A study on estimating body height from length of ulna of adult Nepalese population

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ABSTRACT

Introduction: Stature estimation plays a vital role in anthropological and forensic investigations, particularly in regions like Nepal with diverse ethnic populations. Among long bones, the ulna is frequently utilized due to the ease of palpation of its proximal and distal landmarks. However, limited research exists correlating ulna length and stature in the Nepalese population. So, the objective is to estimate body height from ulna length and assess its correlation with sex in adult Nepalese population.

Methods: A cross-sectional study was conducted at Kathmandu University School of Medical Sciences, involving 299 healthy students (107 males and 192 females). Height was measured using a stadiometer, while ulna length was recorded using a vernier caliper. Data were analyzed using SPSS v16.0. Independent and paired t-tests were employed to assess sex and side differences, while simple linear regression generated stature prediction equations.

Results: In overall population, ulna length showed a strong bilateral correlation with stature, conforming its reliability for height estimation. Males had significantly greater mean height (167.3 ± 12.1 cm) and ulna length (right: 26.7 ± 1.3 cm; left: 26.5 ± 1.3 cm) than females (height: 156.1 ± 6.2 cm; right: 24.5 ± 2.6 cm; left: 24.2 ± 1.3 cm). Statistically significant side asymmetry was observed, with the right ulna slightly longer in both sexes. Regression analysis revealed a stronger correlation between ulna length and height in females, especially with the left ulna ($r = 0.732$, $R^2 = 0.536$). In contrast, males showed weak correlations (right ulna: $r = 0.216$; left: $r = 0.193$).

Conclusion: Ulna length is correlated with height of a person, particularly the left ulna in females, is a reliable predictor of stature in the Nepalese population. The findings highlight the necessity of sex and population specific models for accurate stature estimation, especially in forensic and clinical contexts. Further research including broader geographic representation is recommended for enhanced applicability.

Keywords: Anthropometry, Sex Characteristics, Stature, Ulna.

INTRODUCTION

Stature estimation is a crucial aspect of anthropological and forensic studies, especially for personal identification in medico-legal investigations.[1] Nepal is a country where there is wide variety of ethnic population. Height of individual and length of long bones are affected by many factors such as race, age, sex, heredity, climate and nutritional status.[2] Various body parts have been explored for their correlation with human height, enabling stature estimation through regression models but studies show that because of easily palpation of ulna proximal and distal end it is commonly used.[1-5]

Among the various population it has confirmed that there is strong positive correlation between ulna length with height.[2,6] Studies also reinforced the importance of population-specific regression models due to genetic and environmental influences.[2,6,7] Stature estimation has been carried out using tibial and ulnar measurements, radiographic hand assessments, and skeletal collections, with most studies relying on direct bone measurements and others applying X-rays or scans through advancing technologies.[1,7,8,9] Agnihotri et al. highlighted the significant relationship between ulna length and height in

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the Indo-Mauritian population, emphasizing the utility of combining these measurements for enhanced predictive accuracy.[1] Similarly, Amidu et al. examined ulna length among the Ghanaian population, confirming their strong positive correlation with height and reinforcing the importance of population-specific regression models due to genetic and environmental influences.[2]

Many researchers have traditionally relied on direct measurements of bones from established skeletal collections, such as the Terry Collection, Dart Collection, Giraudi Collection and Hamann-Todd Collection.[9-12] However, more recent studies have increasingly utilized imaging techniques, supported by advancements in technology and improved access to skeletal data.[13-15] Among these, post-mortem computed tomography represents the most advanced approach, aligning with the global shift toward virtual autopsy methods.[16,17] Although direct bone measurements tend to yield more accurate estimations than radiographic methods[19], their application in countries like Nepal remains limited due to the scarcity of comprehensive skeletal collections.[8]

Collectively, these studies affirm the importance of ulna length in height prediction, advocating for tailored models to accommodate population-specific variability.[1,3] These methodologies are pivotal for both forensic applications and anthropometric research, particularly in scenarios involving fragmented or incomplete skeletal remains.[18] The relation between the various dimensions of upper limb and stature has been reported but there is lack of studies about the ulna and the stature of Nepalese population.[1-4] It will assist the Forensic department and support anatomists and anthropologists in advancing research on human growth and biological evolution.

METHODS

A descriptive cross-sectional study was conducted in the Department of Anatomy Kathmandu University School of Medical Sciences (KUSMS), Dhulikhel, Kavrepalanchowk, Nepal during the period of June 2023 – May 2024.The ethical clearance was obtained from Institutional Review Committee of Kathmandu University School of Medical Sciences (IRC-KUSMS Ref. no. 49/23). Convenience sampling technique was used for data collection.

Based on the studies carried by Ilayperuma I et al. and Sah RP et al., a total of 299 (107 males, 192 females) apparently healthy students of KUSMS were included in the present study.[6,19] The participants were explained about the objective of the study and written informed consent was taken. The participants with history of hand injury or surgery and with some congenital deformities were excluded from the study. Ulnar length was measured as distance between the most proximal point of olecranon process and the styloid process, in centimeters,using a vernier caliper. The individual's height was measured by stadiometer, in centimeters, with bare feet in anatomical standing position. All measurements were taken by the same observer using the same instrument to avoid any technical errors and to maintain reproducibility. The data were collected and entered into Microsoft Excel (version), then analyzed using SPSS Statistics for Windows (version 16.0) employing descriptive statistics, independent and paired t-tests, correlation, and regression analysis as the main statistical tools.

RESULTS

The present study analyzed a total of 299 individuals comprising 107 males and 192 females. Descriptive statistics of age, height, and ulna length measurements are presented in Table 1. The mean height of male participants was 167.3 ± 12.1 cm, whereas for females it was 156.1 ± 6.2 cm. The average right ulna length in males measured 26.7 ± 1.3 cm, and the left ulna measured 26.5 ± 1.3 cm. In females, the mean right ulna length was 24.5 ± 2.6 cm, while the left ulna was 24.2 ± 1.3 cm.

Independent samples t-test revealed a highly significant difference ($p < 0.001$) between males and females in terms of stature as well as both right and left ulna lengths. The mean difference in height between sexes was 11.1 cm. Ulna length also varied significantly between sexes, with mean differences of 2.1 cm on the right side and 2.3 cm on the left, with males exhibiting consistently

Table 1. Descriptive Statistics

Variables	Category	Mean	SD	Minimum	Maximum
Age	Male	21.1	0.9	19	24
	Female	20.4	1.2	18	27
Height (cm)	Male	167.3	12.1	152	187
	Female	156.1	6.2	129.9	175.0
Ulna Rt (cm)	Male	26.7	1.3	23.0	29.5
	Female	24.5	2.6	21.0	29.0
Ulna Lt (cm)	Male	26.5	1.3	23.0	29.1
	Female	24.2	1.3	21.0	28.5

Table 2. Comparison of height of the individual and ulna bone length between male and female (Independent t test)

Variables	Male (n=107)	Female (n=192)	Difference between the mean	t	df	Significance
Height	167.3 + 12.1	156 + 6.2	11.1	10.581	297	0.000
Ulna Rt	26.7 + 1.3	24.5 + 2.6	2.2	7.870	297	0.000
Ulna Lt	26.5 + 1.3	24.2 + 1.3	2.3	14.688	297	0.000

Table 3. Comparison of ulna length between right and left in male and female (Paired t-test)

	Ulna Rt	Ulna Lt	Difference in the mean	t	df	Significance
Male	26.7 + 1.3	26.5+ 1.3	0.2	5.086	106	0.001
Female	24.5 + 2.5	24.2 + 1.3	0.3	1.989	191	0.048

Table 4. Regression Equation

Sex	Side	Correlation Coefficient (r)	R^2	% of determination	Regression equation (Y=a+bX)	p-value
Male	Right	0.216	0.047	4.7	Y=115.327 + 1.948X	0.026
	Left	0.193	0.037	3.7	Y=119.837 + 1.792X	0.047
Female	Right	0.325	0.105	10.5	Y=137.1 + 0.777X	0.000
	Left	0.732	0.536	53.6	Y= 70.687 + 3.528X	0.000
Total	Right	0.820	0.673	67.3	Y=53.883 + 4.226X	0.000
	Left	0.821	0.675	67.5	Y=55.324 + 4.200X	0.000

***Note: Y= Height, X= Ulna Length**

longer ulnas than females (Table 2).

The paired t-test showed a statistically significant difference between the right and left ulna lengths in both males and females. In males, the mean right ulna length (26.7 ± 1.3 cm) was slightly greater than the left ulna length (26.5 ± 1.3 cm), and this difference was statistically significant (p = 0.001). Similarly, in females, the right ulna (24.5 ± 2.5 cm) was longer than the left ulna (24.2 ± 1.3 cm), with the difference also reaching statistical significance (p = 0.048).

These findings suggest that, on average, the right ulna is slightly longer than the left in both sexes, with the difference being more strongly significant in males compared to females(Table 3).

Simple linear regression analysis was performed separately for males and females to estimate stature based on ulna length (Table 4). In males, the correlation between ulna length and height was weak, with Pearson's r = 0.216 for the right ulna and r = 0.193 for the left, accounting for 4.7% and 3.7% of the variance in height, respectively. The

derived regression equations were:

Right Ulna (Male): Height = 115.327 + 1.948 × Ulna Length

Left Ulna (Male): Height = 119.837 + 1.792 × Ulna Length

In contrast, female participants demonstrated stronger correlations. The right ulna exhibited a weak correlation ($r = 0.325$, $R^2 = 10.5\%$), while the left ulna showed a markedly strong association ($r = 0.732$, $R^2 = 53.6\%$) with stature. The corresponding regression equations were:

Right Ulna (Female): Height = 137.1 + 0.777 × Ulna Length

Left Ulna (Female): Height = 70.687 + 3.528 × Ulna Length

The overall study population, without stratification of sex, showed stronger correlation between ulna length and height. The correlation between right ulna length and height ($r=0.820$, $R^2 = 67.3\%$) was similar with correlation between left ulna length and height ($r=0.821$, $R^2 = 67.5\%$). The regression equation for overall study population was observed as:

Right Ulna (Overall population): Height = 53.883+4.226 × Ulna Length

Left Ulna (Overall population): Height = 55.324 + 4.200 × Ulna Length

DISCUSSION

The present study aimed to derive regression equations for stature estimation based on ulna length among adult Nepalese males and females. The results demonstrated significant sexual dimorphism in both height and ulna dimensions, consistent with patterns established in previous anthropometric literature across multiple populations.[2,4,19-22] Similar findings have been reported in Ghanaian, Sudanese, Indian and Iranian populations, underlining the influence of sex on ulna metrics.[2,18,20,23] A small but consistent right left difference in ulna length was observed, suggesting mild asymmetry between the upper limbs. Comparable asymmetries have been documented by Mondal et al., Ilayperuma et al. and Sah et al., though their magnitude may vary across ethnic groups and occupational behaviors, supporting the notion of directional asymmetry, possibly influenced by limb dominance or habitual use.[4,6,19,22]

The present study's findings confirm that the ulna length both right and left side has positive linear relationship with height, indicating that the individuals with longer ulna tend to have greater height. The current study's finding is supported by various studies across the globe.[2,6,23,24] The current study has demonstrated sex-and side-specific variations in predictive strength. Lemtur et al., studied in Nagaland observed stronger correlations in females than in males, highlighting better predictive accuracy in women.[21] Likewise, research conducted in Sri Lanka demonstrated the same trend, with females showing a more reliable relationship between ulna length and stature than males.[6] Collectively, these findings, in agreement with our study, emphasize that ulna length serves as a useful predictor of height, with stronger associations observed in females across South Asian populations. In the present study, the regression equation using left ulna in females was the most predictive model, outperforming all others, aligning with the findings of Mondal et al. and Sah et al., both of whom reported slightly greater predictive accuracy for the left ulna in females than the right.[4,19] In our study, the correlation between ulna length and stature in males was much weaker compared to the Iranian and Turkish populations, where moderate to strong male correlations have been reported. Thus, although all studies consistently show that females have stronger predictability than males, the accuracy of male stature estimation from ulna length in our study is notably lower than in these populations.[23,24]

The variability in slope values across populations can be attributed to genetic, nutritional, and environmental factors influencing bone growth and proportionality, reaffirming the need for population-specific models. This underscores the necessity of developing localized models, especially for forensic and clinical applications. Ulna-based height estimation is particularly valuable in situations involving fragmented remains, immobile patients, or retrospective nutritional assessments.[25-28]

Strength of the current study lies in its sex-stratified design and inclusion of side-specific analysis,

which enhances its forensic utility. However, there are certain limitations to the study, the sample was regionally confined and did not account for geographic diversity or lifestyle factors that could influence bone growth, potentially reducing the generalizability of findings across broader age groups or other populations in different geographic regions within Nepal. Future research should include a broader range of geographical groups within Nepal, explore inter-limb asymmetry in greater detail, and examine other upper and lower limb bones in multivariate models. Validation of the derived equations in independent test samples would also enhance their practical application in forensic anthropology and clinical nutrition.

CONCLUSION

The present study establishes ulna length particularly the left ulna in females as a reliable anthropometric parameter for estimating stature in the adult Nepali population. While female regression models demonstrated strong predictive capacity, the models for males showed limited accuracy, highlighting the need for multivariate approaches in male assessments. These findings have practical implications in forensic identification, clinical assessments, and anthropological research where direct height measurement is not feasible.

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