

## ORIGINAL ARTICLE

# Stature Estimation from Humerus bone in Gorkha Population

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## Abstract:

Stature estimation is a key aspect of personal identification, especially in absence of other identification markers. One of the most widely used method for stature estimation is to use the measurements of long bones. Extensive studies have proved that humerus, femur, radius, ulna, tibia, and fibula produce substantial accuracy in predicting the stature. However, the regression equation can vary with the population used in prediction. In the present study, the correlation between the humerus length and stature has been explored for the 89 individuals (80 males and 09 females) of Gorkha population of Jharkhand armed forces. For this, the measurements of left and right humerus of males and females were used. Additionally, two methods were used for the measurements and these measurements were compared to see which yielded better results. Significant p-values were obtained for all the measurements suggesting that the results obtained in the present study were significant and can be used in real cases.

**Keywords:** Stature estimation; Anthropology; Forensic science; Humerus; Personal identification.

## Introduction:

The study of forensic anthropology, a subdivision of physical anthropology, involves analyzing human skeletal remains to assist in legal cases.<sup>1</sup> The estimation of stature is a key focus in forensic anthropology, involving the determination of an individual's height through skeletal remains. Anthropological techniques are used in forensic anthropology to reveal information about human remains, playing a crucial role in the legal system.<sup>2</sup> In cases involving decomposed, mutilated, or fragmented remains, this field becomes relevant because of the limitations of traditional methods. The expertise of forensic anthropologists is used in analyzing skeletal structures to determine a person's identity, age, sex, and stature.<sup>3</sup>

A comprehensive understanding of human skeletal anatomy and its relationship with height is crucial in forensic anthropology, making the estimation of stature one of the primary challenges in this field.<sup>4</sup> The process of estimating stature involves the utilization of mathematical formulas and statistical methods that are derived from analyzing particular skeletal elements. An individual's height is influenced by the long bones, such as the femur, tibia, and humerus, which are vital components in this process because of their significant association.<sup>5</sup> Regression equations that have been developed by researchers can now accurately correlate the length of different bones with stature. These equations take into consideration important factors like sex

and population differences.<sup>6</sup> These equations play a crucial role in forensic anthropology as they provide a valuable tool for accurately estimating stature, which contributes to the establishment of a comprehensive biological profile for an individual.<sup>7</sup>

Stature estimation considers various factors, including sexual dimorphism, which highlight the physical distinctions between males and females. When developing stature estimation methods, forensic anthropologists take into consideration these differences and acknowledge that the correlation between bone length and stature may differ between males and females. The accuracy of stature estimates is enhanced by researchers when they incorporate sex-specific equations, which in turn further refines the identification process.

In forensic investigations, the estimation of stature can assist in victim identification, especially where only skeletal remains are available.<sup>8</sup> By comparing the estimated stature with demographic data and missing person's records, forensic anthropologists can narrow down potential matches and aid law enforcement agencies in solving cases.<sup>9</sup> Stature estimation is valuable in mass disaster scenarios, where the identification of multiple individuals is required in a timely manner. The information obtained from stature estimation can be essential in courtrooms, providing scientific evidence that supports legal proceedings.<sup>10</sup> Forensic anthropologists may be called upon as expert witnesses to present their findings and explain the methodologies used in stature estimation. The reliability and objectivity of these scientific methods contribute to the credibility of forensic anthropology in the legal system.<sup>11-12</sup>

The relation between stature and upper arm length (UAL) or percutaneous humerus length can be explored by researchers, who can then create formulas to elucidate this association within

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Figure 1. Data collection using first method.

Figure 2. Data collection using second method.

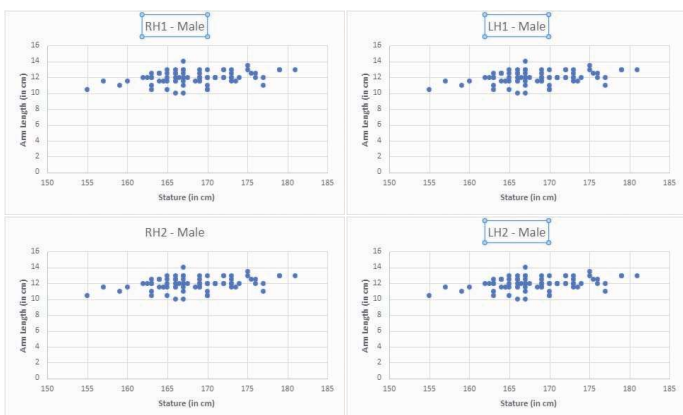


Figure 3. Scatter plot for male for Gorkha population.

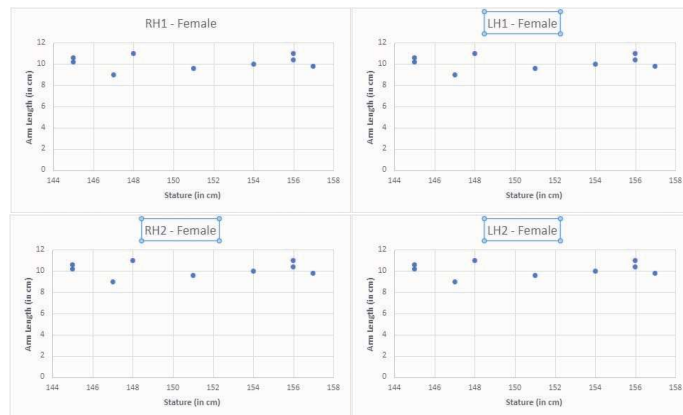


Figure 4. Scatter plot for female for Gorkha population.

diverse age cohorts.<sup>13-16</sup> The formulae derived from the results exhibited varying levels of reliability and prediction power.<sup>17-19</sup> There is a direct correlation between the stature of an individual and the different body parts, highlighting the strong biological and genetic relationship they share. 'Anatomical' and 'mathematical' techniques are commonly employed in forensic cases for the purpose of estimating stature, or body height.<sup>20</sup> In Northern India, specifically in the Ranchi region, the present study was conducted on the Gorkha population. To the best of author's knowledge no previous study on stature estimation of this population are available.

**Materials and methods:**

In order to conduct the study, measurements were obtained from the Gorkha population in Jharkhand Armed Police-1, after receiving approval from the Director General of Police, Jharkhand. Prior to commencing the study, the researchers took the time to explain both the objectives and methods to the sample population, ensuring that they were well-informed about the study's purpose and procedures. It is worth mentioning that prior

to their involvement, all participants were provided with detailed information and they gave their informed consent willingly. In order to obtain precise measurements, standard anthropometric instruments were employed, and all measurements were recorded in centimeters, with a level of detail down to the nearest millimeter. To ensure accurate results and eliminate diurnal variation, all measurements are taken in a reasonably well-lighted room at a fixed time between 12.00 p.m. and 4.00 p.m. The humerus bone of each individual was measured on both the left and right side to ensure precise measurements. The recorded measurements of each person's stature were used to find the average height. In this study, a comprehensive dataset was gathered, which included a total of 160 individuals. The participants selected for this study consisted of an equal number of males and females, totaling 160 individuals, all falling within the age range of 25 to 40 years. Once the data was collected, it was meticulously coded and then entered into MS Excel for analysis. Linear regression was used to evaluate statistical associations. Two types of measurements were taken of humerus bone from left and right side of each individual.

For the first measurement, the subject was instructed to stand in an upright position with equal weight distribution on both feet, while bending the right arm at a 90° angle at the elbow and facing the right palm upwards. By tracing the scapula from the back towards the arm, you will reach the point where its spine ends before it sharply turns in a V-shape towards the front of the body. The uppermost edge of the posterior border of the spine was marked with a horizontal line using the cosmetic pencil, which extended from the acromion process. To measure accurately, the measuring tape was initially positioned at this mark, and then it was carefully extended downwards along the posterior surface of the arm until reaching the tip of the olecranon process, which is the bony protrusion at the mid-elbow area. Then the measurement was taken to the nearest 0.1 cm. The tape must be centered on the posterior surface of the arm. During the second measurement, the examiner could feel the medial and lateral epicondyle through palpation. It was necessary to mark two distinct points on the designated area. Then both the points were joint using a horizontal line; midpoint of this line was taken as reference point. The length of humerus was measured in living subject in between two points.

**Table 1. Table showing data of males and females**

Sex	Measurement	Intercept	Slope	p-value	R2	SEE	EQUATION
Male	LH1	168.865	-0.030	0.00	0.006	5.024	168.865+ (0.030) LH1
Male	RH1	109.218	4.125	0.00	0.389	3.940	109.218901+ (4.125) RH1
Male	LH2	142.929	2.123	0.00	0.115	4.743	142.929+ (2.123) LH2
Male	RH2	140.357	2.327	0.00	0.146	4.658	140.357+ (2.327) RH2
Female	LH1	101.839	3.710	0.0084	0.143	5.094	101.839+ (3.710) LH1
Female	RH1	80.558	5.207	0.0309	0.503	3.877	80.558+ (5.207) RH1
Female	LH2	133.655	1.758	0.006	0.046	5.377	133.65+ (1.7587477) LH2
Female	RH2	155.531	-0.438	0.00	0.078	5.283	155.531+ (-0.438) RH2

**Table 2. Descriptive Statistics of Parameters studied in 80 Males.**

Parameters	Stature	RH1	LH1	RH2	LH2
Mean	168.37	14.33	15.79	12.03	11.98
Median	167	14	14.5	12	12
Mode	167	14	14	12	12
S.D.	5.009	0.757	0.719	0.82	0.8
S.E.M	0.563	0.085	0.08	0.092	0.09
Maximum	181	16	16	14	14
Minimum	155	13	13	10	10
Range	26	03	03	04	04

**Table 3. Descriptive statistics of parameters studied in 80 females.**

Parameters	Stature	RH1	LH1	RH2	LH2
Mean	151	13.7	13.4	9.65	10.17
Median	151	13.5	13.5	10.6	10.2
Mode	145	13.4	14.3	10.5	11
S.D.	4.89	0.715	0.58	0.57	0.65
S.E.M	1.63	0.23	0.19	0.19	0.21
Maximum	157	15	14.3	11.8	11
Minimum	145	12.6	12.7	10.1	09
Range	12	2.4	1.6	1.7	02

**Results:**

In the present study, the data of humerus length and stature was collected from 160 individuals comprising of 80 males and 80 females. The data was then fed to Microsoft excel for further statistical analysis. Table 1 summarizes the results of data analysis for both male and female measurements.

Table-2 shows the descriptive statistics of parameters studied in 80 males. The mean of the stature of the male is 168.37 cm. The mean of right humerus length (RH1) & left humerus length (LH1) from first measurement is 14.3 cm and 15.79 cm respectively. The mean of right humerus length (RH2) & left humerus length (LH2) from second measurement is 12.03 cm and 11.98 cm respectively. Same as the median, mode, standard deviation, and standard error of mean can be seen. The range is highest for stature followed by humerus length from second measurement for both hands and is lowest for humerus length from first measurement for both hands.

Table-3 Shows the descriptive statistics of parameters studied in 80 females. The mean of the stature of the female is 151 cm. The mean of right humerus length (RH1) & left humerus length (LH1) from first measurement is 13.7 cm and 13.4 cm respectively. The

mean of right humerus length (RH2) & left humerus length (LH2) from second measurement is 9.65 cm and 10.17 cm respectively. Same as the median, mode, standard deviation and standard error of mean can be seen. The range is highest for stature followed by humerus length from first measurement in right hand, from second measurement in right hand and is lowest for left hand from both measurements. When compared with the data in Table-2 and 3 we can observe that each parameter has a greater value of range for males except for mode in LH1. In males, the average stature was 168 ±5 cm. The average humerus length of right and left hand from first measurement is 14.3±0.75 cm & 15.7±0.71 cm respectively. The average humerus length of right and left hand from second measurement is 12.03±0.82 cm & 11.98±0.8 cm respectively. In female, the average stature was 151±4.89 cm. The average humerus length of right and left hand from first measurement is 13.7±0.71 cm & 13.4±0.58 cm respectively. The average humerus length of right and left hand from second measurement is 9.65±0.57 & 10.17±0.65 cm respectively.

**Discussion:**

Age, sex and stature are the primary characteristics of identification of the individuality of a person. Stature is an important and useful anthropometric parameter occupies relatively a central position in anthropometric research. Reconstruction of stature used by forensic experts for narrowing down the investigation process. Apart from this, the estimated height is of paramount importance in medico-legal examinations. In establishing the individuality of a person mostly in cases of decomposed bodies and skeletal remains, stature is one of the important parameters.

The observations of the current work claimed that the humerus bone length can be used for prediction of stature by forensic experts, law agencies and by anthropologists. India is a land of genetic and cultural diversity and for all the races and populations these parameters are different due to the differences in nutrition, genetic makeup, geographical location, climatic conditions and due to different levels of physical activity. Hence these formulae are population specific from which the data has been collected.

In the present study, Stature of Gorkha males ranges from a minimum of 155 cm to a maximum of 181 cm which shows a mean stature of 168.37 ± 5 cm and for Gorkha female from a minimum of 145 cm to maximum of 157 cm which shows a mean stature of 151 ± 4.89 cm. Furthermore, the value of co-efficient correlation is found to be significant with p-value (P<0.005).

Humerus length of Gorkha males of Ranchi ranges from a minimum of 13cm to maximum of 16 cm showing a mean value of 14.3±0.75 for right hand and for left hand it ranges from a minimum of 13cm to maximum of 16 cm showing a mean value of 15.7±0.71 cm. Humerus length of Gorkha female ranges from a minimum of 12.6 cm to maximum of 15 cm showing a mean value of 13.7±0.71 cm for right hand and for left hand it ranges from a minimum of 12.7cm to maximum of 14.3cm showing a mean value of 13.4±0.58 cm.

**Conclusion:**

Throughout history, crimes and criminals have consistently been intertwined within all societies across the globe. The interest and

integrity of members of society have always been safeguarded through the collective efforts of many societies, which involve identifying criminals, isolating them, and ensuring appropriate punishment. Solving crime investigation problems now requires the indispensable application of forensic science knowledge. The application of advanced forensic science techniques has the potential to effectively address and resolve the complex issues surrounding heinous crimes. Within the realm of forensic science, there is a specialized branch known as forensic anthropology, which serves the vital purpose of determining the stature or height of an individual who has been linked to a criminal offense. Where the person's identity has been established by analyzing the length of their limbs or other body parts, it becomes feasible to generate a comprehensive evidential report that can significantly impact the outcome of criminal proceedings. Extracting relevant personal information about the victim, through the examination of skeletal remains recovered from crime scenes, has long been a common practice among forensic anthropologists.

Estimation of stature from skeletal remains is a task that they undertake in such situations. The significance of forensic anthropology has increased in today's world, primarily because of the advancements made in scientific methods to uncover foul play. Among the various tasks undertaken by forensic anthropologists, personal identification holds tremendous significance. When we mention "the individual" in this context, we are including a wide range of possibilities, such as a living person, a deceased person, a body that is partially decomposed or mutilated, or even remains that have undergone skeletonization but can still be recognized. An individual's stature, a personal attribute, is anatomically complex and can be determined by evaluating the combined length dimensions of the legs, pelvis, vertebral column, and skull.

The estimation of stature can involve the use of different body dimensions. Numerous studies have unequivocally showed that there is a direct and positive relationship between height and the dimensions of various body parts. Using personal identification as a measure is important in forensic examination, especially when dealing with unknown, highly decomposed, fragmentary, and mutilated human remains. This assistance plays a crucial role in narrowing down the investigation process, ultimately offering valuable clues to the investigating agencies.

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