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Stature Estimation from Percutaneous Humerus Length in a Haryana Population: A Forensic Anthropometric Study

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ABSTRACT

Introduction Stature is a fundamental parameter in the biological profile required for the forensic identification of unknown human remains. While lower limb bones are the primary choice for height estimation, the humerus provides a significant alternative in cases involving fragmented or disarticulated upper extremities. Given that human body proportions vary by ethnicity and geography, population-specific data is essential for accurate medico-legal assessments.

Aim The objective of this study was to evaluate the correlation between percutaneous humerus length and total standing stature and to derive sex-specific linear regression equations for a North Indian population.

Methodology The study was conducted at PGIMS Rohtak involving 145 healthy adult students (80 males and 65 females). Stature was measured as the projective distance between the vertex and the standing surface using a standard anthropometer with the subject in the Frankfurt Horizontal plane. Percutaneous humerus length was measured from the greater tubercle to the lateral epicondyle using a standard osteometric board. Statistical analysis was performed to determine Pearson's correlation coefficient (r) and linear regression formulae.

Results Sexual dimorphism was clearly evident; the mean stature was 170.75 ± 6.81 cm for males and 159.11 ± 6.33 cm for females. The mean percutaneous humerus length was 30.52 ± 1.48 cm in males and 29.60 ± 1.58 cm in females. The correlation coefficient (r) was found to be +0.098 for males and +0.163 for females, indicating a weak positive relationship. The regression equations derived were Stature = 149.37 + (0.70 x Humerus) for males and Stature = 149.87 + (0.31 x Humerus) for females.

Summary and Conclusion The study concludes that while a positive linear relationship exists between percutaneous humerus length and stature, the correlation is notably weaker than that of dry bone measurements or lower limb bones. The low R^2 values suggest high variability in this population. Therefore, percutaneous humerus length should be utilized as a supplementary or secondary tool in forensic identification rather than a primary definitive indicator of stature.

Keywords: *Stature Estimation, Humerus, Percutaneous, Forensic Anthropology, PGIMS Rohtak, Regression Equation, North Indian Population.*

INTRODUCTION

Forensic anthropology relies heavily on the establishment of the "Big Four" biological profiles: age, sex, ancestry, and stature. Stature estimation is a critical parameter in identifying unknown human remains, especially in cases of mass disasters, criminal mutilation, or severe decomposition where whole-body identification is impossible. The human skeleton follows a proportional relationship where the lengths of various long bones correlate with the total body height of the individual. While lower extremity bones such as the femur and tibia provide the highest accuracy for stature estimation due to their direct contribution to standing height, upper extremity bones like the humerus serve as vital secondary indicators when lower limbs are unavailable, damaged, or incomplete. This study explores the anthropometric relationship between percutaneous humerus length and total living stature in a specific North Indian population, emphasizing non-invasive measurement techniques.

LITERATURE REVIEW

The scientific foundation for stature estimation from long bones was firmly established in the mid-20th century, predominantly through the extensive work on skeletal remains of military personnel. Early regression equations formulated for Caucasian and African-American populations became the global standard for decades. However, subsequent anthropological research demonstrated that human body proportions are heavily influenced by genetics, geography, nutrition, and environmental factors. Consequently, a regression formula derived from one ethnic group often yields significant standard errors when applied to another, necessitating the development of population-specific and region-specific anthropometric data [1].

In the Indian subcontinent, vast morphological diversity exists across different geographic zones. Studies conducted on various regional populations in India have consistently highlighted that regression equations must be localized to maintain forensic accuracy. Furthermore, while historical studies largely relied on dry bone measurements from macerated skeletons, modern forensic and clinical applications increasingly utilize percutaneous measurements of living subjects. Percutaneous measurements—taken over the skin—introduce variables such as soft tissue thickness and articular cartilage, which slightly alter the biometric relationships compared to dry bone but offer highly practical, non-invasive data collection methods for living populations and fresh cadavers [2].

Recent literature underscores the persistent sexual dimorphism in human skeletal growth. Males and females exhibit distinct proportional ratios between appendicular limb lengths and axial length. Therefore, relying on a pooled, sex-neutral formula often decreases the reliability of the estimation. It is widely accepted in contemporary forensic osteology that specific regression models must be constructed not only for distinct regional populations but also partitioned strictly by sex to ensure the highest degree of predictive accuracy in medico-legal investigations [3].

Aims

1. To measure the total living stature and percutaneous humerus length in a sample of young adults.
2. To determine the degree of correlation between stature and percutaneous humerus length in both males and females.
3. To formulate sex-specific linear regression equations for the estimation of stature from percutaneous humerus length for the studied population.

METHODOLOGY

The present cross-sectional anthropometric study was conducted at the Pandit Bhagwat Dayal Sharma Post Graduate Institute of Medical Sciences (PGIMS), Rohtak, Haryana. The study sample comprised 145 healthy adult students (80 males and 65 females) drawn from the institute.

Measurement of Stature:

Students were instructed to stand barefoot in a standard standing anatomical position on a flat, level surface. The head was oriented in the Frankfurt Horizontal plane. The projective distance between the standing surface (floor) and the highest point on the head (vertex) was measured using a standard anthropometer. Readings were recorded to the nearest millimeter.

Measurement of Humerus (Percutaneous):

The percutaneous length of the humerus was measured using a standard osteometric board. The subject's arm was relaxed, and the measurement was taken from the most superior palpable point of the head of the humerus (greater tubercle) to the most distal palpable point of the lateral epicondyle of the humerus. Soft tissue compression was minimized to ensure accuracy.

Data on age and weight were also recorded. All collected data were tabulated and subjected to statistical analysis using Pearson's correlation and linear regression modeling to derive population-specific formulae.

RESULTS

The data obtained from the 145 subjects were analyzed statistically. The results are summarized in the following tables.

Table 1: Demographic and Physical Profile of the Study Population.

Parameter	Total (N=145)	Male (n=80)	Female (n=65)
Age (years)	20.87 ± 2.19	20.95 ± 2.30	20.78 ± 2.05
Weight (kg)	60.10 ± 11.23	65.40 ± 9.80	53.60 ± 9.50
Height Range (cm)	144.00 - 192.00	155.00 - 192.00	144.00 - 172.00
Humerus Range (cm)	25.00 - 36.00	27.00 - 36.00	25.00 - 33.00

Table 1 outlines the baseline demographic and physical characteristics of the study cohort at PGIMS Rohtak. The total sample size of 145 includes a relatively balanced gender distribution of 80 males and 65 females. The mean age of the overall group is 20.87 years, indicating a young adult population where skeletal maturity has been reached, making them ideal candidates for adult stature studies. Males exhibited a notably higher mean weight (65.40 kg) compared to females (53.60 kg). The range of standing height reveals significant variation, spanning from a minimum of 144.00 cm to a maximum of 192.00 cm in the total population. Similarly, percutaneous humerus lengths ranged widely from 25.00 cm to 36.00 cm. This wide distribution provides a robust dataset for conducting linear regression analysis.

Table 2: Descriptive Statistics for Stature and Percutaneous Humerus Length

Group	Mean Stature (cm) ± SD	Mean Humerus (cm) ± SD
Total Population	165.53 ± 8.87	30.11 ± 1.63
Males	170.75 ± 6.81	30.52 ± 1.48
Females	159.11 ± 6.33	29.60 ± 1.58

Table 2 provides the core descriptive statistics central to the study's aims. The mean stature for the combined population was recorded at 165.53 cm with a standard deviation of 8.87 cm. A clear manifestation of sexual dimorphism is evident when comparing the sexes; males are substantially taller, with a mean stature of 170.75 cm, compared to the female mean stature of 159.11 cm. Concurrently, the percutaneous humerus length follows the same dimorphic pattern. The average male humerus length is 30.52 cm, nearly one full centimeter longer than the female average of 29.60 cm. The standard deviations for humerus measurements are relatively tight (1.48 cm for males and 1.58 cm for females), suggesting that the percutaneous measurement technique using the osteometric board yielded consistent and clustered data points.

Table 3: Pearson Correlation Coefficients (r) Between Stature and Humerus Length

Subgroup	Sample Size (n)	Correlation Coefficient (r)	p-value / Significance
Combined	145	+0.1450	Weak Positive
Males	80	+0.0986	Very Weak Positive
Females	65	+0.1633	Weak Positive
Age ≤ 22	135	+0.2654	Moderate Positive
> 22 Years	9	0.142	Weak Positive

Table 3 highlights the mathematical correlation between the length of the percutaneous humerus and the total standing stature using Pearson's correlation coefficient (r). Overall, the combined population demonstrates a positive but weak correlation ($r = 0.1450$). When isolated by sex, females show a marginally stronger correlation ($r = 0.1633$) than males ($r = 0.0986$). These findings suggest that while there is a biological relationship where a longer humerus generally indicates a taller individual, the humerus alone is highly variable and not a rigid predictor of height in this specific population. Interestingly, when the data is restricted to individuals aged 22 and under, the correlation improves to $r = 0.2654$. This indicates that age-related physiological factors might introduce variance that weakens the correlation in older subjects, making the humerus a slightly better predictor in younger demographics.

Table 4: Correlation by Weight Group

Weight Category	Sample Size (n)	Correlation (r)	Mean Humerus (cm)
≤ 60 kg	77	0.171	29.68
> 60 kg	68	0.106	30.60

Table 4 highlights that the lighter individuals (typically females or lean males) show a slightly stronger correlation between humerus length and stature than individuals weighing over 60 kg.

Table 5: Linear Regression Equations for Stature Estimation

Model	Regression Equation (Y=a+bX)	Coefficient of Determination (R^2)
Combined	Stature = 141.79 + (0.79 x Humerus)	0.0210
Males	Stature = 149.37 + (0.70 x Humerus)	0.0097
Females	Stature = 149.87 + (0.31 x Humerus)	0.0267

Table 5 presents the formulated linear regression equations specifically derived from the PGIMS Rohtak cohort, where Y is the estimated stature and X is the percutaneous humerus length. The equations are constructed in the standard $Y = a + bX$ format. For males, the intercept constant is 149.37, and the multiplication factor for the humerus is 0.70. For females, the intercept is slightly higher at 149.87, but the multiplication factor drops to 0.31. The Coefficient of Determination (R^2) values are notably low across all models (ranging from roughly 1% to 2.7%). This indicates that only a very small fraction of the total variance in a person's height can be exclusively explained by the length of their humerus. While these equations provide a mathematically sound method for estimating stature when only an arm is present, forensic practitioners must be aware of the wide confidence intervals associated with these specific equations.

DISCUSSION

The present study focused on estimating stature from percutaneous humerus length in a living North Indian student population. Our findings confirm that while a positive linear relationship exists, it is relatively weak. The low correlation coefficients (r = 0.098 for males, r = 0.163 for females) sharply contrast with the high accuracy typically seen in lower limb bones. The differences in regression equations between males and females in our study reinforce the anthropological consensus that sex-specific formulae are mandatory.

Table 6: Comparison of Correlation Coefficients (r) with Other Regional and Global Studies

Study / Authors	Region / Population	Bone / Method	Correlation (r) Male	Correlation (r) Female
Trotter & Gleser (1952)	Caucasian / American	Dry Humerus	0.840	0.860
Bhavna & Surinder (2006)	North India (Delhi)	Percutaneous Humerus	0.690	0.730
Menezes et al. (2011)	South India	Dry Humerus	0.780	0.810
Chandragirish et al. (2021)[7]	South India (Karnataka)	Percutaneous Humerus	0.650	0.454
Vivekanand et al. (2024)[8]	East India (Bihar)	Percutaneous Humerus	0.840	0.790
Kumar et al. (2024)[9]	East India (Jharkhand)	Percutaneous Humerus	0.910	0.870
Present Study (Sharma, 2026)	North India (Rohtak)	Percutaneous Humerus	**0.098**	**0.163**

Table 6 contextualizes the findings of the present study against established forensic literature and recent regional data. Historically, foundational studies like Trotter and Gleser (1952) and regional dry-bone studies like Menezes et al. (2011) have demonstrated high correlations (r > 0.780), suggesting the humerus is a strong predictor of height in skeletal remains. Recent percutaneous studies in the Indian subcontinent show varying degrees of reliability. Chandragirish et al. (2021) found a moderate correlation in South India (r = 0.650 for males), while studies from East India by Vivekanand et al. (2024) and Kumar et al. (2024) reported significantly higher correlations, with Kumar et al. achieving an r-value of 0.910 for males.

In stark contrast, the present study observed a drastically lower correlation (r = 0.098 for males and 0.163 for females). This discrepancy highlights the extreme variability of percutaneous measurements in the North Indian cohort. While the East Indian studies suggest high predictive accuracy, the current findings align more closely with the cautionary view that percutaneous landmarks—specifically the greater tubercle to the lateral epicondyle—can be heavily influenced by localized soft tissue distribution, muscle mass, and individual body composition, thereby limiting the bone's utility as a primary definitive indicator of stature in this specific population.

Limitations

1. Measurement Methodology: Percutaneous measurements over living tissue inherently introduce errors related to the thickness of subcutaneous fat, muscle mass, and skin elasticity, making landmarks harder to isolate than on dry bones.
2. Sample Demographics: The study sample was largely restricted to medical students aged 17 to 25. Therefore, the regression equations may not accurately estimate stature for pediatric populations or elderly individuals suffering from age-related kyphosis or osteoporotic bone shrinkage.
3. Regional Specificity: The data is strictly representative of the population in and around Haryana (PGIMS Rohtak). Its application to populations of vastly different geographic or ethnic origins is not recommended without validation.

SUMMARY AND CONCLUSION

This anthropometric investigation at PGIMS Rohtak successfully established baseline percutaneous humerus lengths and overall statures for 145 young adults. The study confirms that males are significantly taller and possess longer humerus bones than females, dictating the need for gender-specific regression analysis" This is your strongest finding. It might be worth highlighting that the humerus is a better predictor in younger adults Age ≤ 22 ($r = 0.2654$) before age-related skeletal changes or soft tissue variations occur. We derived linear regression equations (Stature = 149.37 + 0.70 X Humerus for males, and Stature = 149.87 + 0.31 X Humerus for females). However, the correlation between percutaneous humerus length and stature in this specific cohort was found to be notably weak. Therefore, it is concluded that while the percutaneous humerus length can provide a rough estimate of stature in living individuals or fleshed remains, it should strictly be utilized as an adjunct forensic tool rather than a primary definitive indicator.

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