



Original Research Article

ESTIMATION OF STATURE FROM PERCUTANEOUS RIGHT FEMORAL LENGTHS IN 2ND AND 3RD PHASE UNDERGRADUATE MBBS MALE STUDENTS OF A MEDICAL COLLEGE OF INDIA

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ABSTRACT

Background: When an individual passes away in a large, densely populated, and diverse country like India, identifying the deceased is a critical task with significant legal implications. Forensic pathologists face a considerable challenge in this environment, as the rapid rate of decomposition and other post-mortem changes can quickly degrade a body. However, skeletal remains, particularly bones, are more resistant to these processes and can provide valuable evidence for a longer period. Stature is one of the most important data for identification, necessitated by medico-legal experts or medical jurisprudence as well as in anthropological research. Given the different factors influencing human development (e.g., racial factors, dietary habits, occupational status, etc.), this study will attempt to establish a relationship between human stature and percutaneous femoral length of right side, as well as to correlate with sex. In the current study, an attempt has been made to determine the linear relationship between stature and percutaneous length of Right Femur of male students studying in 2nd and 3rd Phase of MBBS Examination in a Government College of West Bengal

Materials and Methods: After getting institutional ethical committee clearance, the study was conducted over the 122 Male Undergraduate Students screened through the inclusion and exclusion criteria.

Results: In the current study, the study population comprises of 122 Male undergraduate students of 2nd and 3rd phase of MBBS Curriculum, selected through the complete enumeration method. This study was conducted to establish a correlation and linear regression between the percutaneous lengths of the right radius with stature. The mean height of male subjects was **171.37 ± 5.726 cm**. The mean percutaneous length of the right Femur was **42.39 ± 2.27 cm**. The right femoral length also showed a strong correlation with stature: Right femur : **r² = 0.427, p < 0.0001**. Regression analysis was performed to derive equations for estimating stature from right femoral lengths : **Right Femur : Y = 1.137X + 90.127**

Conclusion: The morphometrical determination of stature from right femoral length will help to reduce the subjective variation to an extent that can be modified and sophisticated later through more thorough detailing.

Keywords: Anthropometry, Male, MBBS, Students, Stature, Right, Femur, Percutaneous length.

INTRODUCTION

Personal identification is a fundamental component in forensic science, medical jurisprudence, and anthropology, serving as the backbone for a wide range of critical applications. From solving criminal cases and conducting medico-legal investigations to identifying victims in mass disasters, accidents, and cases of missing persons, the ability to accurately establish identity holds both legal and humanitarian significance. In many instances, especially where bodies are mutilated, decomposed, or dismembered, traditional methods such as facial recognition, fingerprinting, or dental comparison may not be feasible. Forensic anthropology plays a pivotal role by reconstructing an individual's biological profile using skeletal or soft tissue remains. This includes determining key characteristics such as sex, age, ancestry, and stature. Among these, stature is particularly valuable as it helps significantly narrow the field of potential matches in unidentified cases.

Absolute identification refers to the definitive establishment of an individual's identity through unique and unchanging biological markers. These include fingerprint patterns, DNA profiling, iris recognition, and dental records. All of which are highly specific and remain consistent over time. These methods provide the highest degree of certainty in forensic investigations, enabling conclusive matching with existing records. DNA analysis, in particular, has revolutionized forensic science due to its unparalleled accuracy, even when only small or degraded biological samples are available.

Stature is one of the most important data among the "Big 4" for identification, necessitated by medico-legal experts or medical jurisprudence as well as in anthropometrical research. There are studies that utilize different length from "womb to tomb" to estimate an individual's stature. However, there is relative lack of important information regarding the estimation of stature based on percutaneous femoral length in recent years, especially in this part of the nation.

Estimating an individual's stature is a fundamental practice in forensic anthropometry and in different medico-legal investigations. The femur, being the longest bone of the body, can be considered as one of the reliable predictor of height due to its strong correlation with overall body size.

Stature estimation from available fragments becomes a critical component of the forensic toolkit. It not only assists in narrowing down the victim's identity but also contributes significantly to the reconstruction of a biological profile, especially when other identifying features are absent. These challenges highlight the growing need for reliable, scientifically validated, and population-specific methods for estimating stature from partial remains, methods that are indispensable in forensic medicine,

legal investigations, mass disaster response, and human rights inquiries.

Accurate stature estimation requires consideration of various factors, including ethnicity, nutrition, occupation, and environmental influences. These elements significantly impact human growth and body proportions, underscoring the importance of population-specific models particularly in a diverse country like India. The present study addresses this need by examining the correlation between stature and percutaneous right sided femoral lengths of the body, with a focus on male sex to improve the reliability of forensic identification methods.

Arif Viqar (2018) conducted a study to estimate the stature based on femur length in the North Indian male population. The research focused on individuals aged 21 to 30, with a mean age of 22.31 ± 1.61 years. Heights ranged from 152.4 cm to 193 cm, with a mean height of 173.89 ± 6.77 cm. The mean percutaneous femur length for both sides was 45.72 ± 2.02 cm, with measurements of 45.75 ± 2.03 cm for the left and 45.68 ± 2.01 cm for the right femur. The difference between the two sides was not statistically significant ($p > 0.05$). The average stature estimated from femur length was 174.19 cm, with the femur providing the most accurate stature estimate (SD = 6.77 cm) in this population.^[1]

In 2016, Rameswarapu Suman Babun conducted a study estimating body stature using femoral length in a South Indian population. The study involved 100 dried human femurs and used a regression equation based on femoral length and inter-trochanteric crest measurements, which averaged 41.66 cm and 5.98 cm, respectively. A Pearson correlation coefficient of 0.64 was found, leading to the regression equation: $y = 18.85 + 3.2x$. The R-squared value was 0.426. Comparing estimated and observed femoral lengths showed consistent results, with the differences being statistically insignificant ($p > 0.05$), validating the regression model.^[2]

In 2022, Sunanda Raina estimated femur length using 50 dry, processed femora from complete adult cadavers at the Department of Anatomy. The total femur length was first measured with an osteometric board and then confirmed using a thread. The study included 25 left and 25 right femora. The mean lengths of the right femur segments were: Segment 1 = 8.10 ± 0.706 cm, Segment 2 = 8.30 ± 1.346 cm, Segment 3 = 10.43 ± 1.914 cm, Segment 4 = 13.52 ± 1.543 cm, and Segment 5 = 3.10 ± 0.413 cm. The overall mean length of the left femur was 43.53 ± 2.785 cm, and the right femur was 43.43 ± 2.434 cm, with a p-value of 0.782.^[3]

In a study by Tapas Ghosh(2015), femur fragments (specifically popliteal length) were used to estimate stature in the Bengalee population. The measurement of popliteal length was taken from the lower end of the linea aspera to the ground where the condyles meet. The findings showed a strong correlation between total femur length and the measured fragment. The regression equation derived from the study ($n=148$) is $y = 20.1184x$, where "x" is the

popliteal length in centimeters and “y” is the total femoral length. This equation can be used to estimate stature with an appropriate multiplying factor.^[4]

In 2022, Jaydip Trivedi conducted a study on estimating body height using tibia and femur measurements across different age groups. The study relies on linear regression models, assuming a linear relationship between long bone size and living stature. Accurate stature determination requires complete femur lengths, including proximal and distal epiphyses. This study aimed to estimate femur length from bone fragments, such as intertrochanteric crest length, transverse diameter of the femoral head, and bicondylar breadth. The findings show that the transverse diameter significantly influences the results, allowing for stature estimation based on calculated femur length from fragments using regression equations. that the transverse diameter significantly influences the results, allowing for stature estimation based on calculated femur length from fragments using regression equations.^[5]

Joshua Tetteh (2021) studied the estimation of height and sex from percutaneous femoral length in the Ghanaian population, involving 505 participants (261 males and 244 females). The study found that males were significantly taller than females ($p < 0.001$) with a mean height difference of 9.23 cm, and males also had longer left and right femur lengths ($p < 0.001$). A paired samples t-test showed no significant difference in femur lengths between left and right sides. Binary logistic regression revealed that a negative value indicated male and a positive value indicated female. The left femoral length accurately estimated sex for 62.1% of males and 56.1% of females, while the right femoral length did so for 60.9% of males and 57% of females, leading to an overall classification accuracy of 59.2%, compared to 51.7% for the null model.^[6]

Diana Laishram (2021) studied the derivation of a regression equation for estimating stature based on femur measurements from 200 unpaired, pathology-free femurs of both genders. The results revealed that the mean difference between the minimum and maximum neck-shaft angles was greater on the right side, while the vertical diameters of the head were consistent on both sides. Femur lengths ranged from 37.5 cm to 50.7 cm on the right side and from 36 cm to 48.6 cm on the left side, showing mean differences of 2.14 cm and 2.28 cm, respectively. The correlation coefficient between the right and left femurs was significant, ranging from 0.5 to 0.7 on the right and from 0.3 to 0.5 on the left, although the neck-shaft angle had a poor correlation. The mean maximum femur length was 43.21 cm for 108 right femurs and 43.2 cm for 92 left femurs. In males, the maximum femur length was approximately 45.9 cm, while in females, it was about 42.6 cm. Pearson and Bell reported maximum lengths of 44.7 cm in males and 40.9 cm in females.^[7]

Pankaj Kumar conducted a study on estimating stature based on femur length, using a sample of 80 rural individuals (40 males and 40 females) aged 18

to 55 years. The study measured cadaveric length and femur segments, focusing only on the right femur to ensure consistency. The regression analysis showed that for the rural male group, segment-2 of the femur had a high determination index of approximately 0.89, indicating accurate stature predictions in 89% of cases. In contrast, the index for segment-1 was lower at around 0.63 and did not prove significant when all segments were analyzed together, suggesting it may have a counter effect on the other segments. Overall, segment-2 was preferred for predicting stature, followed by segments-3 and 4. The findings align with previous research indicating that longer segments correlate better with stature.^[8]

Rakesh K. Vora (2019) studied the estimation of total femoral length from the epicondylar length of the femur using 208 normal dry human femurs (104 right and 104 left, with 150 male and 58 female). The study measured Epicondylar Breadth (EB) and Total Femoral Length (TFL), revealing a high correlation (0.828) between EB and TFL. A regression equation was derived for estimating TFL from EB: $B = 338.004 + A * 1.390$ (where A is EB and B is TFL). This equation allows for estimating total femoral length even without an intact femur, which can aid in estimating stature across different sexes and population samples.^[9]

Laxman Khanal (2016) studied the estimation of femur length from its proximal and distal segments in the Nepalese population using a regression formula. The cross-sectional study analyzed sixty femora (30 right and 30 left) without sex distinctions. The intertrochanteric (ITC) measurement was (5.04 ± 0.71) cm, lower than the Indian population average reported by Singh et al. (6.31 cm). ITC showed a weak correlation with the mid-femur length (MFL), with a coefficient of (0.275), compared to (0.58) in Singh S et al.'s study. This discrepancy may be due to geographic and racial differences. The mean neck length (NL) was (3.78 ± 0.53) cm, with a high NL considered a risk factor for proximal femoral fractures, influenced by osteoporosis and bone mineral density.^[10]

In 2013, Chhikara et al. conducted a study comparing body height and percutaneous femur length among North Indian students. The study demonstrated a statistically significant and positive correlation between stature and percutaneous femur length in both male and female participants. They developed linear regression equations for estimating stature based on femur length. The mean percutaneous femur length was found to be 41.9 cm for males and 42.4 cm for females, while the mean height measured 172.75 cm for males and 159.10 cm for females. Additionally, the study indicated that a male's height is approximately 4.11 times the length of his femur, whereas a female's height is about 3.74 times the length of her femur.^[11]

In 1976, B. R. Kate and R. D. Mujumdar conducted a study on stature estimation from the femur and humerus using regression and autometry. The focus of this study was to enhance the accuracy of stature

estimation from long bones for forensic applications in India. This study aimed to determine whether regression formulas developed for Western populations, specifically Pearson's formula, were applicable for estimating the height of individuals from India. A new method called autometry was introduced, which suggests that certain body proportions, such as the ratio of a long bone's length to an individual's stature, remain constant regardless of race or sex. They developed new regression equations for stature estimation based on the femur and humerus of Indian cadavers from Amritsar and Nagpur. The newly formulated equations showed statistically significant differences from Pearson's formulas. The equations are as follows: for male humerus ($s = 51.767 + 3.612h$); for female humerus ($s = 49.800 + 3.705h$); for male femur ($s = 51.905 + 2.592f$); and for female femur ($s = 50.501 + 2.599f$). This method is based on the concept that a bone's length has a consistent, proportional relationship to an individual's total stature, expressed as a multiplication factor or percentage. The study established a total average multiplication factor of 3.7 (or 27% proportion) for the femur and 5.2 (or 19.2% proportion) for the humerus in the Indian population.^[12]

Kumar A, Shangloo P, Sharma M conducted a study on the estimation of stature from length of the femur in the adult population of Jammu and Kashmir. This study derived a reliable regression formula for estimating stature from femur length in the adult population of Jammu and Kashmir, addressing a gap in previous data. It establishes a direct correlation between stature and femur length, resulting in specific regression equations tailored to this population. These findings relate to a more accurate method for stature estimation compared to formulas from other populations, identifying the importance of population-specific standards in forensic science and anthropology.^[13]

Ashish Kumar Singh conducted a study on Estimation of Stature Based on Lower Limbs: A Study Among the Male Children from Uttar Pradesh's Chandauli, Mirzapur Districts. This study involves a cross-sectional sample of 501 male children, aged 8 to 14 years, to explore the relationship between lower limb segments and stature. Four measurements were taken: stature, trochanterion length (TL), tibial-lateral length (TLL), and bi-epicondylar femur breadth (BFB). The average heights were: Actual Height: 137.96±11.89 cm, TL: 70.19±6.98 cm, TLL: 36.63±4.16 cm, BFB: 8.15±0.68 cm. All measurements showed a strong positive correlation with height at $p < 0.01$: Height vs. TL ($r = 0.960$), TLL ($r = 0.899$), and BFB ($r = 0.824$). The models explained a significant portion of variance: TL ($R^2 = 0.922$), TLL ($R^2 = 0.809$), and BFB ($R^2 = 0.680$). An independent t-test indicated no significant difference between actual and predicted heights ($p > 0.01$), with a mean actual height of 137.96 cm and predicted heights around 137.9 cm, affirming

the strong correlation between height and the measured segments.^[14]

MATERIALS AND METHODS

After getting the permission from IEC of the Institute, the informed valid consents were collected from willing participant Male and Female Students of 2nd and 3rd Phase of MBBS curriculum. Only the Male participants were included in the current cross-sectional observational study after being screened through following exclusion criteria:-

Exclusion Criteria

1. Any apparent bone diseases.
2. Any apparent skeletal deformities.
3. History of fracture of long bones of forearms

Study sample:- 122 male students were included as study population by complete enumeration method depending on the inclusion and exclusion criteria.

Techniques: The measurements for the study were taken as specified below: -

Measurements were taken by the same instruments (Stadiometer and Standardized Spreading calliper) by same observer, ignoring the soft tissue thickness. All these measurements had been repeated thrice and the mean value of the observation were noted to reduce the intra observer bias.

Stature (height) of the individual had been measured using Stadiometer in Frankfurt plane (with head adjust instrument) with subjects on standing and trunk straight position. The measurement was recorded in centimeters up to one decimal.

To measure the Femoral Length, subjects were asked to stand upright in the anatomical position, facing forward with arms at the sides and knees fully extended. This standardized posture ensures consistent identification of anatomical landmarks. The observer initiated the process by palpating the superior surface of the greater trochanter, a prominent bony structure located just below the hip joint on the lateral side of the thigh. To facilitate easier palpation, the subject was then instructed to flex the knee to approximately 20 degrees. This slight bend relaxes the surrounding musculature, making deeper bony landmarks more accessible. In this position, the lateral epicondyle of the femur, located on the outer surface of the distal thigh just above the knee can be more easily identified. Once both the greater trochanter and lateral epicondyle were located, the observer marks these reference points on the skin using a surface marking pencil.

Then, following the identification of surface landmarks, the same observer performed three separate measurements using a spreading caliper to ensure reliability and consistency. The mean of these three readings had been calculated and recorded in centimeters, rounded to one decimal place for standardization. This procedure was conducted independently for right femur.

Then the data had been tabulated and appropriate statistical tests [e.g. Mean, SD, SE, Correlation Coefficient etc] were done.

RESULTS

Total 199 students out of 400 of the 2nd and 3rd phase undergraduate MBBS Students, only 199 gave informed consent for being the study subject. The gender frequency distribution of the sample is shown in Table 1. Total sample size 199 among them 122 male and 77 female subjects. But only Male Samples have been included in the current study.

Table 1: Frequency distribution of study subjects according to their gender (n=199)

Sex	Frequency	Percent
Female	77	38.7
Male	122	61.3
Total	199	100.0

Table 2: Frequency distribution of Male study subjects according to their Age. (n=122)

Sex	Age in Years	Frequency	Percentage
Male	<20	4	3.3
	20-22	86	70.5
	>23	32	26.2
	Total	122	100.0

The age frequency distribution of the sample is shown in Table 2. Age Males varied between 18 years to 24 years

Table 3: Descriptive Statistics- Mean, Standard deviation, minimum, and maximum of Male subjects according to their Age. (n=122)

Gender	N	Mean	Std. Deviation	Minimum	Maximum
Male	122	21.53	1.306	19	24

The Descriptive statistics of all samples are shown in Table 3, The Mean and standard deviation of age of the male sample was 21.53 ± 1.306 years.

Table 4: Frequency distribution of Male study subjects according to their Age & Height. (n=122)

Sex	Age in Years	Ht. cm	Frequency	Percentage
Male	<20	164-171	4	3.3
	20-22	160-184	86	70.5
	>23	156-188	32	26.2
	Total		122	100.0

Table 5: Descriptive Statistics- Mean, Standard deviation, minimum, and maximum of Male study subjects according to their height

Gender	Ht.(cm)	Minimum (cm)	Maximum (cm)	Mean (cm)	Std. Deviation
Male	Ht.(cm)	152	188	171.37	5.726

The height and age frequency distribution of all samples are shown in Table 5. Height and age of Males between 18 years to 24 years, 152cm to 188cm, The Mean and standard deviation of the height of the male sample were 171.37 ± 5.736 (cm).

Table 6: Descriptive Statistics- Mean, Standard deviation, minimum, and maximum of all study subjects according to their Height & Percutaneous Length of Right Femur

Gender	Ht.(cm)	Minimum (cm)	Maximum (cm)	Mean (cm)	Std. Deviation
Male	Ht.(cm)	152	188	171.37	5.726
	RPFLF. (cm)	37.50	50.50	42.39	2.27

The Descriptive statistics of Right Percutaneous Length Femur (RPFLR) of all samples are shown in Table 6, The Mean and standard deviation of height

of the male sample was 171.37 ± 5.726 (cm). The mean and standard deviation of Right Percutaneous Length of Radius of the males are 42.39 ± 2.27 (cm).

Table 7: Pearson's correlation coefficient of Height & Percutaneous Length of Right Radius of the Male study subjects

	Ht.(cm)	RPFLR. (cm)
Ht.(cm)	Pearson Correlation	1
	Sig. (2-tailed)	.654**
	R ²	.427
	N	122
RPCLF. (cm)	Pearson Correlation	.654**
	R ²	.427
	Sig. (2-tailed)	.000
	N	122

**Correlation is significant at the 0.01 level (2-tailed).

The prediction of a significant relationship amongst the pair of variables was determined by the "Correlation coefficient" i.e., Pearson's 'r'. The relationship between the changes of a dependent variable (say, y) and an independent variable (say, x) was ascertained by simple linear regression, with the "Regression coefficient (m)"; where the model of the regression equation was $y = mx + c$ [where $c = y$ -intercept, when $x = 0$]. As in every equation; a 95% confidence interval (which was equivalent to 1.96

standard deviation) was accepted and the standard error of regression (STE) was calculated. The final equation model was $y = (mx + c) \pm (1.96 \times \text{STE})$.

The parameters were tabulated and statistically analyzed. The correlation coefficient (r) was found to be 0.654 ($p=0.000$) for the right ulna with stature.

Correlation Analysis: The correlation coefficients indicate the strength of the association between height and the percutaneous length of the femur.

Table 8:

Bone	Correlation Coefficient (r ²) with Stature	p-value
Right Femur (RPCLF)	0.427	<0.01

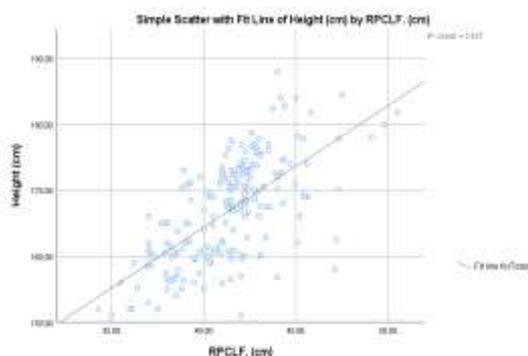
- All correlation values above (r²) 0.4 indicate a strong positive relationship between the femurs of the study samples and stature.
- The Right femur ($r^2 = 0.427$) had the strong correlation with height, making it one of good predictor of stature from long bones.
- The p-values (<0.01) indicate that these relationships are highly statistically significant, meaning there is a less than 1% probability that these correlations occurred by chance.

Table 11: Regression Equations for Stature with Percutaneous femur length of right side

Bone	Correlation Coefficient (r ²)	Regression Equation (Y = mx + c)	p-value
Right Femur (RPCLF)	0.427	$Y = 1.137 X + 90.127$	<0.01

The regression coefficient (m) indicates the increase in stature per cm increase in bone length:

- For the right femur ($m = 1.37$): Every 1 cm increase in right femoral length results in an increase of approximately 1.37 cm in stature.



Graph 1: Right Percutaneous Length of femur (RPCLF)

- Scattered diagram showing the percutaneous length of the right femur to height taken in centimeters of all study subjects.

DISCUSSION

Personal identification is a crucial aspect of forensic anthropology, especially in criminal investigations, mass disasters, and medico-legal cases. Stature estimation plays a significant role in forensic science, anthropology, and legal medicine, as it helps identify individuals when only body fragments are available. The estimation of stature from skeletal remains, particularly long bones, has been an area of extensive research. The present study aimed to determine stature from the percutaneous length of the radius and ulna in both sexes among 2nd and 3rd professional M.B.B.S. students at Burdwan Medical College.

The study analyzed the correlation between stature and percutaneous forearm bone lengths using statistical methods, including correlation coefficients and regression equations. The results demonstrated a strong positive correlation between stature and the percutaneous lengths of the radius and ulna, consistent with previous research conducted in different populations.

In the Current Study: The mean height of male subjects was 171.37 ± 5.726 cm.

The mean percutaneous length of the right femur was 42.39 ± 2.27 cm.

The right femoral length also showed a strong correlation with stature:

Right femur: $r^2 = 0.427$, $p < 0.0001$

These findings indicate that right femoral length can be used reliably for stature estimation

Regression analysis was performed to derive equations for estimating stature from radial bone lengths

Right Femur: $Y = 1.137X + 90.127$

The current study's regression equations align closely with findings from other Indian population studies, suggesting that region-specific anthropometric models are valid but should be further refined with larger datasets.

This study concludes that the percutaneous lengths of the right femur can be effectively used to estimate stature. The findings reinforce the well-established relationship between long bone measurements and height estimation in forensic anthropology. The regression equations derived from this study can serve as a useful reference for forensic experts in cases where only femur bones are available for identification.

A broader study with a more diverse population can further validate these findings.

CONCLUSION

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Conflict of Interest

The authors declare that there is no conflict of interest. This research work is a part of the Dissertation of the First Author, submitted at the West Bengal University of Health Sciences in compliance with partial fulfilment of eligibility for the MD Examination for the year 2026.

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