999).**

Statistical analysis:

Statistical analysis was conducted using SPSS "Statistical Package for the Social Sciences" version 20. Mean, standard deviation, and range were calculated for hands and their corresponding print dimensions of both sides for both sexes.

The unpaired t-test was performed to determine if there is a significant difference in stature between males and females. Student t-test was used to detect the presence of significant sexual dimorphism in hand and its corresponding print dimensions between males and females. Karl Pearson's correlation coefficient (r) was used to assess the correlation between stature and each measurement of the hand/corresponding print (of both sides for both sexes). Regression equations for stature estimation were calculated (using simple linear regression analysis) for each measurement; for both sexes. They were derived according to this formula (Đurić et al. (2005): **Y (Stature) = a+bx.** Where **(a:** regression coefficient of stature, **b**: regression coefficient of hand/handprint dimensions & **x**: individual variable).

SEE (Standard error of estimate) was calculated to predict deviation of the estimated stature from the real one, where the lower its value, the higher reliability & accuracy of the estimated stature.

RESULTS

Descriptive statistics

The study included 150 adult Egyptians, 75 males (their mean age was 25.23 ± 8.44 years; range: 18-55 years), and 75 females (their mean age was 25.24 ± 9.12 years; range: 19-65 years).

The study showed that the mean of measured stature for males (177.71±6.83cm; range: 159-198cm) was significantly higher than that for females (161.05±5.97 cm; range: 148-175) with the P-value < 0.0001.

Tables 1 and 2 showed that the mean for all hands and their corresponding print dimensions were significantly higher in males. Handbreadth, hand length, palm length, and their corresponding prints of both sides were the most sexually dimorphic measurements as indicated by the t-test.

Regarding the bilateral difference in hand and its corresponding print dimensions; measurements of palm length, hand length, handbreadth, handprint breadth, palm print length, index finger length, and ring finger length were significantly different between right and left sides in males (P < 0.05) (table.3). However, in females, the measurements of handbreadth, index finger length, and handprint breadth were significantly different between both sides (P < 0.05) (table.4).

Table (1): Descriptive statistics of hand dimensions in both sexes in the study group

Hand Dimensions (N=150)		Male (n=75)	Female (n=75)	Independent t-test	
				t-value	P (2-tailed)
Right					
HL	Mean ± SD	19. 89 ± 1.10	17.71 ± 0.94	13.05	<0.001*
HB	Mean ± SD	8.60 ± 0.49	7.57 ± 0.47	13.20	<0.001*
PL	Mean ± SD	11.54 ± 0.71	10.16 ± 0.56	13.24	<0.001*
1D	Mean ± SD	5.80 ± 0.71	5.00 ± 0.62	7.34	<0.001*
2D	Mean ± SD	7.41 ± 0.49	6.74 ± 0.45	8.62	<0.001*
3D	Mean ± SD	8.40 ± 0.52	7.56 ± 0.49	10.16	<0.001*
4D	Mean ± SD	7.81 ± 0.53	6.98 ± 0.47	10.24	<0.001*
Left					
HL	Mean ± SD	19.75 ± 1.07	17.64 ± 1.24	11.17	<0.001*
HB	Mean ± SD	8.36 ± 0.50	7.39 ± 0.46	12.39	<0.001*
PL	Mean ± SD	11.40 ± 0.67	10.17 ± 0.55	12.18	<0.001*
1D	Mean ± SD	5.81 ± 0.61	5.02 ± 0.51	8.55	<0.001*
2D	Mean ± SD	7.36 ± 0.50	6.69 ± 0.46	8.63	<0.001*
3D	Mean ± SD	8.35 ± 0.60	7.55 ± 0.50	8.89	<0.001*
4D	Mean ± SD	7.73 ± 0.54	6.94 ± 0.48	9.44	<0.001*

HL: hand length; HB: hand breadth; PL: palm length; 1D: thumb length; 2D: index finger length; 3D: middle finger length; 4D: rings finger length. SD: Standard Deviation.
***Statistically significant at p <0.05. All measurements are in cm**

Table (2): Descriptive statistics of handprint dimensions in both sexes in the study group

Handprint dimensions (N=150)		Male (n=75)	Female (n=75)	Independent t-test	
				t-value	P (2-tailed)
Right					
HPL	Mean ± SD	19.81 ± 1.08	17.68 ± 0.94	12.93	<0.001*
HPB	Mean ± SD	8.32 ± 0.43	7.29 ± 0.40	15.21	<0.001*
PPL	Mean± SD	11.50 ± 0.71	10.16 ± 0.56	12.86	<0.001*
1DP	Mean ±SD	6.02 ± 0.62	5.19 ± 0.59	8.46	<0.001*
2DP	Mean ± SD	7.44 ± 0.47	6.72 ± 0.46	9.49	<0.001*
3DP	Mean ± SD	8.31 ± 0.54	7.53 ± 0.48	9.35	<0.001*
4DP	Mean ± SD	7.80 ± 0.54	6.98 ± 0.48	9.90	<0.001*
Left					
HPL	Mean ± SD	19.74 ± 1.10	17.69 ± 0.96	12.19	<0.001*
HPB	Mean ± SD	8.19 ± 0.48	7.21 ± 0.42	13.35	<0.001*
PPL	Mean ± SD	11.42 ± 0.72	10.18 ± 0.57	11.59	<0.001*
1DP	Mean ±SD	5.95 ± 0.64	5.13 ± 0.56	8.36	<0.001*
2DP	Mean ± SD	7.43 ± 0.48	6.70 ± 0.45	9.70	<0.001*
3DP	Mean ± SD	8.33 ± 0.52	7.51 ± 0.51	9.76	<0.001*
4DP	Mean ± SD	7.81 ± 0.53	6.94 ± 0.50	10.24	<0.001*

HPL: handprint length; HPB: handprint breadth; PPL: palm print length; 1DP: thumb print length; 2DP: index fingerprint length; 3DP: middle fingerprint length; 4DP: ring fingerprint length.
SD: Standard Deviation, *Statistically significant at p <0.05. All measurements are in cm

Table (3): Bilateral difference of hand and its corresponding print dimensions in a male sample of Egyptian population

Dimensions (N=150)	Paired t-test	
	t	p value
Rt and Lt Hand length	3.07	0.003*
Rt and Lt Hand breadth	5.17	<0.001*
Rt and Lt Palm length	2.90	0.005*
Rt and Lt Thumb finger length	-0.10	0.92
Rt and Lt Index finger length	2.21	0.03*
Rt and Lt Middle finger length	1.53	0.13
Rt and Lt Ring finger length	3.30	0.001*
Rt &Lt Handprint length	1.81	0.08
Rt and Lt Handprint breadth	2.94	0.004*
Rt and Lt Palm print length	2.09	0.04*
Rt and Lt Thumb fingerprint length	1.01	0.32
Rt and Lt Index fingerprint length	0.27	0.79
Rt and Lt Middle fingerprint length	-0.72	0.47
Rt and Lt Ring fingerprint length	-0.17	0.87
Rt: Right Lt: left *Statistically significant at p <0.05.		

Table (4): Bilateral difference of hand and its corresponding print dimensions in a female sample of Egyptian population

Dimensions (N=150)	Paired t-test	
	t	p-value
Rt and Lt Hand length	0.90	0.37
Rt and Lt Hand breadth	-	<0.001*
Rt and Lt Palm length	4.39	0.75
Rt and Lt Thumb finger length	-	0.78
Rt and Lt Index finger length	2.50	0.02*
Rt and Lt Middle finger length	0.74	0.46
Rt and Lt Ring finger length	1.82	0.07
Rt &Lt Handprint length	-	0.78
Rt and Lt Handprint breadth	2.15	0.03*
Rt and Lt Palm print length	-	0.60
Rt and Lt Thumb fingerprint length	1.05	0.30
Rt and Lt Index fingerprint length	1.05	0.30
Rt and Lt Middle fingerprint length	0.90	0.37
Rt and Lt Ring fingerprint length	1.42	0.16
Rt: Right Lt: left *Statistically significant at p <0.05.		

Table (5): Correlation between stature and hand dimensions in both males and females.

Hand dimensions [1] (N=150)	Male (n=75)		Female (n=75)	
	r	p value	r	p value
Right				
HL	0.65	<0.001*	0.75	<0.001*
HB	0.39	<0.001*	0.42	<0.001*
PL	0.61	<0.001*	0.65	<0.001*
1D	0.35	0.002*	0.41	<0.001*
2D	0.53	<0.001*	0.66	<0.001*
3D	0.51	<0.001*	0.70	<0.001*
4D	0.44	<0.001*	0.60	<0.001*
Left				
HL	0.63	<0.001*	0.60	<0.001*
HB	0.43	<0.001*	0.36	0.002*
PL	0.52	<0.001*	0.56	<0.001*
1D	0.41	<0.001*	0.42	<0.001*
2D	0.51	<0.001*	0.69	<0.001*
3D	0.56	<0.001*	0.68	<0.001*
4D	0.42	<0.001*	0.62	<0.001*

Karl Pearson's correlation coefficient HL: hand length; HB: hand breadth; PL: palm length. 1D: thumb finger length; 2D: index finger length; 3D: middle finger length; 4D: ring finger length
*** Statistically significant at $p< 0.05$ level (2-tailed).**

Table (6): Correlation between stature and handprint dimensions in males and **females.**

Handprint dimensions [1] (N=150)	Male (n=75)		Female (n=75)	
	r	p value	R	p value
Right				
HPL	0.61	<0.001*	0.74	<0.001*
HPB	0.34	<0.001*	0.44	<0.001*
PPL	0.54	<0.001*	0.63	<0.001*
1DP	0.35	<0.001*	0.48	<0.001*
2DP	0.53	<0.001*	0.69	<0.001*
3DP	0.52	<0.001*	0.70	<0.001*
4DP	0.45	<0.001*	0.63	<0.001*
Left				
HPL	0.64	<0.001*	0.72	<0.001*
HPB	0.43	0.005*	0.32	0.005*
PPL	0.59	<0.001*	0.60	<0.001*
1DP	0.48	0.001*	0.39	0.001*
2DP	0.55	<0.001*	0.69	<0.001*
3DP	0.54	<0.001*	0.69	<0.001*
4DP	0.45	<0.001*	0.60	<0.001*

[1]Karl Pearson's correlation coefficient. HPL: handprint length; HPB: handprint breadth;PPL: palm print length;
1DP: thumb fingerprint length; 2DP: index fingerprint length; 3DP: middle fingerprint length; 4DP: ring fingerprint length
*** Statistically significant at $p< 0.01$ level (2-tailed).**

Table (7): Simple linear regression equations for stature determination from right and left hand dimensions in both sexes.

Male (n=75)		**Female** (n=75)	
Equation	**SEE**	**Equation**	**SEE**
Right			
S=97.53+4.03 HL	±0.55	S=76.58+4.77 HL	±0.49
S=130.38+5.50 HB	±1.51	S=120.88+5.31 HB	±1.34
S=109.45+5.92 PL	±0.89	S=90.46+6.95 PL	±0.96
S=157.97+3.40 1D	±1.06	S=141.44+3.92 1D	±1.04
S=123.87+7.27 2D	±1.38	S=101.32+8.86 2D	±1.17
S=121.11+6.74 3D	±1.33	S=97.14+8.45 3D	±1.02
S=133.04+ 5.72 4D	±1.36	S=107.84+7.62 4D	±1.21
Left			
S=98.38+4.02 HL	±0.58	S=109.63+2.92 HL	±0.45
S=128.80+5.85 HB	±1.45	S=127.02+4.61 HB	±1.41
S=117.48+5.28 PL	±1.01	S=99.63+6.04 PL	±1.06
S=150.97+4.60 1D	±1.19	S=136.58+4.87 1D	±1.25
S=126.42+6.97 2D	±1.38	S=100.83+9.01 2D	±1.11
S=124.49+6.37 3D	±1.10	S=99.38+8.17 3D	±1.03
S=136.25+5.37 4D	±1.35	S=108.38+7.59 4D	±1.14
SEE: standard error of the estimate; S: stature; HL: hand length; HB: hand breadth. PL: palm length; 1D: thumb finger length; 2D: index finger length; 3D: middle finger length. 4D: ring finger length N.B: all measurements are in cm.			

Table (8): Simple linear regression equations for stature determination from right and left handprint dimensions in both sexes**.**

Male (n=75)		**Female (n=75)**	
Equation	**SEE**	**Equation**	**SEE**
Right			
S=101.09+3.87 HPL	±0.58	S=77.09+4.75 HPL	±0.50
S=133.02+5.37 HPB	±1.75	S=113.08+6.58 HPB	±1.56
S=117.14+5.27 PPL	± 0.95	S=92.07+6.79 PPL	±0.97
S=154.18+3.91 1DP	±1.21	S=135.42+4.95 1DP	±1.04
S=121.26+7.59 2DP	±1.44	S=100.36+9.03 2DP	±1.11
S=123.71+6.50 3DP	±1.26	S=94.32+8.86 3DP	±1.04
S= 132.95+5.76 4DP	±1.33	S=106.52+7.82 4DP	±1.12
Left			
S=98.83+3.99 HPL	0.56±	S=82.19+4.46 HPL	±0.51
S=128.14+4.56 HPB	±1.58	S=127.63+6.12 HPB	±1.52
S=113.77+5.6 PPL	±0.89	S=97.84+6.21 PPL	±0.98
S=147.37+5.1 1DP	±1.09	S=139.81+4.14 1DP	±1.15
S=119.61+7.81 2DP	±1.40	S=99.50+9.19 2DP	±1.12
S=118.68+7.09 3DP	±1.30	S=100.49+8.06 3DP	±1.00
S=132.69+5.77 4DP	±1.35	S=111.57+7.13 4DP	±1.11
SEE: standard error of the estimate; S: stature; HPL: handprint length; HPB: handprint breadth; PPL: palm print length; 1DP: thumb fingerprint length; 2DP: index fingerprint length; 3DP: middle fingerprint length; 4DP: ring fingerprint length N.B: all dimensions are in cm.			

Correlation with stature

It was evident that all measured hand dimensions were significantly correlated to stature in both sexes ($p < 0.01$) (table.5). In males, hand dimensions that most strongly correlated to stature on both sides were left-hand length (r= 0.63); right-hand length (r =0.65). However, in females, hand dimensions that most strongly correlated to stature on both sides were left index finger length (r= 0.69) and right-hand length (r = 0.75).

Regarding measured handprint dimensions, all of them were significantly correlated to stature in both sexes ($p < 0.01$) (table.6). In males, handprint dimensions that most strongly correlated to stature on both sides were right handprint length (r= 0.61) and left handprint length (r= 0.64). In females, handprint dimensions that most strongly correlated to stature on both sides were right handprint length (r = 0.74) and left handprint length (r = 0.72).

Simple linear regression analysis:

Stature estimation regression equations along with SEE-depending on hand and its corresponding print dimensions of both sides were presented in tables 7 and 8. In males, the hand length of both sides had the lowest SEE (left hand: ±0.58 cm & right hand: ±0.55 cm). The same finding was found in females (SEE was ±0.45 in the left hand and ±0.49 cm in the right hand). Regarding handprint dimensions, regression equations for stature determination showed that handprint length for both sides had the lowest SEE in males (±0.56 cm in the left hand & ±0.58 cm in the right hand), the same result was detected in females (SEE was ±0.51 cm in the left hand & ±0.50 cm in the right hand).

DISCUSSION

Stature determination is an important parameter of human remains identification **(Agnihotri et al .2008)**. Mathematical methods can be used for stature estimation from long bones **(Lundy 1985)**. Formulas derived from regression analysis depending on hand dimensions are considered reliable tools for stature estimation **(Krishan et al., 2012)**. However, those formulas are population specific **(Agnihotri et al., 2008)**.

The current study found that males had significantly higher mean values of stature and all hand/corresponding print dimensions. These results are in agreement with that of other studies from Egypt **(Abdel-Malek et al.1990; Habib and Kamal 2010; Paulis 2015)**, Sudan **(Ahmed 2013),** Saudi Arabia **(Kornieieva and Elelemi 2016),** Mauritius **(Agnihotri et al. 2008),** Australia **(Ishak et al. 2012),** Iran **(Akhlaghi et al. 2012),** India **(Krishan and Sharma 2007; Rastogi et al. 2008),** Turkey **(Ozaslan et al. 2012),** Malaysia **(Moorthy and Zulkifly 2015),** Slovak Republic **(Uhrova et al. 2015) and** China **(Tang et al. 2012).** This can be explained by the early maturity of females and the fusion of their epiphyses two years earlier than males, so males have two more years for growth **(Krishan and Sharma 2007)**. Also, a relation between the Y chromosome and stature was detected. This suggests that establishing sex-specific equations is necessary for stature estimation **(Rastogi et al., 2008; Sharaf El-Din et al., 2016)**.

The mean value of stature in the present study was 177.71cm±6.83 for males and 161.05 cm ±5.97 for females. These values were close to those reported in studies from Egypt **(Habib and Kamal 2010; Sharaf El-Din et al. 2016)**, Sudan **(Ahmed 2013),** Slovakia **(Uhrova et al. 2015),** Australia **(Ishak et al. 2012)** and higher than those reported in other studies in Egypt **(Abdel-Malek et al. 1990; Paulis 2015),** Saudi Arabia **(Kornieieva and Elelemi 2016),** China **(Tang et al. 2012).** These variations might be explained by genetic/ethnic differences, variation in the age ranges of the studied groups of different studies; variation in the geographical regions where those studies have been conducted; and differences in the sample size. Several factors are reported to be responsible for ethnic differences in stature and other body dimensions. These include genetic, sociodemographic, economic, environmental, climate, type of work, and physical activity **(Ahemad and Purkait 2011; Zaher et al. 2011; Rastogi et al. 2008)**. This confirms the need for population-specific formulas for stature estimation **(Abdel-Malek et al., 1990)**. The time factor is very important, as secular changes have implications for stature estimation **(Pal et al. 2016)**.

Bilateral asymmetry was found in some hands and their corresponding print dimensions. Significant differences were detected between the left and right sides in males regarding lengths of the hand, palm, index, and ring fingers, handbreadth, handprint breadth, and palm print length, while in females, asymmetry was found in hands and their corresponding print breadth, length of the index finger. In line with the present study, some studies reported significant asymmetry in handbreadth and handprint breadth **(Ishak et al., 2012; Kornieieva and Elelemi 2016; Krishan and Sharma 2007)**, hand length showed asymmetry in a study in Northern and Southern Indians **(Rastogi et al. 2008)**. On the contrary, no significant asymmetry was found in other studies **(Pal et al. 2016; Uhrova et al. 2015; Varu et al. 2015; Agnihotri et al. 2008)**. The significant bilateral difference of the hand and its corresponding print dimensions may be attributed mainly to the muscular dominance of one side over the other **(Ahemad and Purkait 2011)**. Due to the detected bilateral asymmetry in the hands and their corresponding print dimensions, regression equations were developed for each side separately.

The current study showed a significant correlation between stature and all the measured hand/corresponding print dimensions in both sexes ($p < 0.01$). This means that regression equations could be derived from all hands and their corresponding print dimensions for stature estimation. This finding agrees with findings from other studies **(Ahemad and Purkait 2011; Choksi et al. 2014; Kornieieva and Elelemi 2016; Krishan et al. 2012)**. However, no significant correlation was detected between handbreadth and stature in a study conducted in Bangladesh populations **(Hossain et al. 2010).**

It was evident from the present study that right-hand length in both sexes was the most strongly correlated hand variable to stature; hence it can be used for stature estimation. Various studies concluded that hand length was strongly correlated to stature **(Ishak et al., 2012; Pal et al., 2016; Rastogi et al., 2008; Varu et al., 2015)**. The present study showed that handprint length achieved the strongest correlation with stature for both sexes, which agrees with other studies **(Ahemad and Purkait 2011; Paulis 2015; Shende et al. 2013).** Females had higher correlation coefficient values for all measurements, which is consistent with **Moorthy and Zulkifly 2015**.

In the current study, linear regression equations have been developed for each sex, hands of both sides, and their corresponding print dimensions along with SEE. The lowest SEE values were obtained when using hand length on both sides in both sexes. This ensured better accuracy of using hand length dimensions in stature determination. These results agree with those of other studies **(Agnihotri et al., 2008; Ozaslan et al., 2012; Pal et al., 2016; Varu et al., 2015).** However, in a study from China, handbreadth showed the lowest SEE **(Tang et al., 2012).**

The same observation was detected regarding handprint dimensions, as handprint length recorded the lowest SEE for stature estimation. This supports results from other studies **(Ahemad and Purkait 2011; Shende et al. 2013; Paulis 2015)**. This finding might indicate that the derived print is representative of the flesh hand. In the present study, it was noticed that SEE values for hand measurements were close or like those for handprint measurements, which comes in agreement with previous studies **(Jasuja and Singh 2004; Kornieieva and Elelemi 2016)**. However, Ishak and his colleagues detected that direct hand measurements provided higher accuracy in stature estimation **(Ishak et al., 2012).**

The resultant regression models using both hands and their corresponding print lengths showed lower SEE (0.45-0.58 cm for hand length; 0.50-0.58 cm for handprint length) than those recorded in previous studies **(Pal et al. 2016; Paulis 2015; Rastogi et al. 2008).** This improved accuracy in the present study may be due to the lack of genetic diversity in the studied population, contrary to some other studies. It might also be attributed to genetic, ethnic, and environmental differences between the differences in the techniques used for measuring hand and its corresponding print dimensions in different studies. In the present study, a flatbed scanner and a Photoshop measuring program have been used for obtaining the hand and its corresponding print dimensions. This is considered a novel technique and is assumed to be more accurate than the traditional manual methods used in other studies (e.g., using a sliding caliper for measuring hand dimensions and ink for measuring handprint dimensions).

CONCLUSION

Dimensions of the hand and its corresponding print can be used for estimation of adult stature of both sexes, as they are significantly correlated with stature. “Right-hand length” had the strongest correlation in both sexes, while "left handprint length" in males and "right handprint length" in females had the strongest correlation with stature. SEE was the lowest using hand length and its corresponding print length in both sexes, as revealed by simple linear regression analysis, ensuring their lowest prediction error in stature estimation.

LIMITATION OF THE STUDY

The study was conducted in one region (the Suez Canal area). It had a small sample size. Image processing and Photoshop software packages are prone to certain errors; this may lead to the change in dimensions of the prints that may affect prediction accuracy. Therefore, TEM and rTEM were calculated to minimize this error.

RECOMMENDATIONS

Further similar studies on a larger sample size should be carried out. Furthermore, more research should be conducted on Egyptians from other geographical regions to develop a biologically specific standard for Egyptians.

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إستخدام أبعاد اليد والبصمة المقابلة لها في تقديرطول القامة

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يعد تحديد الهوية الشخصية أحد أهم التحديات التي تواجه خبراء الطب الشرعي خاصة في حالات البقايا الآدمية المجزأة أو غير المكتملة. كما يعد تقديرطول القامة أحد المعايير الرئيسية لتحديد الهوية. تهدف الدراسة الحالية إلي تطوير معادلات الانحدار التنبؤية التي يمكن استخدامها لتقدير طول القامة بإستخدام أبعاد اليد البشرية والبصمة المقابلة لها. وقد أجريت الدراسة على مائة وخمسين مشاركًا بالغًا (75 ذكرًا و75 أنثى). تم قياس طول القامة كما تم قياس سبعة أبعاد لكل يد والبصمة المقابلة لها لكل مشارك.

وقد أوضحت الدراسة أن جميع القياسات الخاصة بمجموعة الذكور أعلى بكثيرمن المقابل لها عند الإناث. كما وجدت فروق ذات دلالة إحصائية في بعض أبعاد اليد وبصمتها في كلا الجنسين. كما أظهر طول اليد اليمنى أقوى ارتباط مع طول القامة في كلا الجنسين، بينما أظهر طول بصمة اليد اليمنى عند الإناث وطول بصمة اليد اليسرى عند الذكورأقوى ارتباط مع طول القامة. كما أوضحت الدراسة أن لأطوال اليد والبصمة في كلا الجانبين لكلا الجنسين أدنى خطأ معياري في التقدير مما يضمن أدنى خطأ للتنبؤ في تقدير طول القامة. هذا وتخلص الدراسة إلي أنه يمكن استخدام أبعاد اليد وبصمتها في تقدير طول قامة البالغين.