# STATURE PREDICTION FROM HAND MEASUREMENTS AMONG FOUR POPULATIONS: A NOVEL COMPARATIVE STUDY

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## ABSTRACT

**Background**: The dilemma for stature estimation from the skeleton is of great medico-legal importance. Stature is one of the fundamental features that may assist in the recognition of an individual in situations of mass disasters or in cases of absent main body parts. **Aim:** To predict stature from hand measurements, (length and breadth) in four different population groups (Egyptians, Saudi Arabians, Indians, and Filipinos) and to establish formulae for stature estimation for each group. **Methods:** Eight hundred right- hand predominant subjects (400 males and 400 females) belonging to four different population groups (100 males and 100 females for each group) aged 17-58 years have participated in the current work. Each one has been investigated for measurements of stature, hand length, and the hand breadth. Obtained data were statistically analysed using the SPSS Statistics for Windows version 25. **Results:** Linear regression equations reveal a fairly accepted rate of accuracy with a standard error of estimate (1.92 - 4.77) in respect to hand length of males and (3.31 - 4.24) for females. For hand breadth, the standard error of estimate was (2.43 - 4.73) for males and (3.01 - 4.51) for females. **Conclusion:** this study can be useful to predict stature from a dismembered hand when it is subjected for medico-legal examination that may highlight the expected medico-legal implications on the practical background.

**Keywords:** Hand measurements; anthropometry; stature; four populations.

## INTRODUCTION

Establishing the identity of an unknown person is a very essential part of forensic investigation process. Forensic anthropologists depend on certain skeletal features to estimate race, sex, age and stature to build up a biological profile of an unknown person **(Wilson et al., 2010)**. Stature estimation is one of the crucial criteria in this aspect; especially in decomposed and mutilated body remains. In many cases of mass disasters, fatal assaults and acts of

terrorism, it is very difficult to identify the stature of a victim by using the anatomical method due to lack of a complete skeleton from a scene of a crime **(Karaman et al., 2008).**

Estimation of stature is based on the principle that the height of an individual has a more or less constant relationship with different body parts. Thus, forensic anthropologists use the mathematical methods for stature reconstruction. These methods calculate the height of a person by using the regression coefficients obtained from the measurements of different bones of the body **(Richard et al., 2017)**.

As regression formulae for stature estimation are specific for each population, formulae applied for one population do not give reliable results for other population **(Krogman & Işçan, 1986; Duyar & Pelin, 2010)**. These variations may be referred to the influence of various factors such as nutrition, climate, and lifestyle **(Malina, 1994; Liu et al., 2015)**.

Several studies in the literature have been conducted to establish a relationship between statures and different bones of the body. These studies include metatarsals measurements **(Bidmos, 2008)**, femur length **(Feldesman,1992; Feldesman &Fountain , 1996)**, tibia and fibula length **(Pelin& Duyar , 2003; Duyar& Pelin, 2003; Wang et al., 2012)**, clavicle dimensions **(Rani et al., 2011)**, head length **(Singh ,2013; Kpela et al., 2016 )**, metacarpal bones measurements **(Meadows & Jantz,1992; Amitava et al., 2016)**, length of arm bones **(Shahar&Pooy, 2003;Datta et al., 2012)**, foot dimensions **(Sen & Ghosh , 2008; Flave et al., 2013;Gwania et al., 2017)**, and sternum length **(Saraf et al., 2018)**.

The hand bone dimensions have been reported as good anthropometric parameters for prediction of both sex **(Sangeeta &Kapoor , 2016; Ibrahim et al., 2016 )** , and stature **(Jee&Yun, 2015)**.These dimensions have proven to exhibit great sexual dimorphism and they are population-specific. Parameters that have been used for these studies include hand length, palm length, hand breadth, hand, and palm indices as well as fingers measurements **(Ishak et al., 2012; Paulis, 2015; Oladipo et al., 2015; Zulkifly et al., 2018)**.

## AIM OF WORK

The aims of the present study are:

- To detect the possibility of stature prediction using different measurements of hands belonging to random, living four populations' samples and
- To investigate differences between them
- As well as establishment of formulae for stature estimation for each group.

## MATERIALS & METHODS

The current cross sectional work was exercised on 800 subjects (400 males and 400 females) belonging to four different population groups (Egyptians, Saudi Arabians, Indians and Filipinos) who live in Al-Ahsa, Governorate, the Eastern Province, Saudi Arabia. Each population group includes 200 subjects (100 male and 100 female). The ages of the included persons range between 17-58 years. Measurements were taken from right-handed persons to ensure similarity and avoid the impact of hand domination on the taken measurements. The ethical

assent was gained from our institute ethical committee; also an informed consent of each person included in this study was carried out. While the hand is extended, with the palm in the supine position, two morphometric parameters **(Fig.1)** were recorded by the same investigator for each hand to the nearest 0.1 cm using a sliding calliper as previously described in the literature **(Means & Walters, 1982)**. Length of the hand (HL): the distance between the midpoint of the distal crease of the wrist joint and tip of the middle finger. Breadth of the hand (HB): The distance between the radial side of the 2nd metacarpo-phalangeal joint and the ulnar side of the 5th metacarpo-phalangeal joint.

Height was measured in centimetres between the vertex and floor **(Fig.2)**, after asking the individual to stand erect and barefooted in anatomical position using a standard standing height-measuring instrument **(Means &Walters, 1982)**.

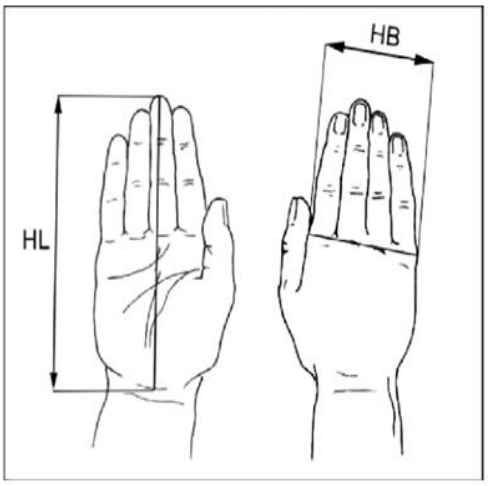


**Figure (1):** Human hand illustrating the landmarks used in the study; hand length (HL), hand breadth (HB) **(Means & Walters, 1982).**

- Statistical analysis

Data analysis was achieved using IBM SPSS Statistics for Windows version 25 to calculate means ± standard deviation, median and range for Quantitative data and number and percentage for Qualitative data. Shapiro-Wilk test was used to test the acquired data for normality. For data that were not normally distributed, Wilcoxon Signed Ranks, Mann Whitney, Kruskal–Wallis and Spearman's correlation tests were used. Linear regression analysis was employed for formulation of regression equations for estimation of stature for each group and both sex. P value of less than 0.05 was adopted as significant **(Asghar & Saleh, 2012)**.

## RESULTS

**Table (1)** shows a comparison between the four population groups regarding stature and hand measurement irrespective of sex. The mean height of the Indian group is the longest when compared with the other three groups. They also have the longest mean hand length. Saudi Arabian group has the longest mean of hand breadth.

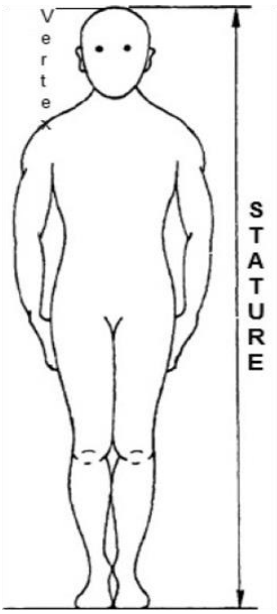


**Figure (2):** Stature illustrates the vertical distance from vertex to floor **(Means & Walters, 1982).**

In each group there is a significant relation between stature and both hand length and hand breadth (P value <0.001).

There is also a significant difference in the hand breadth (P<0.05) between the Egyptian group when compared to the Saudi Arabian group. There is no significant difference between the Egyptian and Saudi Arabian groups regarding their stature and hand length. No significant difference can be observed between the Egyptian group and the Indian group in relation to their stature, hand length and hand breadth. Conversely, a significant difference is present between the Egyptian group and the Filipinos one (P<0.05).

The mean values of stature and hand measurements for the male participants of the four populations are described in **table (2)**. Egyptian males have the longest mean height and the longest mean hand length when compared with the other groups. Males of Saudi Arabia group have the longest mean of hand breadth. A significant relation between stature and both hand length and hand breadth (P-value <0.001) is present in each male group. There is also a significant difference in the height and hand breadth (P<0.05) between the Egyptian male group when compared to the Saudi Arabian male group.

There is no significant difference between the Egyptian and Saudi Arabian male groups regarding their hand length. No significant difference can be observed between the Egyptian male group and the Indian male group in relation to their stature, hand length and hand breadth. A statistically significant difference is observed between the Egyptian male group and the Filipinos male group regarding height, hand length and hand breadth (P<0.05).

**Table (1):** Comparison of stature (cm) and hand measurement (cm) between the four groups. (N=800)

| Variables | Egyptians (N=200) | Saudi Arabians (N=200) | Indians (N=200) | Filipinos (N=200) |
|---|---|---|---|---|
| **Height (Mean± SEM)** | 169.35 ± 0.55 | 168.15± 0.42 | 169.48 ± 0.47 | 165.22 ± 0.51 [C] |
| **HL (Mean± SEM)** | 20.02 ± 0.07 | 19.89 ± 0.09 | 20.12 ± 0.09 | 19.46 ± 0.07 [C] |
| **r** | 0.822 | 0.763 | 0.63 | 0.744 |
| **P-value** | < 0.001* | < 0.001* | < 0.001* | < 0.001* |
| **HB (Mean± SEM)** | 10.77 ± 0.04 | 11.01 ± 0.03 [b] | 10.82 ± 0.04 | 10.67 ± 0.03 [C] |
| **r** | 0.664 | 0.591 | 0.546 | 0.333 |
| **P-value** | < 0.001* | < 0.001* | < 0.001* | < 0.001* |

**r : spearman correlation coefficient ; SEM: Standard Error of Mean ; HL:hand length ; HB:hand breadth**

***statistically significant**

**[b]P<0.05 for Egyptian vs Saudi Arabian group**

**[C]P<0.05 for Egyptian vs Filipinos group**

**Table (2):** Comparison of stature (cm) and hand measurement (cm) difference between male participants in the four studied groups regarding height and hand anthropometry**.** (N=400)

| Variables | Egyptians (N=100) | Saudi Arabians (N=100) | Indians (N=100) | Filipinos (N=100) |
|---|---|---|---|---|
| **Height** | | | | |
| **Mean± SEM** | 175.06 ± 0.56 | 172.44 ± 0.42 [b] | 174.11 ± 0.58 | 170.99 ± 0.25 [C] |
| **Hand length** | | | | |
| **Mean± SEM** | 20.6 ± 0.09 | 20.54 ± 0.05 | 20.59 ± 0.08 | 20.03 ± 0.08 [C] |
| **r** | 0.824 | 0.654 | 0.545 | 0.435 |
| **P-value** | < 0.001* | < 0.001* | < 0.001* | < 0.001* |
| **Hand breadth** | | | | |
| **Mean± SEM** | 10.99 ± 0.05 | 11.01 ± 0.03 [b] | 10.96 ± 0.05 | 10.77 ± 0.03 [C] |
| **r** | 0.832 | 0.312 | 0.556 | 0.567 |
| **P-value** | < 0.001* | < 0.002* | < 0.001* | < 0.001* |

**r = spearman correlation coefficient; SEM: Standard Error of Mean; *statistically significant, [b]P<0.05 for Egyptian vs Saudi Arabian males ; [C]P<0.05 for Egyptian vs Filipinos males.**

Similarly, the mean values of stature and hand measurements for the female participants of the four populations are described in **table (3)**. Indian females have a longer mean height and hand length when compared with the other studied groups. Females of Saudi Arabian group have the longest mean of hand breadth. Again, a significant relation between stature and both hand length and hand breadth is clearly seen in each female group (P value <0.001). There is a significant difference in the hand breadth (P<0.05) between the Egyptians female group when compared to the Saudi Arabians female group. There is no significant difference between the Egyptians and Saudi Arabians female groups regarding their height and hand length. No significant difference can be observed between the Egyptians female group, and the Indians female group in relation to their stature, hand length and hand breadth. A statistically significant difference is observed between the Egyptians females group, and the Filipinos females group regarding height and hand length (P < 0.05). On the contrary, there is no significant difference in respect of hand breadth.

Linear regression equations derived for stature estimation from hand length and hand breadth for both sex are shown in **table (4)**. These equations were used to calculate the estimated stature from hand length and hand breadth. A comparison between actual stature and estimated stature using hand length and hand breadth for the four population groups is shown in **table (5)** and **table (6)** respectively. It is clearly observed that no significant difference between the actual and estimated statures in each case (P > 0.05). So, these formulae can be used to estimate stature for the four population groups.

The results of this study revealed that, upon comparing the stature and hand dimensions of the four population groups regardless of sex, Indians have the longest mean height and mean hand

length while the Saudi Arabians have the longest mean of hand breadth. Within each group, there is a significant relation between stature and hand measurements. These findings are in agreement with preceding studies that showed a positive significant relation between hand length and stature **(Laila et al., 2009; Agrawal et al., 2013)**.

**Table (3):** Comparison of stature (cm) and hand measurement (cm) difference between female participants in the four studied groups regarding height and hand anthropometry (N=400)

| Variables | Egyptians (N=100) | Saudi Arabians (N=100) | Indians (N=100) | Filipinos (N=100) |
|---|---|---|---|---|
| **Height** | | | | |
| **Mean± SEM** | 163.63 ± 0.49 | 163.85 ± 0.39 | 164.84 ± 0.35 | 159.45 ± 0.55 [C] |
| **Hand length** | | | | |
| **Mean± SEM** | 19.44 ± 0.06 | 19.25 ± 0.15 | 19.63 ± 0.14 | 18.89 ± 0.08 [C] |
| **r** | 0.676 | 0.639 | 0.46 | 0.68 |
| **P-value** | < 0.001* | < 0.001* | < 0.001* | < 0.001* |
| **Hand breadth** | | | | |
| **Mean± SEM** | 10.54 ± 0.06 | 10.86 ± 0.04 [b] | 10.68 ± 0.05 | 10.57 ± 0.05 |
| **r** | 0.52 | 0.609 | 0.432 | 0.687 |
| **P-value** | < 0.001* | < 0.001* | < 0.001* | < 0.001* |

**r = spearman correlation coefficient ; SEM: Standard Error of Mean ; *statistically significant [b]P<0.05 for Egyptian vs Saudi Arabian females ; [C]P<0.05 for Egyptian vs Filipina females**

**Table (4):** Linear regression equations for stature estimation from hand length and hand breadth for each sex. Stature = (Constant x independent variable) + regression coefficient

| Parameter | Regression equation ± SEE | Regression equation ± SEE |
|---|---|---|
| **Egyptian group (N=200)** | Male : 79.53 + 4.64 (HL) ± 3.21<br>Female: 58.79 + 5.39 (HL) ± 3.48 | Male :83.09 + 8.36 (HB) ± 3.52<br>Female: 130.78 + 3.12 (HB) ± 4.51 |
| **Saudi Arabian group (N=200)** | Male : 73.44 + 4.82 (HL) ± 3.32<br>Female : 143.95 + 1.03 (HL) ± 3.54 | Male: 129.65 +3.83 (HB) ± 3.99<br>Female: 101.003+5.79 (HB) ± 3.01 |
| **Indian group (N=200)** | Male : 95.36 + 3.83 (HL) ± 4.77<br>Female : 148.19+ 0.85 (HL) ± 3.31 | Male: 104.86 + 6.32 (HB) ± 4.73<br>Female: 141.69 + 2.17 (HB) ± 3.36 |
| **Filipino group (N=200)** | Male : 127.9 + 2.15 (HL) ± 1.92<br>Female: 75.61 + 4.44 (HL) ± 4.24 | Male: 145.87 +2.33 (HB) ± 2.43<br>Female: 81.55 +7.37 (HB) ± 4.21 |

**HL: Hand length ; HB: Hand breadth ; SEE : Standard Error of Estimate**

**Table (5):** Comparison of stature (cm), and estimated stature by hand length (N =800)

| Group | Gender | Actual height Mean± S.E. | Estimated height by HL Mean± S.E. | P-value |
|---|---|---|---|---|
| **Egyptians** | Males | 175.06 ± 0.56 | 175.13 ± 0.46 | 0.071 |
| | Females | 163.63 ± 0.49 | 163.57 ± 0.34 | 0.874 |
| **Saudi Arabians** | Males | 172.44 ± 0.42 | 172.42 ± 0.25 | 0.657 |
| | Females | 163.85 ± 0.39 | 163.78 ± 0.16 | 0.604 |
| **Indians** | Males | 174.11 ± 0.58 | 174.2 ± 0.33 | 0.718 |
| | Females | 164.84 ± 0.35 | 164.87 ± 0 .12 | 0.547 |
| **Filipinos** | Males | 170.99 ± 0.25 | 170.96 ± 0.17 | 0.693 |
| | Females | 159.45 ± 0.55 | 159.49 ± 0.36 | 0.705 |

**P- value was calculated by Wilcoxon Signed Ranks Test *Statistically significant**

**Table (6):** Comparison of stature (cm), and estimated stature by hand breadth (N=800)

| Group | Gender | Actual height Mean± S.E | Estimated height by HB Mean± S.E. | P-value |
|---|---|---|---|---|
| Egyptians | Males | 175.06 ± 0.56 | 175.04 ± 0.43 | 0.458 |
| | Females | 163.63 ± 0.49 | 163.68 ± 0.18 | 0.778 |
| Saudi Arabians | Males | 172.44 ± 0.42 | 172.39 ± 0.12 | 0.749 |
| | Females | 163.85 ± 0.39 | 163.86 ± 0.24 | 0.951 |
| Indians | Males | 174.11 ± 0.58 | 174.11 ± 0.33 | 0.989 |
| | Females | 164.84 ± 0.35 | 164.87 ± 0 .1 | 0.458 |
| Filipinos | Males | 170.99 ± 0.25 | 170.96 ± 0.08 | 0.123 |
| | Females | 159.45 ± 0.55 | 159.48 ± 0.36 | 0.962 |

**P- value was calculated by Wilcoxon Signed Ranks Test *Statistically significant**

## DISCUSSION

Stature is usually determined by employing the anatomical or the mathematical methods **(Hall, 2017)**. In the anatomical method, heights of the skull, vertebral column, and length of lower limb are added together. In the mathematical method, stature is determined using regression equations that reflect a linear relationship between stature and various body bones and body parts.

As a fact, the anatomical method is more accurate than the mathematical method albeit it needs all the component of the skeleton are available. In several forensic scenarios, the mathematical method is the only applicable when the body is mutilated or incomplete skeletal remains are available. Various body bones have been used for stature estimation **(Feldesman, 1992; Bidmos, 2008; Jee&Yun, 2015)** using mathematical regression equations, which are specific to the population of interest.

In other studies conducted by **(Numan et al., 2013; Supare et al., 2015; Amitava et al., 2016)**, it was concluded that hand length and palm

length revealed an utmost correlation with stature than hand breadth. A recent study was carried out on a sample of Northern Saudi Arabian population that reported similar results **(Ibrahim et al., 2018)**. In this Saudi recent study, it was concluded that there is no significant variations among the Egyptians and the Indians in relation to stature, hand length, and hand breadth. The reverse is true on comparing the Egyptians with the Filipinos where there is a statistically significant difference as regard of the previous three parameters

As concluded in the current results, a significant relation between stature and both hand length and hand breadth is present in each male group. In the four groups, the male participants showed higher mean values of stature, hand length and hand breadth than the female participants. This can be attributed to the male's genetic constitution. Moreover, the age of puberty in males is two years later than females, which give them a long time for growth **(Ibrahim et al., 2018)**.

As illustrated in our results, Egyptian males have the longest mean height and the longest mean hand length when compared with the other three groups. Saudi Arabian male group has the longest mean of hand breadth and this also indicates that regression formulae are sex-specific **(Supare, et al., 2015)**.

In the present study, a statistically significant difference is observed between the Egyptian male group and the Filipino male group regarding the three studied parameters but no significant difference can be reported between the Egyptian male group and the Indian male group. There is also a significant difference of the height and hand breadth ($P<0.05$) between the Egyptian male group and the Saudi Arabian male group. The current results are in accordance with those obtained by **Numan et al., 2013, Supare, et al., 2015 and Ibrahim et al., 2018** whose studies were conducted on Indian male and female medical students, three major ethnic groups in Nigeria and on North Saudi Arabian population respectively.

As shown in this work, a statistically significant difference is observed between the Egyptian female group and the Filipino female group regarding height and hand length. Nevertheless, no significant difference can be observed between the Egyptian female group and the Indian female group in relation to their stature, hand length, and hand breadth. These results regarding sex differences in measurements are in accordance with the results announced by **(Laila et al., 2009)** on Bengali population and **(Numan et al., 2013)** on Nigerian population.

Linear regression equations were postulated in the results of the current research to estimate stature using hand length and hand breadth for each sex in the four population groups. Comparing the estimated statures with the actual statures of each sex in the four groups had revealed no statistically significant difference between them. So, the postulated regression formulae derived for each sex in the four population groups could be employed effectively for stature estimation.

Several studies in the literature have used the hand dimensions for estimation of stature **(Ishak et al., 2012; Jee&Yun, 2015; Paulis, 2015;Oladipo et al., 2015; Zulkifly et al., 2018)** . These studies were based on

the investigation of a single population group while the current study was carried out on persons belonging to four different population groups (Egyptians, Saudi Arabians, Indians, and Filipinos). All measurements were taken from the different populations' samples once using the same tool and by the same investigator aiming to reduce both inter and intra-observers variations. These two criteria could be considered as the main strength of this work.

To the best of our knowledge, the current research is a pioneering one among the anthropological comparative works designed to investigate more than one population in the same locality by a single observer. On the other hand, it does possess some limitations; the premier is that it was carried out on relatively limited numbers of cases. Moreover, like any anthropological study, the popularization of the obtained regression equations cannot be absolutely settled.

## CONCLUSION & RECOMMENDATIONS

The existing method of stature prediction relying on finding the relations between body heights with hand measurements is considerably efficient and offers statistically significant impacts in either sex. For most accurate and more specific regression equations, it is recommended to conduct such comparative studies on a wider scale employing a larger number of subjects.

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**الملخص العربى**

# التنبؤ بالقامة من قياسات الكف لأربعة أجناس مختلفة: دراسة مقارنة جديدة

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تعد الحاجة لتحديد الطول من الهيكل العظمى أمر ذو أهمية طبية شرعية كبيرة والذي قدُيساعد في التعرف على الأشخاص خصوصا في حالات الكوارث الطبيعية أو في حالة عدم توافر أجزاء الجسم الرئيسية. وتهدف هذه الدراسة الى تقدير الطول باستخدام طول الكف وعرضه وذلك في أربعةجنسيات مختلفة (المصريون- السعوديون- الهنود – الفلبينيون) ، كما تهدف إلى وضع صيغ الإنحدار المناسبة لكل مجموعة وكذلك دراسة أوجه الاختلاف والتشابة بين المجموعات الأربعة. وقدُأجريت هذه الدراسة على ثمانمائة شخصا (400 من الذكور و 400 من الإناث) بمعدل 100 من الذكور و 100 من الإناث لكل مجموعة من المجموعات الأربعة و الذين تتراوح أعمارهم ما بين 17و 58 سنة. وقدُأخذت قياسات لطول القامة وكذلك طول الكف وعرضه لكل شخص من المشاركين في الدراسة بعد الحصول على موافقته المستنيرة ، وبإجراء التحليل الإحصائي للقياسات تكشفت نتائج معادلات الانحدار الخطي عن معدل دقة مقبول مع خطأ قياسي معياري في التقدير يقدر بنحو (1.92 - 4.77) فيما يتعلق بطول الكف للذكور وبنحو (3.31 -4.24) للإناث. وبالنسبة إلى عرض الكف، كان الخطأ القياسي المعياري للتقدير يقدر بنحو(2.43 -4.73) بالنسبة للذكور و بنحو (3.01 -4.51) بالنسبة للإناث. وخلصت الدراسة إلى انه يمكن التنبؤبطول القامة من قياسات الكف باستخدام المعادلات المستنبطة وذلك عند القيام بفحص أكف مبتورة من الأجساد مما يوضح الأهمية العملية والتطبيقية للدراسة الحالية.