Stature Estimation Using Different Upper Limb Anthropometric Measurements

Naira Fahmi Girgis

Amira Mohammed Elseidy

Maha Salah Elnady Afify

Shaimaa Abdel-hamid Hassanein

Shireen Ragab Slima

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Naira F. Girgis, Amira M. Elseidy, Maha S.E. Afiyy, Shaimaa A.H. Hassanein, Shireen R. Slima

Abstract

Objectives: To analyze percutaneous and radiographic measurements of some upper limb parameters (ulna and hand) and their relationship to stature via the use of statistical analysis in an Egyptian sample, Menoufia governorate.

Background: Identification is the process of identifying a person, based on specific characteristics which differentiate him from other individuals. One key component of a person’s identity is their stature. As there is a significant relationship between the dimensions of various body parts and stature, particularly bone lengths, estimating stature using long bone measurements provides an essential tool in the identification of unknown remains.

Methods: The cross-sectional study was conducted on an Egyptian sample, Menoufia governorate. All the anthropometric measurements were taken independently on the left side of each individual in a good, illuminated room by one observer.

Results: A study was conducted on 387 Egyptian participants aged from 21 to 40 years old with different occupations and most of them had middle socioeconomic standard. Single linear regression formula obtained from percutaneous and radiological ulnar length showed the least standard error of estimate. Regarding to R² value, the accuracy of the multiple regression equation of percutaneous and radiologically measured parameters represented 60 and 59%, respectively.

Conclusion: Ulnar length and hand length were the best parameters to predict stature. A simple linear regression equation using a single parameter could significantly be used for stature estimation. For stature prediction, using multiple regression equations is more accurate than simple regression equations.

Keywords: Hand length, Percutaneous, Radiological, Stature, Ulnar length

1. Introduction

Anthropometry—the study of representing human shape in numerical form has been applied extensively in forensic identification. Identifying a person involves figuring out their sex, age, race, and stature [1]. Identification of victims from isolated extremities is crucial in mass catastrophe situations [2]. The importance of stature assessment in human identification has piqued the interest of forensic experts [3]. Stature estimation is an essential indicator of life expectancy, nutritional quality, and overall health. Also, stature is used to diagnose genetic illnesses [4].

Based on the concept that there is a known correlation between height and different bodily sections, such as the head, trunk, and upper and lower extremities, estimation of stature may be done using human skeletal remains.

In forensic investigations, stature estimation is mostly done using two methods: mathematical and anatomical. The direct reconstruction of stature using the anatomical technique entails measuring and adding the lengths or heights of many adjacent skeletal parts extending from the cranium to the foot. The mathematical method uses regression formulae (or ratios) based on the correlation of individual skeletal elements to measured stature.
Even though the anatomical method is more accurate, it is frequently not possible to acquire complete skeletal remains from a crime scene. As a result, forensic anthropologists and medicolegal experts must reconstruct stature using the somewhat less accurate mathematical method, which can still be used even in cases where only one long bone is available [5].

The aim of the present study was to analyse percutaneous and radiographic measurements of some upper limb parameters (ulna and hand bones) and their relationship to stature via the use of statistical analysis in an Egyptian sample, in Menoufia governorate.

2. Methods

The cross-sectional study was conducted on a convenient nonrandom sample of the Egyptian population, Menoufia governorate. The age of the patients included in this study ranged from 21 to 40 years old. The lower age limit was 21 years to be sure of skeletal maturity and the higher limit is 40 as the stature starts to decline after the age of 40 years. Time of measurements was fixed at daytime light (from 10 am to 2 pm) to avoid any diurnal variation [1].

The sample size was calculated by Academic research department (Public Health and Community Medicine Department, Faculty of Medicine, Menoufia University), using the following formula:

\[ n \geq \frac{NZ^2_{1-\alpha/2}p(1-p)}{d^2(N-1) + Z^2_{1-\alpha/2}p(1-p)} \]

Here: n: Sample size
N: Total population of Menoufia Governorate = 100,000 persons
\( Z_{1-\alpha/2} \): standard normal variate at 5% type I error \( (P < 0.05) = 1.96 \)
\( P \): Expected proportion of abnormality = 0.5
\( d \): Absolute error or precision = 0.05

The number of the studied participants was 387 volunteers (270 were students, manual workers, and employees, and 117 were cases arrived at the radiology outpatient clinic in Menoufia university hospital for doing chest or abdominal radiography). All participants in this study were right-handed as the existence of a significant asymmetry in upper limb dimensions associated with dominance [6]. All the anthropometric measurements were taken independently on the left side of each individual in a good, illuminated room by one observer to avoid inter-observer error [7].

All participants were selected according to inclusion and exclusion criteria. Inclusion criteria include healthy individuals free from any apparent skeletal deformity. Exclusion criteria include any apparent hand, limb, or vertebral column deformity, left-handed persons since the effect of hand dominance on hand measurements, subjects with poorly defined wrist creases, history of pathological or traumatic fractures.

The study was conducted according to standard ethics drawn by Menoufia University Ethical Committee for Human Research and after obtaining written informed consent from every one of study subjects, after explanation of the method of examination and, the purpose of the study. The present study was approved by the ethical committee in our faculty with a number (19519FORE20).

Stature was measured with a stadiometer while, the participant was standing upright, barefooted, with a straight back, hands by the side, and recorded to the nearest 0.1 cm. It was taken as a distance from the outmost point on the head (vertex) to the heel. The head of each participant was kept in the Frankfort horizontal plane (eye ear plane) by supporting the participant's chin [6].

All percutaneous parameters were measured by anthropometry tap: Hand length (HL): The subjects were asked to place their hands supine on a flat hard horizontal surface with fingers extended and adducted. Then the hand length was measured as a straight perpendicular line from the distal end of the most anterior projecting point that is the tip of the middle finger to the distal crease of the wrist joint (the point of convergence of the perpendicular straight line with the distal crease) [8].

Palm length (PL): was measured as a distance from the mid-point of the distal transverse crease of the wrist to the proximal flexion crease of the middle finger [9].

Palm width (PW): The subjects were asked to place their hands supine on a flat hard horizontal surface with the thumb abducted and other fingers in extended and adducted position. Then the palm width was measured on a distance between the radial side of the second metacarlo-phalangeal joint and the ulnar side of the fifth metacarlo-phalangeal joint [8].

Percutaneous ulnar length (PCUI) was measured with the elbow flexed and palm placed over the opposite shoulder and marking the tip of the olecranon process and the tip of the styloid process of the ulna with a skin marker and measuring the distance between these two points [10].

Radiographic measurements of upper limb bones: All included subjects were examined by a conventional x-ray machine (Schimadzu Corp., Kioto, Japan) for standard left-hand postero-anterior view
and left forearm antero-posterior view. After imaging the distance icon was pressed and started to measure the different parameters. Hand length was measured as the distance from the tip of the distal phalanx of the middle finger to the midpoints of the interstyloid line [11].

PL was measured as the distance from the head of the third metacarpal bones to the midpoints of the inter-styloid line [11].

PW was measured as the distance from the most prominent distal point of the head of the second metacarpal to the most prominent distal point of the head of the fifth metacarpal [12].

The ulnar length was measured from the highest point of the olecranon and the lowest point of the ulnar styloid process (Fig. 1) [12].

2.1. Statistics analysis

The data were collected, tabulated, and statistically analyzed by IBM personal computer and statistical package SPSS version 22 (Armonk NY: IBM Corp). Two types of statistics were done including descriptive statistics and analytic statistics. Descriptive statistics used were percentage (%), mean (x), standard deviation (SD), and range. Analytic statistics included students t-test, paired t test, Pearson’s correlation coefficient, linear regression, and multiple analyses and equations. P value less than 0.05 was considered statistically significant. P value less than 0.001 was considered statistically highly significant [13].

3. Results

The total number of the studied participants was 387 participants (180 males and 207 females). The mean value of stature of the studied participants was 166.24 ± 9.15 cm. In the male sample, the mean value was 173.87 ± 5.88 cm, while in the females was 159.60 ± 5.63 cm. The stature in males was significantly higher than in females. The current study revealed that there were significantly higher mean values for all percutaneous and radiological measures in males than females where the P value was less than 0.001 (Table 1).
Table 1. Stature, percutaneous, and radiological measures of different parameters of the studied participants (N = 387).

<table>
<thead>
<tr>
<th>Measures (cm)</th>
<th>All participants (N = 387)</th>
<th>Male (N = 180)</th>
<th>Female (N = 207)</th>
<th>t-test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Stature</td>
<td>166.24</td>
<td>9.15</td>
<td>173.87</td>
<td>5.88</td>
<td>159.60</td>
</tr>
<tr>
<td>Percutaneous measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length</td>
<td>20.24</td>
<td>1.41</td>
<td>21.08</td>
<td>1.37</td>
<td>19.51</td>
</tr>
<tr>
<td>Palm length</td>
<td>11.60</td>
<td>0.99</td>
<td>11.90</td>
<td>0.94</td>
<td>11.33</td>
</tr>
<tr>
<td>Palm width</td>
<td>9.12</td>
<td>0.90</td>
<td>9.58</td>
<td>0.79</td>
<td>8.72</td>
</tr>
<tr>
<td>Ulnar length</td>
<td>28.48</td>
<td>2.17</td>
<td>29.84</td>
<td>1.73</td>
<td>27.30</td>
</tr>
<tr>
<td>Radiological measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length</td>
<td>19.39</td>
<td>1.43</td>
<td>20.23</td>
<td>1.35</td>
<td>18.66</td>
</tr>
<tr>
<td>Palm length</td>
<td>10.25</td>
<td>0.92</td>
<td>10.68</td>
<td>0.80</td>
<td>9.87</td>
</tr>
<tr>
<td>Palm width</td>
<td>7.81</td>
<td>0.79</td>
<td>8.25</td>
<td>0.70</td>
<td>7.43</td>
</tr>
<tr>
<td>Ulnar length</td>
<td>27.14</td>
<td>2.17</td>
<td>28.68</td>
<td>1.65</td>
<td>25.80</td>
</tr>
</tbody>
</table>

Significance: **P value less than 0.05 significant, ***P value less than 0.001 high significance.
Cm, centimeter; N, number; SD, standard deviation.

Regarding Pearson correlation, the results showed that there was a strong positive, statistically significant correlation between stature, hand length, PW, and ulnar length for percutaneously measured parameters, while showed a moderate positive, statistically significant correlation between stature and PL. In radiologically measured parameters, all parameters showed a strong positive, statistically significant correlation with stature.

Concerning percutaneous measures for males, PW, ulnar length, and hand length showed a moderate positive correlation with stature, while PL showed a weak correlation. In radiologically measures, all parameters moderately correlated with male stature.

In females, hand length had strong correlation with stature either percutaneously or radiologically measured. Percutaneously and radiologically measured ulnar length revealed a moderate correlation. Palm width showed a weak correlation (Table 2).

Simple linear regression analysis and regression equations that were performed to predict stature showed that all percutaneous and radiological measures significantly predicted stature in the studied participants, where the P value is less than 0.001 (Table 3).

Simple linear regression equations depending on percutaneous and radiological ulnar length showed the least standard error of estimate (SEE) for all subjects, male, and female samples.

Multiple linear regression equation from percutaneous measures of the left upper limb parameters in the studied participants that could predict stature was \( S = 0.67067 + 3.654xHL - 3.313 \times PL + 2.875xPW + 1.314xUL \). Also, stature could be estimated from radiological measures by the regression equation \( S = 0.68934 + 1.540xHL - 1.146 \times PL + 2.337xPW + 2.245xUL \). The accuracy of the multiple regression equation of percutaneously and radiologically measured upper limb parameters was nearly the same (60% and 59%, respectively) (Table 4).

Table 2. Pearson correlation between stature with percutaneous and radiological measures of different parameters in the studied participants (N = 387).

<table>
<thead>
<tr>
<th>Measures (cm)</th>
<th>All participants (N = 387)</th>
<th>Male (N = 180)</th>
<th>Female (N = 207)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>P value</td>
<td>r</td>
</tr>
<tr>
<td>Percutaneous measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length</td>
<td>0.65</td>
<td>&lt;0.001***</td>
<td>0.31</td>
</tr>
<tr>
<td>Palm length</td>
<td>0.38</td>
<td>0.001**</td>
<td>0.25</td>
</tr>
<tr>
<td>Palm width</td>
<td>0.57</td>
<td>&lt;0.001***</td>
<td>0.47</td>
</tr>
<tr>
<td>Ulnar length</td>
<td>0.65</td>
<td>&lt;0.001***</td>
<td>0.36</td>
</tr>
<tr>
<td>Radiological measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length</td>
<td>0.64</td>
<td>&lt;0.001***</td>
<td>0.31</td>
</tr>
<tr>
<td>Palm length</td>
<td>0.55</td>
<td>&lt;0.001***</td>
<td>0.33</td>
</tr>
<tr>
<td>Palm width</td>
<td>0.55</td>
<td>&lt;0.001***</td>
<td>0.38</td>
</tr>
<tr>
<td>Ulnar length</td>
<td>0.73</td>
<td>&lt;0.001***</td>
<td>0.41</td>
</tr>
</tbody>
</table>

0.10–0.29 ‘weak.’; 0.30–0.49 ‘moderate.’; greater than or equal to 0.50 ‘strong.’ Significance: **P value less than 0.05 significant, ***P value < 0.001 high significance.
Cm, centimeter; N, number; r, Pearson correlation.
Table 3. Simple linear regression analysis and regression equations for stature estimation from percutaneous and radiological measures of different parameters in the studied participants (N = 387).

<table>
<thead>
<tr>
<th>Measures (cm)</th>
<th>All participants (N = 387)</th>
<th>Male (N = 180)</th>
<th>Female (N = 207)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P value</td>
<td>Regression equation</td>
<td>SEE</td>
</tr>
<tr>
<td>Percutaneous measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length (HL)</td>
<td>&lt;0.001***</td>
<td>S = 80.542 + 4.235xHL</td>
<td>0.249</td>
</tr>
<tr>
<td>Palm length (PL)</td>
<td>&lt;0.001***</td>
<td>S = 125.463 + 3.516xPL</td>
<td>0.437</td>
</tr>
<tr>
<td>Palm width (PW)</td>
<td>&lt;0.001***</td>
<td>S = 113.254 + 5.804xPW</td>
<td>0.427</td>
</tr>
<tr>
<td>Ulnar length (UL)</td>
<td>&lt;0.001***</td>
<td>S = 88.26 + 2.738xUL</td>
<td>0.163</td>
</tr>
<tr>
<td>Radiological measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length (HL)</td>
<td>&lt;0.001***</td>
<td>S = 86.706 + 4.101xHL</td>
<td>0.251</td>
</tr>
<tr>
<td>Palm length (PL)</td>
<td>&lt;0.001***</td>
<td>S = 110.012 + 5.487xPL</td>
<td>0.425</td>
</tr>
<tr>
<td>Palm width (PW)</td>
<td>&lt;0.001***</td>
<td>S = 115.841 + 6.450xPW</td>
<td>0.494</td>
</tr>
<tr>
<td>Ulnar length (UL)</td>
<td>&lt;0.001***</td>
<td>S = 82.702 + 3.078xUL</td>
<td>0.147</td>
</tr>
</tbody>
</table>

Cm, centimetre; N, number; S, stature; SEE, standard error of estimate.

Regression equation: Y = a + bx, Y is the dependent variable (stature); X is the explanatory independent variable (different measures); b is the slope of the regression line; a (constant) is the intercept (the value of y when x = 0). Significance: ***P value less than 0.001 significant, **P value less than 0.01 high significance.

Table 4. Multiple linear regression analysis and regression equations for stature estimation from percutaneous and radiological measures of the left upper limb parameters in the studied participants (N = 387).

<table>
<thead>
<tr>
<th>Measures (cm)</th>
<th>R²</th>
<th>Constant</th>
<th>B</th>
<th>SEE</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percutaneous measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length (HL)</td>
<td>0.597</td>
<td>67.067</td>
<td>3.654</td>
<td>0.366</td>
<td>9.978</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>Palm length (PL)</td>
<td>-3.313</td>
<td>0.484</td>
<td>6.851</td>
<td>0.001***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm width (PW)</td>
<td>2.875</td>
<td>0.450</td>
<td>6.394</td>
<td>0.001***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar length (UL)</td>
<td>1.314</td>
<td>0.181</td>
<td>7.242</td>
<td>0.001***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression equation S = 67.067 + 3.654xHL - 3.313xPL + 2.875xPW + 1.314xUL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiological measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand length (HL)</td>
<td>0.589</td>
<td>68.934</td>
<td>1.540</td>
<td>0.370</td>
<td>4.160</td>
<td>&lt;0.001***</td>
</tr>
<tr>
<td>Palm length (PL)</td>
<td>-1.146</td>
<td>0.581</td>
<td>1.974</td>
<td>0.049***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm width (PW)</td>
<td>2.337</td>
<td>0.533</td>
<td>4.382</td>
<td>&lt;0.001***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar length (UL)</td>
<td>2.245</td>
<td>0.196</td>
<td>11.426</td>
<td>&lt;0.001***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression equation S = 68.934 + 1.540xHL - 1.146xPL + 2.337xPW + 2.245xUL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B, regression coefficient; Cm, centimetre; N, number; R², R square; SEE, standard error of estimate.

Regression equation: Y = a + bx₁ + bx₂ + … + bxₜ, Y is the dependent variable (stature); X is the explanatory independent variable (different measures); b is the slope of the regression line; a (constant) is the intercept (the value of y when x = 0). Significance: **P value less than 0.05 significant, ***P value less than 0.001 high significance.

There was no significant difference between measured stature and stature estimated by multiple linear regression equations for percutaneous or radiological measures in the upper limb. The mean value of the measured stature of the studied participants was 166.24 ± 9.15 cm, and the percutaneous estimated stature and radiological estimated stature of the upper limb were 166.25 ± 7.07 cm and 166.24 ± 7.02 cm, respectively (Fig. 2).

4. Discussion

In many civil and legal contexts, the identity of the living and the deceased is crucial. Identification relies greatly on the skeleton [14]. Forensic anthropology in medical-legal settings examines anonymous skeletal remains; it primarily focuses on determining the individual’s age, sex, stature, and race [15].

This study was conducted on 387 Egyptian participants. The lower age limit was 21 years to be sure of skeletal maturity and the higher limit is 40 as the stature starts to decline after the age of 40 years. Similar studies were conducted on the same age group for Malaysian and Egyptian populations [16,17]. This study was conducted on volunteers with different occupations and most of them had middle socioeconomic standard.

The mean value of stature of the studied sample was 166.24 ± 9.15 cm nearer values were demonstrated by various Egyptian studies [17–19]. While higher values were recorded in Turkey and in Nigeria [8,20]. A shorter mean stature was observed in the Indian population [21]. Human populations differ genetically in terms of race [22].

The present study revealed that the mean stature of males was 173.87 ± 5.88 cm, while that of females...
was 159.60 ± 5.63 cm. Similar Egyptian studies found that males were significantly taller than females [2,11]. A cross-sectional study conducted in Pakistan stated that the mean height of male students was 171.70 ± 8.05 cm and was significantly greater than the height of female students (157.30 ± 8.22 cm) [23].

Regarding percutaneous and radiological measures of different upper limb parts, there were significantly higher mean values for all percutaneous and radiological measures in males than in females. One explanation for the differences between males and females is that boys grow physically for two longer years than girls do because girls mature sooner than boys. The difference in height between men and women can also be attributed to a combination of genetics, hormones, and evolutionary factors [15,24].

In studying the correlation between stature with all studied parameters, ulnar length had the highest value of the Pearson correlation coefficient, so it was the best parameter (radiologically measured) to predict stature \( (r = 0.73) \). Regarding percutaneous measures, ulnar length, and hand length showed the highest correlation \( (r = 0.65 \text{ for both}) \). Petrovecki et al. in their study on Croatian population found that all correlation coefficients between long bones (humerus, ulna, radius, femur, tibia, fibula) and stature were significant [25]. The result of the present study agrees with a study in Pakistan by Gul et al., who concluded that the length of the ulna is significantly superior to arm span for the prediction of height [23]. Similar results were observed on Bangladeshi population by Hossain et al. [26].

In radiologically measured parameters in the present work, the second-best predictor in upper limb was hand length \( (r = 0.64) \), followed by PL and PW \( (r = 0.55 \text{ for both}) \).

Krishan and Sharma also observed that a single dimension of hand or foot can estimate the stature of an unknown person with great accuracy in North Indians [27]. The same result regarding hand dimensions was observed in a study by Ibrahim et al., where there was a positive correlation between measured hand dimensions in both sexes of the North Saudi population and stature which is highly significant [15]. Also, Moustafa found that the stature of Egyptians was significantly and positively correlated with all hand measurements [18]. Hand length showed a higher correlation coefficient than that of the other hand dimensions. As concluded in a study among four populations by Foad et al. a significant relation between stature and both hand length and hand breadth is present in males [19]. Several studies in Egypt and India showed that hand length was more useful in estimating stature than hand breadth [11,27].

In the current study, hand length -either measured percutaneously or radiologically-showed strong positive correlation with female stature, while in males showed moderate correlation.

This was in coincidence with Salama, who found that hand and handprint length had a stronger correlation to stature in Egyptian females than in Egyptian males [6].

Concerning simple linear regression equations for stature estimation using different measured parameters, the present work revealed that all
percutaneous and radiological measures predicted stature in the studied sample with a highly significant P value. So, simple linear regression equation using a single parameter could significantly be used for stature estimation. Simple regression equations using ulnar length and hand length showed the best accuracy for predicting stature. The usefulness of regression equations is generally assessed based on their SEE. SEE is a good parameter to show the relation between real and estimated values [28].

The present study showed that the stature of overall volunteers could be estimated using percutaneous ulnar length by the simple regression equation (\( S = 88.26 + 2.738 \times \text{UL} \pm 0.163 \)). Male stature could be estimated by (\( S = 137.124 + 1.231 \times \text{UL} \pm 0.238 \)), and female stature by (\( S = 125.284 + 1.257 \times \text{UL} \pm 0.200 \)).

This is in line with the study conducted on (231) healthy adults who were medical students and officers in Menoufa Faculty of Medicine, the regression equations for stature estimation using percutaneous ulnar length were as follows: Stature in males = \( 107.849 + 2.427 \times \text{Lt ulna} \) (SEE = 4.879). Stature in females = \( 76.753 + 3.214 \times \text{Lt ulna} \) (SEE = 3.981). Stature in overall sample = \( 39.957 + 4.720 \times \text{Lt ulna} \) (SEE = 3.148) [29].

In the current research, using radiological ulnar length, stature in all participants could be predicted by (\( S = 82.702 + 3.078 \times \text{UL} \pm 0.147 \)), stature in males could be predicted by (\( S = 132.307 + 1.779 \times \text{UL} \pm 0.244 \)), and in females by (\( S = 114.869 + 1.734 \times \text{UL} \pm 0.215 \)). simple regression equations using either percutaneous or radiological ulnar length showed the least SEE.

In a study on Turkish population by Açökgoz and colleagues the regression equations for stature estimation by the radiological measurement of left maximum ulnar length (LMUL) were as follow: \( S = 94.912 + 2.906 \times \text{LMUL} \pm 2.67 \) for males. \( S = 41.081 + 4.943 \times \text{LMUL} \pm 3.21 \) for females. \( S = 62.087 + 4.108 \times \text{LMUL} \pm 3.23 \) for all participants. These results showed higher values of SEE than those present in the current research [12].

The population’s racial and ethnic diversity, diet, genetics, sex, landscape, age, and activity level all have an impact on stature. Consequently, a model that works for one population may not work for another [29].

The results of the present work revealed that the simple regression equation of percutaneous hand length which could predict stature was (\( S = 80.542 + 4.235 \times \text{HL} \)) for overall studied subjects, (\( S = 145.876 + 1.328 \times \text{HL} \)) for males, and (\( S = 94.521 + 3.337 \times \text{HL} \)) for female. The SEE was 0.249, 0.307, and 0.325 for the overall sample, male and female samples, respectively. According to the results of an Egyptian study by Salama. The regression equation of stature estimation in males using percutaneous hand length was (\( S = 105.110 + 3.641 \times \text{HL} \)). The equation related to females was (\( S = 72.709 + 4.943 \times \text{HL} \)). The SEE of these equations was 1.442 and 0.978 for males and females, respectively, which was higher than the SEE in the present study [6].

In the current study, the equation of radiological hand length was (\( S = 86.706 + 4.101 \times \text{HL} \pm 0.251 \)) for stature estimation in all subjects. In males, the equation that could estimate stature was (\( S = 146.928 + 1.331 \times \text{HL} \pm 0.310 \)) and in females was (\( S = 106.284 + 2.857 \times \text{HL} \pm 0.323 \)).

In a comparative study of stature prediction from hand measurements among four populations (Egyptians, Saudi Arabians, Indians, and Filipinos) by Foad et al. the regression equation for stature prediction in Egyptian males was \( 79.53 + 4.64 \times \text{HL} \pm 3.21 \), and in Egyptian females was \( 58.79 + 5.39 \times \text{HL} \pm 3.48 \) [19].

All the mentioned formulae of other researchers are specific to their studied populations therefore application of these by the other populations might cause incorrect results [29].

In the current research, multiple linear regression equations using different percutaneous and radiological measurements were significant in stature estimation in the studied sample with high accuracy (R2≈60% and 59%, respectively). Multiple regression equations are better than single linear regression equations for predicting stature [11]. On studying the percutaneous parameters in the left upper limb, the following regression equation could be used to estimate stature in the studied volunteers (\( S = 67.067 + 3.654 \times \text{HL} - 3.313 \times \text{PL} + 2.875 \times \text{PW} + 3.144 \times \text{UL} \)). Regarding the radiological parameters in the left upper limb, the following regression equation could be used to estimate stature in the studied volunteers (\( S = 68.934 + 1.540 \times \text{HL} - 1.146 \times \text{PL} + 2.337 \times \text{PW} + 2.245 \times \text{UL} \)).

In agreement with these results, Ghaleb and colleagues illustrated in their study on the Egyptian population that the multivariate linear regression equation of stature estimation using percutaneous measurements is as follows: \( S = 100.220 + 9.578 \times (\text{gender}) + 2.422 \times \text{(hand length)} - 0.098 \times (\text{age}) + 0.509 \times (\text{foot length}) + 1.123 \times (\text{hand width}) - 0.539 \times (\text{foot width}) \). Sex is coded as 1 for males and 0 for females while all other variables are in cm [2].

Another Egyptian study by Gheat et al. concluded that height could be predicted from different right-hand dimensions as follows: \( S (\text{cm}) = 95.88 + (0.30 \times \text{Right hand length}) + (0.29 \times \text{Right index length}) - (5.74 \times \text{sex}) - (2.03 \times \text{Race}) \) and concluded that the model was statistically significant, and the
The present results concluded that there was no significant difference between measured stature and stature estimated by multiple linear regression equations for percutaneous or radiological measures in all studied participants. Similar result was observed by Salama. who found that the measured stature in males was 176.17 ± 5.8 and the estimated stature was 176 ± 6.07 by using the multiple regression equation: 
\[
S = 103.285 + (0.493 \times \text{hand breadth (HB)}) + (1.385 \times \text{HL}) + (2.095 \times \text{PL}) + (1.841 \times \text{middle finger length (MFL)}) + (4.488 \times \text{Thumb Finger length (TFL)}) - (3.962 \times \text{Index finger length (IFL)}) - (1.937 \times \text{Ring Finger length (RFL)}) + (2.306 \times \text{little finger length (LFL)})
\]
Also, he stated that the measured stature in females was 161.84 ± 5.55 and the estimated stature was 159.9 ± 5.95 by using the multiple regression equation:
\[
S = 80.306 - (3.621 \times \text{HB}) + (3.055 \times \text{HL}) + (1.372 \times \text{PL}) + (2.374 \times \text{MFL}) + (2.894 \times \text{TFL}) - (0.516 \times \text{IFL}) - (0.169 \times \text{RFL}) + (1.535 \times \text{LFL})
\] [6].

4.1. Conclusion and recommendation

Measurements of the upper limbs in adult Egyptians can be used to reasonably predict stature. By studying simple regression analysis and Pearson correlation ulnar length was the best parameter to predict stature. Hand length showed a strong positive correlation with female stature.

In the current research, percutaneous and radiological measures did not differ significantly for the prediction of measured stature. So, the percutaneous method for stature estimation could be used for saving time and cost.

Since upper limb measurements are a quick, easy, and inexpensive method of identification that have shown to be highly effective and timesaving, more research is needed to validate the derived equations in a larger sample of Egyptians and to test the equations validity in other age groups.

Since all of the study’s participants were volunteers from the governorate of Menoufia, we also advise expanding the research to include governorates and other regions of Egypt.

Ethics information

The study was conducted according to standard ethics drawn by Menoufia University Ethical Committee for Human Research and after obtaining written informed consent from every one of study subjects, after explanation of the method of examination and, the purpose of the study. The present study was approved by the ethical committee in the Faculty of Medicine, Menoufia University with a number (19519FORE20).

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Conflict of interest

There are no conflicts of interest.

References


