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ORIGINAL ARTICLE

# Stature Estimation in Living Humans Using Hand Measurements Among Different Ethnicities Residing in Karachi, Pakistan

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## ABSTRACT

**Background:** Stature estimation is an essential component of establishing a biological profile of an individual. especially in cases where the bodies recovered are mutilated or in the form of fragmentary remains. As stature is population specific, we aim to determine association between hand measurements and stature, and develop predictive formulas for estimating stature among different ethnic groups in Karachi.

**Methods:** A Descriptive Cross-sectional study conducted at OPD of University Hospital from April 2024 till March 2025. This study included 271 individuals from 5 major ethnicities residing in Karachi by convenient sampling. Both males and females between 18-60 years of age were included in the study. A proforma was used to record data. Stature was measured using a stadiometre and hand length and breadth using a Vernier calliper. Correlation analysis was conducted using Pearson's coefficient. A simple linear regression analysis was performed to generate the model that can be used for stature prediction.

**Results:** Significant difference was revealed between males and females with p value of <0.001 in all measured dimensions with higher mean values in males than females. Significant difference was observed between different ethnicities on the basis of their Left Hand Length (p value = .031) Left Hand Breath (p value = .050) Right Hand Breath (p value = .025). All variables showed a moderate to strong positive correlation with stature with highest correlation with hand breadth in Balochis (r = 0.890) whereas weakest correlation is seen with hand length in Punjabis (r = 0.568).

**Conclusion:** This study concluded that hand measurements can serve as a reliable tool for estimating stature among living adult population of different ethnicities residing in Karachi.

**Keywords:** Forensic Anthropology, Ethnic Variation, Hand Measurements, Hand Anthropometry, Stature Estimation

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## Introduction

Forensic anthropology is the application of biological anthropology to medico-legal investigations, primarily involving the identification and analysis of human skeletal remains. Identification of a body is more complicated and challenging in situations when bodies have been dismembered or deformed as a result of mass disasters, such as plane crashes, earth quakes and terrorist activities like bomb blasts (1).

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Sex, ancestry, teeth and stature are significant components for building a comprehensive biological profile for unidentified human remains (2,3).

Stature estimation is an essential component of establishing a biological profile of an individual. It plays a vital role in identification, especially in cases where the bodies recovered are mutilated or in the form of fragmentary remains (3,4). Studies have demonstrated that measurements of the skull, spine, sternum, and long bones can all be used to estimate stature (5,6,7,8,9). Many studies conducted in different parts of the world have used hand dimensions for estimation of stature in various populations. Regression analyses are typically employed in these types of studies (3,4,5,10,11,12,13). In Pakistan, one of such studies conducted in Punjab predicted stature with hand dimensions (14). Syed S *et al* have estimated the stature of male population of Khyber Pakhtunkhwa based on hand dimensions (15).

Pakistan is a developing country where the field of Forensic Medicine is still in its formative stages. In addition, Pakistan has had a lot of terrorist attacks in recent decades including bombings and other large catastrophes which have left a large number of victims mutilated. Karachi is a metropolitan city with a dense population that hosts diverse ethnic groups, including Urdu speaking, Sindhis, Punjabis, Balochis, Pashtuns, and others. To the extent of our knowledge, so far, no study has been done in Karachi to determine stature from hand measurements in different ethnicities. Different populations have different anthropometric measurements owning to genetic makeup, nutritional and other environmental factors, (16) so body measurements derived from one ethnic population cannot be utilized for other ethnic population (12,13). Therefore, applying generalized formulas for stature estimation may result in inaccuracies for multi-ethnic populations like Karachi. This study will be useful for forensic investigators by developing a reliable method to predict the stature of unidentified bodies that are mutilated or torn apart, providing on-site stature estimation, in cases of mass disasters.

The objective of this study is to determine association between hand measurements and stature, and provide ethnicity-specific regression model for estimating stature based on the hand measurements for the different ethnic groups residing in Karachi. Developing an ethnicity-specific model for stature estimation, improves the reliability of stature estimation from segmented human body remains.

## Methods

This is a descriptive, cross-sectional study based on the samples of 271 individuals of both genders between 18-60 years of age. The sample size of at least 271 patients was calculated using PASS version 2021 (NCSS,Kaysville, Utah, USA) software, based on the test for Pearson's correlation with 95% confidence of interval and 80% power of test, ($H_0 : r=0.60$ vs $H_1 : r=0.70$) correlation coefficient between right hand length and stature (15).This study was conducted in OPD of University Hospital from April 2024 till March 2025 after taking ethical approval from University Ethical review committee (reference no: 8480224 MFFOR)

All individuals attending the OPD of University Hospital who met the inclusion criteria were invited to participate in the study. Both male and female between 18-60 years of age were included in the study. The subjects were recruited by convenient sampling and data was collected from individuals of five major ethnicities residing in Karachi. (Sindhi, Punjabi, Baluchi, Pathans

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and Urdu speaking). Individuals with scoliosis, musculoskeletal deformity of hands, spine and lower limbs, physical growth disorder like gigantism, partial or complete limb amputations were excluded from the study. Written informed consent was obtained at the time of data collection. The physical examination was conducted in privacy at a separate designated place in the same OPD. Instruments were calibrated before use to ensure precision and consistency.

This study is based on five anthropometric measurements. Stature was measured using a stadiometre, as the straight vertical distance from the floor to the head's vertex, with the subject standing barefoot in an erect posture with straight head and eyes looking forward. For hand measurements a Vernier calliper was utilized to measure hand length and breadth. For hand length measurements participants were instructed to place their hands supine on a firm, flat surface with fingers extended and adducted. Subsequently, participants were asked placed their hands prone on the same surface, with the thumb abducted and the remaining fingers adducted and extended, to measure hand breadth. (Fig. 1) All measurements were recorded in centimetres between 11:00 and 13:00 hours to minimize diurnal variation (5). To minimize measurement error, all measurements were performed by the same trained observer.

The IBM SPSS (Version 24.0) was employed to statistically analyse data. Normality of the data was checked using normality plots. Descriptive statistics were calculated for all the study variables. Quantitative variables such as age, stature and hand measurements were presented as mean and standard deviation. For qualitative variables such as sex and ethnicity percentages were deduced. One-way ANOVA was employed to compare measurements in different ethnicities. Correlation analysis was conducted using Pearson's coefficient. A simple linear regression analysis was performed to generate the formulae that can be used for stature prediction. P value of less than or equal to 0.05 was considered as significant.

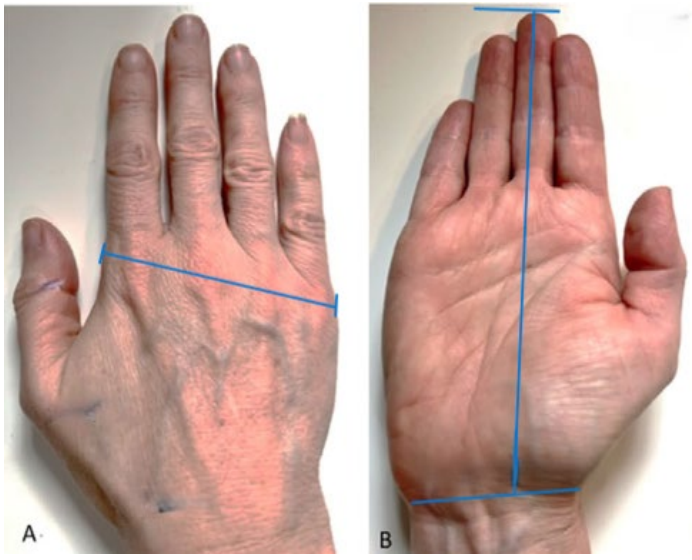


**Fig: 1 Measurement of hand breadth and hand length**

**A. Hand Breadth (HB): Hand breadth was measured as the linear distance between the most lateral point of the second metacarpal head and the most medial point of the fifth metacarpal head.**

**B. Hand Length (HL): Hand length was measured the straight distance from the midpoint of the distal wrist crease to the apex of the middle finger.**

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## Results

Table 1 summarize the descriptive statistics for stature and hand dimensions (cm) and t test results among males and females. Mean value of all measured parameters was higher for males than that for females. Independent t-test was applied to assess differences between males and females are statistically significant. Significant difference was revealed between males and females with p value of < 0.001 in all measured dimensions. In hand dimensions, right hand breadth(RHB) displayed the largest difference in T value (t = 16.59) whereas left hand length(LHL) showed the smallest difference in T value (t = 9.84).

**Table 1 Comparison of stature and hand dimensions (cm) between male and female participants**

| Measurements | Male (n=137) | | Female (n=134) | | t- test | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | t | p |
| S | 175.81 | 6.04 | 159.77 | 5.75 | 22.37 | <0.001 |
| RHL | 18.65 | .93 | 17.47 | 1.01 | 9.90 | <0.001 |
| LHL | 18.66 | .86 | 17.52 | 1.02 | 9.84 | <0.001 |
| RHB | 8.65 | .49 | 7.51 | .62 | 16.59 | <0.001 |
| LHB | 8.71 | .50 | 7.60 | .60 | 16.41 | <0.001 |

S(stature), RHL (Right hand length), LHL (Left hand length), RHB (Right hand breadth), LHB(Left hand breadth)

On one-way ANOVA significant difference was observed between different ethnicities on the basis of their LHL (p value = .031) LHB (p value = .050 ) RHB (p value = .025). As these differences were statistically significant so a post hoc analysis was performed. Due to heterogeneous groups Games Howel test was applied for post hoc analysis which revealed statistically significant difference among Urdu speaking, Pathans and Sindhis (Table 2)

**Table 2 Significant Post hoc comparisons between ethnic groups by Games Howell test**

| Dependent Variable | Group (I) | Group (J) | Mean Difference (I–J) | P value |
|---|---|---|---|---|
| LHL | Sindhi (n=49) | Pathan (n=48) | -0.66029 | 0.029 |
| LHL | Pathan (n=48) | Urdu (n=97) | 0.54076 | 0.017 |
| RHB | Sindhi (n=49) | Pathan (n=48) | -0.48580 | 0.026 |
| RHB | Pathan (n=48) | Urdu (n=97) | 0.39798 | 0.033 |
| LHB | Sindhi (n=49) | Pathan (n=48) | -0.43563 | 0.050 |

RHL (Right hand length), LHL (Left hand length), RHB (Right hand breadth), LHB(Left hand breadth)

**P-values were calculated from ANOVA followed by using post hoc test (Games Howell test).**

Table 3 illustrates the correlation between stature and hand measurement in males and females. Hand length measurements showed moderately positive relation with stature in both males (r =0.497 for RHL, r = 0.539 for LHL) and females (r =0.533 for RHL, r = 0.577 for LHL). However, when hand breadth was correlated with stature, a moderate positive relationship was obtained in males (r =0.671 for RHB, r = 0.623 for LHB) but the hand breadth of both right and left hands is very weakly correlated with stature in females. (r =0.264 for RHB, r = 0.275 for LHB). Across both male and female groups, the correlation coefficients indicated a strong positive relationship between stature and hand breadth (r = 0.759 for RHB, r = 0.752 for LHB.) In contrast, analysis of hand length revealed a positive but moderate correlation with stature (r = 0.677 for RHL, r = 0.697 for LHL)

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The correlations between the anthropometric measurements and stature, in different ethnicities as well as regression equations are summarized in Table 3. All variables showed a moderate to strong positive correlation with stature. Stature showed the highest correlation with hand breadth in Balochis (r = 0.890) whereas weakest correlation is seen with hand length in Punjabis (r = 0.568). It was observed that hand breadth shows a stronger correlation with stature than hand length in all ethnicities. (Table 3)

**Table 3 Linear regression equations for stature (cm) derived from hand measurements, categorized by sex and ethnicity.**

| **Linear regression equations for stature (cm) derived from hand measurements, categorized by sex.** | | | | |
|---|---|---|---|---|
| Males | | | | |
| Measurements | Formula | R | $R^2$ | SEE |
| RHL | S=116.034+3.205x RHL | .497 | .247 | 5.26 |
| LHL | S=105.813+3.751×LHL | .539 | .290 | 5.11 |
| RHB | S=104.713+8.216×RHB | .671 | .450 | 4.50 |
| LHB | S=110.252+7.524x LHB | .623 | .388 | 4.74 |
| Females | | | | |
| RHL | S=107.087+3.015×RHL | .533 | .284 | 4.88 |
| LHL | S=103.145+3.231×LHL | .577 | .333 | 4.71 |
| RHB | S=141.592+2.418×RHB | .264 | .070 | 5.57 |
| LHB | S=139.864+2.616x LHB | .275 | .075 | 5.55 |
| Combined | | | | |
| RHL | S=60.922+5.919x RHL | .677 | .458 | 7.34 |
| LHL | S=54.270+6.277xLHL | .697 | .485 | 7.16 |
| RHB | S=91.450+9.446xRHB | .759 | .576 | 6.50 |
| LHB | S=89.576+9.588x LHB | .752 | .566 | 6.57 |
| **Linear regression equations for stature (cm) derived from hand measurements, categorized ethnicity** | | | | |
| Punjabi (n=53) | | | | |
| Measurements | Formula | R | $R^2$ | SEE |
| RHL | S=82.498+4.663×RHL | .568 | .322 | 7.93 |
| LHL | S=78.890+4.848×LHL | .578 | .334 | 7.86 |
| RHB | S=105.599+7.481×RHB | .607 | .368 | 7.65 |
| LHB | S=105.397+7.435×LHB | .615 | .379 | 7.59 |
| Sindhi (n=49) | | | | |
| RHL | S=71.728+5.264×RHL | .704 | .495 | 7.03 |
| LHL | S=63.006+5.748×LHL | .726 | .527 | 6.80 |
| RHB | S=92.348+9.285×RHB | .788 | .621 | 6.09 |
| LHB | S=91.621+9.269×LHB | .756 | .571 | 6.48 |
| Balochi (n=24) | | | | |
| RHL | S=36.751+7.250×RHL | .823 | .678 | 5.68 |
| LHL | S=33.993+7.408×LHL | .834 | .695 | 5.53 |
| RHB | S=71.311+11.948×RHB | .885 | .784 | 4.65 |
| LHB | S=64.517+12.688×LHB | .890 | .792 | 4.56 |
| Pathan (n=48) | | | | |
| RHL | S=52.176+6.545×RHL | .630 | .396 | 8.01 |
| LHL | S=36.492+7.375×LHL | .666 | .443 | 7.69 |
| RHB | S=83.452+10.694×RHB | .782 | .611 | 6.43 |
| LHB | S=84.356+10.535×LHB | .766 | .586 | 6.63 |
| Urdu (n=97) | | | | |

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| | | | | |
|---|---|---|---|---|
| RHL | S=60.252+5.939×RHL | .680 | .463 | 6.96 |
| LHL | S=55.243+6.207×LHL | .698 | .488 | 6.80 |
| RHB | S=95.413+8.948×RHB | .769 | .591 | 6.08 |
| LHB | S=91.418+9.347×LHB | .779 | .607 | 5.95 |
| RHL (Right hand length), LHL (Left hand length), RHB (Right hand breadth), LHB(Left hand breadth) | | | | |

Regression analysis was conducted to estimate stature. Results of linear regression analysis based on sex and on ethnicity are shown in Table 3. Hand breadth measurements exhibit a lower value in males and give better reliability in prediction of stature (Table 3). However, in females the hand length measurements show lower values of Standard Error of the Estimate **(**SEE). With regard to ethnicities, value of SEE is lower for hand breadth than hand length in all ethnicities thus indicating hand breadth as better predictor of stature as compared to hand length. (Table 3)

Multiple linear regression is not suitable for this dataset as severe multicollinearity among predictors leads to unstable and unreliable estimates. The collinearity diagnostics revealed very high condition indices (above 30) and variance proportions concentrated across pairs of predictors (e.g., right and left hand lengths, right and left hand breadths). This indicates that the independent variables are highly correlated with each other, leading to unstable regression coefficients, inflated standard errors, and difficulty in interpreting the individual contribution of each predictor to stature.

## Discussion

Stature estimation from body parts is one of the fundamental methods for identifying unknown bodies. In cases of disasters, when bodies are recovered in damaged, decomposed, or dismembered states determining the identity becomes challenging and forensic experts must rely on whatever body parts are available (11,15). Thus, there is a need to develop linear regression equations that help estimate stature from partial remains.

In the present study, statistically significant larger hand measurements were observed in males than that of females, agreeing with results of similar studies conducted in other populations (17,18). These differences in measurements are largely influenced by genetic and biological factors (19). Thus, it can be deduced that regression equations should be developed separately for each gender for estimating stature using body measurements. In previous studies, hand measurement has showed positive correlations with stature with strongest correlation seen with hand length (11,15,20,21). Madadin *et al.* used regression analyses to determine the stature of the Eastern Saudi Arabian population using hand length and width as variables that showed a statistically significant correlation with stature. The strongest correlation with stature was found for hand length (0.633 and 0.643), followed by palm length (0.613 and 0.627) for the right and left hands, respectively (13). Shetty *et al* predicted the stature of adult South Indian population using dimensions of hand and reported a significant positive correlation between stature and hand length. (P value 0.01) (5). In Pakistan, one of such studies conducted in Punjab reported a positive correlation was found between hand length and stature compared to other parts of the body, $R^2$ (0.919) (14). Another similar study conducted in Khyber Pakhtunkhwa also reported hand length as the most reliable parameter to estimate stature in males with R for right hand length (0.6) and for left hand

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length (0.58) (15). However, in the current study hand breadth displayed a stronger correlation with stature as compared to hand length, which could be explained by population-specific genetic and environmental factors influencing hand proportions in the studied ethnic groups and thus, emphasizing the importance of developing population-specific regression models. Similar findings were observed in studies conducted in Bangladesh and Nepal and may be attributed to overlapping genetic ancestry or comparable nutritional and socioeconomic conditions (22,23).

The present study revealed that there is significant difference between hand measurements of different ethnicities. The post hoc analysis revealed that hands of Pathans differ significantly in hand measurements from hands of Sindhis and Urdu speaking with left hand length showing highest mean difference between Urdu speaking and Pathans. Similar findings were observed in two other studies conducted in Nigeria where significant difference was observed between hand measurements of different ethnicities (24,25). Thus, it is crucial to develop ethnicity specific regression formulas. On correlational analysis all hand measurements display a moderate correlation with stature in all ethnic groups but the strongest correlation was observed in Balochs. This finding may be attributed to the heterogeneous groups with small sample size of Balochs included in study.

**Limitations of study**: This study had several limitations. Due to convenient sampling technique and with an unequal ethnic sample sizes used for this study the results cannot be generalised to the population outside Karachi and should be undertaken with caution in mixed-ethnicity populations. Future studies with larger sample size are recommended. Another limitation is lack of cross validation of the regression equations on a separate sample from same population. Technical Error of Measurement (TEM) was not formally calculated to quantify intra-observer reliability. Furthermore, as the present study is conducted with adult population the results are not applicable for stature estimation of juveniles.

## Conclusion

This study concluded that hand measurements can serve as a reliable tool for estimating stature among adult population of different ethnicities residing in Karachi. The findings of this study hold forensic value and provide data that can support forensic anthropology, particularly in estimating stature from unidentified, dismembered, or mutilated body parts recovered in mass disasters. Establishing such ethnicity specific anthropometric standards assist law enforcement and crime investigation agencies in Karachi by providing a practical reference for identifying unknown individuals.

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| CONTRIBUTION OF AUTHORS | |
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| **AUTHOR** | **CONTRIBUTION** |
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| Data acquisition, analysis and interpretation | MF,QH |
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| All the authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed. | |