Original Research Article

Estimation of Stature from Percutaneous Upper Limb Measurements in the North Indian Population

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How to cite this article: Avesh Kumar Gautam, Ruma Purkait. Estimation of Stature from Percutaneous Upper Limb Measurements in the North Indian Population. Indian Journal of Forensic Medicine and Toxicology / Vol. 18 No. 4, October-December 2024.

Abstract

Background: In the field of forensic anthropology, stature estimation plays an important role in the identification of unknown dismembered bodies and skeletal remains. When forensic experts find body parts during a police investigation, their first task is to determine the age, sex, and height of the person. They assist law enforcement by using scientific methods in criminal cases.

Material and Methods: A cross-sectional study was carried out in the city. Measurements were taken on both the left and right sides of all males. The sample size was 563 individuals aged between 20 and 40 years. Accurate measurements of five upper extremities and stature were measured with the help of an Anthropometer and Sliding calliper.

Results: The correlation observed between stature and upper limb showed varying degrees of correlation, ranging from moderate to strong0.315 to 0.859. The precision of these equations was established by the obtained correlation value, where a greater correlation nearest to 1 indicated the highest significance.

Conclusion: This research addresses a critical gap by focusing on the upper extremities in a contemporary Central Indian population. Developing stature estimation models from specific body parts not only advances anthropological research but also aids forensic investigations, especially in warm climates like Uttar Pradesh.

Key words: Biological profile; Correlation; Forensic Anthropology; Regression; Stature; Upper limb

Introduction

In the present scenario, there are increasing instances of criminal incidents where the perpetrator cuts the victim's body into pieces and scatters the body parts in different locations to conceal their identity. When the police recover any of these body parts, identifying them becomes a formidable challenge for the police department. The role of forensic experts becomes crucial in unravelling the mystery of the dismembered body parts. In such criminal cases, one of the primary tasks of forensic experts is to estimate the stature of the victim.

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Submission date: May 7, 2024 **Revision date:** Jun 23, 2024 **Published date: Oct 9 , 2024**

In the specialized fields of forensic anthropology, the assessment of stature assumes particular significance, especially when dealing with dismembered body remains. In each situation, forensic anthropologists take into account a variety of variables and apply their knowledge to produce the most precise predictions [1, 2].

The process of stature estimation in the context of forensic anthropology involves the prediction of an individual's height by measuring recovered dismembered remains with the flesh[3, 4]. Forensic anthropologists employ sophisticated techniques, including the use of regression equations derived from extensive population-specific studies. Stature represents a significant parameter in the identification process, contributing to the establishment of an individual's uniqueness[5]. It's widely recognized that there's a well-established connection between a person's height and different anatomical features, including the head, trunk, and the lengths of their upper and lower limbs. The assessment of an individual's height through measurements of distinct body parts has consistently captivated the attention of anatomists, anthropologists, and forensic experts[6].

In cases involving recovered dismembered remains with flesh, anthropometric measurements taken from these body parts can be utilized to estimate the individual's sex and stature[7, 4, 8, 3]. As height demonstrates a correlation with limb lengths[9], and considering the average differences in height and body proportions between males and females, statistical models can be applied to predict the sex and stature of an individual based on these recorded measurements[10].

A considerable body of international literature has been dedicated to height estimation based on skeleton and mutilated bodies focused on hand and foot dimensions [11]. However, the corresponding research focusing on the upper extremities is notably limited. The pace of decomposition of deceased bodies is accelerated by elevated temperatures. The speed at which this degradation occurs can have a major effect on the gathering and examination of forensic evidence[12]. This temperature zone's state of Uttar Pradesh serves as an example of the difficulties Indian forensic experts confront. Particularly, the scant literature on stature estimate in Uttar Pradesh reveals a deficiency in the application of scientific techniques to the particular forensic requirements of this area.

A key component of forensic anthropology is stature estimation, which is used to identify people and piece together events connected to a crime[12].

Materials and Methods

A study of a cross-sectional nature was conducted in the city of Prayagraj, located in Uttar Pradesh, North India. A total of 588 male individuals participated in the data collection process during the time span of August 2019 to October 2023. written informed consent was obtained from all participants .Following data cleansing, 25 outliers were identified and removed. Consequently, the analysis was conducted on 563 cases. The ages of participants ranged from 20 to 40 years. Individuals with physical disabilities or any form of impairment affecting their extremities were excluded from the study.

To undertake this study, ethical approval was provided by the Institutional Ethics Review Board (IERB) with IERB ID: 2019-132 University of Allahabad, Prayagraj, Uttar Pradesh, India.

Measurements: In the present study, two instruments, namely the Anthropometer and Sliding calliper (manufactured by Jaico Electro Works, Western Ex. Highway Road, Malad East, Mumbai–400097). were employed for data collection. The Anthropometer was utilised to measure stature, upper arm, and forearm dimensions, while the Sliding calliper was utilized for assessing hand length and handbreadth. The least count of the anthropometer and sliding calliper was one millimetre.

To ensure comprehensive data, measurements were conducted on both the right and left sides of the upper extremities. Rigorous precautions were observed throughout the measurement process to maintain accuracy and consistency.

Stature: it measures the vertical distance from vertex to floor[13].

Total arm length: it measures the distance between acromion and dactylion, when the arm is hanging downwards[13].

Upper arm length: it measures the straight distance between acromion and radiale [13].

Forearm length: it measures the distance between radiale and stylion[13].

Hand length: it measures the distance between the mid-point of a line joining the two stylion and phalangion and dactylion of the middle finger [13].

Hand breadth: it measures the distance between 2nd metacarpal radialis and 5^{th} metacarpal ulnare [13].

Statistical Analysis

To ensure the quality of our data, we first conducted a pilot study using a smaller sample. This helped us evaluate how precise and consistent our methods were for measuring stature and upper limbs. This initial analysis was then followed by a more in-depth analysis using IBM SPSS Statistics (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.).

We summarised the measurements by calculating averages, standard deviations, and ranges (minimum and maximum), as well as discrepancies. Pearson correlation coefficients (r) were then calculated to determine the degree of correlation between stature and upper limb measurements. In statistics, regression is the process of determining a statistical relationship between two or more variables[5].

The accuracy of these equations was demonstrated by the obtained Standard Error of Estimate (SEE), where a lower SEE indicated greater precision. Using upper limb dimensions, both simple and multiple regression equations were developed for stature estimation. Significance was established $p<0.05$. The predictive performance of all equations was evaluated through comparison[14].

Result

The main aim of this study is to perform a thorough assessment of stature among the population of Prayagraj in Uttar Pradesh. To achieve this goal, ten specific body dimensions pertaining to the upper extremity were accurately measured. Through the careful analysis of these body dimensions, this study aims to contribute valuable information to the understanding of anthropometric characteristics within the specified population group.

Table 1 offers descriptive statistics for TAL, UAL, FAL, Hland HB, presented for both the left and right sides and stature. With noted positive correlations between stature and arm measurement dimensions, regression analysis was conducted to predict stature. Identification of the most appropriate regression equations for stature estimation relied on assessing the determination of coefficient and the standard error of estimated values. Table 2 displays the outcomes of the linear regression analysis. It is calculated that the TAL exhibits the highest correlation (r) with stature (0.859 for left arm, 0.850 for right arm) and HB exhibits the lowest (0.315 for left and 0.348 for right). The associations between the measured stature and the lengths of long bones exhibited a range of moderate to strong correlations, as indicated by Pearson's correlation coefficient (r) ranging from 0.315 to 0.859[15], as shown in Table 2.

Table 3 displays the outcomes of the stepwise regression analysis. The analysis indicates that the combination of upper arm length and forearm length yielded the highest prediction accuracy, accompanied by the lowest standard error of estimate (SEE) values in this male population. The statures estimated using upper arm length and forearm length demonstrated R^2 values of 0.536 for the left arm and 0.526 for the right side. The SEE was calculated at ± 3.292 for the left side and ± 3.326 for the right side[11].

Table 4 illustrated the comparison between estimated stature and actual stature. Through a tabular analysis, they ascertained that the differences between the predicted and actual statures, as determined by the regression model, were negligible. This suggests that their method demonstrated a high degree of accuracy with minimal margin for error. In this equation, it was determined that the largest measurement corresponds to TAL, while the smallest measurement corresponds to HB. With the increase in the parameter length, there is a reduction in the average disparity between the current stature and the predicted stature. Among these measurements, HB exhibits the highest mean difference at 3.6, while TAL demonstrates the lowest at 2.0.

Table 1: Routine statistical analysis of the parameters measured bilaterally - (in cm)

	Parameters	Mean	SD	Minimum	Maximum
1	TAL Left	75.25	2.68	68.20	82.00
2	TAL Right	75.28	2.68	68.80	81.60
3	UAL Left	31.89	1.56	27.40	34.80
4	UAL Right	31.90	1.55	27.90	34.90
5	FAL Left	25.69	1.27	23.10	29.10
6	FAL Right	25.67	1.25	22.70	29.00
7	HL Left	19.27	0.71	17.40	21.10
8	HL Right	19.27	0.73	17.10	21.30
9	HB Left	8.33	0.51	7.20	10.10
10	HB Right	8.35	0.50	7.10	10.00
11	Stature	167.0	4.83	155.8	183.2

TAL= Total Arm Length, UAL = Upper arm length, FAL= Forearm Length, HL= Hand Length, HB= Hand Breadth.

Table 2: Simple linear regression models of all parameters for stature estimation

SN		Regression Equation	r	r^2	SEE	p value
1	Left	S=50.814+1.545*TAL	0.859	0.737	2.474	0.000
2	Right	S=51.683+1.533*TAL	0.850	0.722	2.546	0.000
3	Left	S=95.412+2.247*UAL	0.726	0.527	3.321	0.000
4	Right	S=96.099+2.225*UAL	0.715	0.511	3.378	0.000
5	Left	S=118.835+1.878*FAL	0.496	0.246	4.195	0.000
6	Right	S=114.653+2.042*FAL	0.529	0.279	4.099	0.000
7	Left	S=97.402+3.616*HL	0.532	0.283	4.090	0.000
8	Right	S=97.355+3.618*HL	0.548	0.301	4.039	0.000
9	Left	S=142.157+2.991*HB	0.315	0.099	4.584	0.000
10	Right	S=139.138+3.345*HB	0.348	0.212	4.527	0.000

Table 3: Multiple regression models of all parameters for stature estimation

S. No.	Parameter	Left/ Right	Multilinear regression	r	r^2	SEE	Significance
1	UAL+FAL	Left	S=90.740+2.041*UAL+0.438*FAL	0.732	0.536	3.292	0.000
		Right	S=89.875+1.932*UAL+0.606*FAL	0.726	0.526	3.326	0.000
2	FAL+HL	Left	S=81.601+1.290*FAL+2.716*HL	0.617	0.381	3.803	0.000
		Right	S=78.370+1.445*FAL+2.678*HL	0.648	0.420	3.680	0.000
3	HL+HB	Left	S=94.109+3.285*HL+1.161*HB	0.543	0.295	4.058	0.000
		Right	S=93.427+3.219*HL+1.391*HB	0.564	0.318	3.992	0.000
4	FAL+HL +HB	Left	S=77.343+1.379*FAL+2.314*HL+ 1.350*HB	0.631	0.398	3.753	0.000
		Right	S=74.259+1.449*FAL+2.272*HL+ 1.418*HB	0.662	0.439	3.625	0.000

Table 4: Descriptive statistics of estimated stature comparison with present stature (in cm)

S. No.	Parameters	Left/Right	Present Stature	Estimated Stature	Mean Difference
1	Total Arm Length	Left	167.0	167.079	0.079
		Right	167.0	167.080	0.080
2	Upper Arm Length	Left	167.0	167.065	0.065
		Right	167.0	167.085	0.085
3	Forearm Length	Left	167.0	167.082	0.082
		Right	167.0	167.075	0.075
4	Hand Length	Left	167.0	167.076	0.076
		Right	167.0	167.075	0.075
5	Hand Breadth	Left	167.0	167.069	0.069
		Right	167.0	167.070	0.070

Discussion

The objective of this research was to develop novel stature prediction equations specifically tailored for the Indian male population, thereby enhancing the existing, constrained norms for stature estimation within Indian forensic anthropology. Recognising bilateral asymmetry in the measurements on the left side, adjustments were made for right-handedness in the presented data by formulating side-specific formulas[15].

Bilateral asymmetry, a well-known characteristic observed in human anatomy, carries important implications for stature estimation in forensic investigations[16]. This natural phenomenon has been extensively studied across various research endeavours examining human body proportions and skeletal structures[17]. Notably, a comprehensive study was conducted by Krishan[18] to shed light on the substantial bilateral asymmetry found in limb dimensions, emphasising its significant impact on stature estimation methodologies.

Regression formulas are an important component in forensic investigations involving partial or complete skeletal remains or body parts, particularly in determining stature, a crucial aspect of such inquiries. These formulas serve as indispensable tools when computing stature from bone measurements. Within the forensic domain, a regression formula embodies a meticulously crafted mathematical expression utilized to explain the intricate relationship between one or more independent variables typically skeletal dimensions and a dependent variable, such as stature.

The study revealed the strongest correlation with stature in the left total arm length and upper arm length (r=0.859, 0.726, respectively) and the right upper extremity length, total arm length, and upper arm length (r=0.850, r=726, respectively). Notably, our findings exhibited higher correlation values compared to the results reported in the study conducted North Indian population. However, our results aligned closely with those reported by Akhlaghi[19] for the right sides in the Iranian population[20].

All dimensions underwent assessment regarding their capability to predict stature through simple linear regression, considering Standard Error of Estimates (SEEs) and r^2 values. Among the hand dimensions, length consistently demonstrated the lowest SEEs and the highest R^2 values. This discovery aligns with the outcomes reported in studies by[21, 22].

By combining multiple measurements, such as body, arm, forearm, hand length, hand breadth, and second to fifth finger length inside the upper limb, Akhlaghi[19] was able to accurately determine the stature of an Iranian community. Upper limb length and hand length were found to be predictive variables for both male and female respondents in multiple linear regression analyses. Furthermore, hand length and breadth were found to be significant predictors irrespective of gender differentiation[11].

In the current study, a similarly robust correlation was observed for total arm length, with a high coefficient, similar to how stature was classified, the 15th and 85th percentiles served as the cut-off points. This underscores the significance of recognising and utilising specific anatomical measurements, even in cases where only isolated bones or body parts are available, to make accurate estimations of stature.

The significance of this study lies in its potential to provide more accurate and reliable stature estimation methods for North Indian males. This can have important implications in identifying human remains Table 5. In the present study, it has been found that total arm length and upper arm length demonstrate the most robust correlation with stature, surpassing similar correlations observed in different population groups.

Table 5: Comparison of Correlation Coefficient value of Upper extremity in different population groups.

Author	Population	TAL		UAL		FAL		HL		HB	
		L	R	L	R	L	R	L	R	L	R
Akhlaghi et al.[19] (2012)	Iran		0.635		0.602		0.354		0.696		0.310
Ahmed[5] (2013)	Sudan			0.698		0.725		0.602		0.358	
Chauhan et al.[23] (2017)	Lucknow			0.680	0.684						
Kaur et al.[24] (2016)	Haryana			0.660							
Yadav et al.[25] (2018)	Madhya Pradesh					0.837	0.835				
Howley et al.[26] (2018)	Australia					0.740	0.748	0.686	0.647	0.592	0.505
Uzun et al. (2019)	Turkey	0.716	0.675	0.534	0.497	0.473	0.486	0.350	0.339	0.231	0.248
Nandi et al.[27s] (2018)	Nigeria			0.80	0.79	0.75	0.72				
Present Study	North India	0.859	0.850	0.726	0.715	0.496	0.529	0.532	0.548	0.315	0.348

Conclusion

The findings of this study lead to the conclusion that the upper extremities can effectively serve as a means for estimating the stature of adults in forensic applications, benefiting law enforcement agencies and forensic scientists. Moreover, the study highlights the superiority of multiple regression equations over single linear regression equations for this purpose. Given the diverse racial, ethnic, and cultural composition in India, each population group necessitates a dedicated study in this context. Specifically, this study furnishes regression equations derived from hand and arm dimensions applicable for estimating the stature of adult males in Prayagraj City, North India. However, caution is advised against using these equations for other population groups.

Ethical Clearance: ethical approval was provided by the Institutional Ethics Review Board (IERB) with IERB ID: 2019-132 University of Allahabad, Prayagraj, Uttar Pradesh, India.

Source of funding: None

Conflict of interest: None

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