Nepalese Journal of Zoology

ISSN: 2705-4403 (Print) & 2705-4411 (Online)
www.cdztu.edu.np/njz

Volume 8 | Issue 1 | June 2024

https://doi.org/10.3126/njz.v8i1.67106

Research article

Estimation of human height using ulnar length in the Muslim community of Golbazar Municipality, Siraha, Nepal

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Suggested citation: Shamim S. and Ghimire T.R. 2024. Estimation of human height using ulnar length in the Muslim community of Golbazar Municipality, Siraha, Nepal. Nepalese Journal of Zoology, 8(1):1–6.
https://doi.org/10.3126/njz.v8i1.67106

Article history:
Received: 12 September 2023
Revised: 01 January 2024
Accepted: 13 January 2024

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Abstract

Calculating an individual's height based on bone measurements is critical in identifying unknown bodies, body parts, or skeletal remains. Anthropologists, anatomists, and forensic experts have used a variety of anthropometric approaches to forecast stature from skeletal remains. Although few studies have been conducted to understand ulnar length and height, it has not been conducted in a few ethnic communities of Nepal. This study aimed to analyze the relationship between human height and ulnar length in Muslim communities of Golbazar Municipality, Siraha, Nepal. Two hundred people (male 100 and female 100) aged 20 to 40 years were purposively selected from Golbazaar, Siraha, Nepal. Ulnar length was measured as the distance between the tip of the Olecranon process and the styloid process with the elbow fully flexed. Height was measured from the top of the head to the floor while the participants stood upright in the anatomical position with their heads in the Frankfort plane. Statistical techniques, such as linear regression analysis and correlation coefficients, were used to determine a correlation between ulna length and height. The population's mean ulna length was 26.53 cm (SD = 2.06), and the mean height was 159.59 cm (SD = 9.72). The correlation between ulna length and height was stronger in males (0.46) than in females (0.36). The study established regression equations for height estimation based on ulna length for different age groups, with the strongest correlations found in the 31–35 years age group and weaker ones in the 20–25 years and 26–30 years age groups. The study suggests that ulna length could be a reliable predictor of height, especially when direct measurement is challenging or impossible. However, additional study is required to explore potential differences based on age, ethnicity, and gender and to validate the findings in more extensive and more diverse populations.

Keywords: Anthropometry; Correlation; Height estimation; Regression equation; Ulna length

1 | Introduction

Anthropometry is a discipline that involves standardized measurements of the human body (Popovic et al. 2013). Height is a crucial attribute used for identification and has various applications, such as calculating body mass index, assessing energy requirements, and evaluating growth in children (Satyal et al. 2017; Sah et al. 2018). Estimating height can be important in forensic sciences, and when direct measurement is not possible, it can be estimated using regression equations based on anthropometric indicators. Height varies with race, age, sex, diet, and geographical region (Satyal et al. 2017).

Height measurement is crucial for determining body mass index (BMI), a widely utilized parameter for nutritional assessment. However, measuring height can be challenging for individuals who are bedridden, elderly, frail, and unable to stand, or have spinal deformities (Ilayperuma et al. 2010). The estimation of height from skeletal remains that are incomplete or decomposed is crucial in forensic investigations and anthropological research. In these cases, it is essential to have formulas that rely on the length of the ulna bone as a substitute predictor of stature (Ebite et al. 2008). The ulna bone offers distinct surface features that can be easily identified, allowing measurements to be taken even when the body is in compromised positions (Ilayperuma et al. 2010). Researchers emphasized the importance of developing stature estimation formulas specific to particular populations, as the proportions of different body parts concerning height vary among populations (Yadav et al. 2015). Yadav et al. (2015) emphasized the importance of knowing an individual's age group, race, and geographical region before using a regression equation specific to that group to estimate their height accurately.

This study focused on estimating height from ulna length in a sample of 200 healthy individuals from Nepal's Golbazar Municipality. The goal was establishing a regression equation to predict height based on ulna length, considering gender differences. This research is significant because limited work has been conducted on human height estimation in Nepal using ulna length. By understanding the relationship between ulna length and height, this study aimed to provide

a valuable tool for height estimation in individuals where direct measurement is not feasible or accurate.

2 | Materials and methods

2.1 | Study area

The current study was conducted in Golbazar Municipality of Siraha District in Madhesh Province of south-eastern Nepal (Fig. 1). The municipality covers an area of 111.94 km^2. It is accessible via Bishweshwar Prasad (B.P.) Highway, which is 247 km east of the capital city, Kathmandu. The population of Golbazar Municipality consists of various castes and ethnic groups. Muslim, Yadav, Thakur, Chaudhary, Haluwai, Teli, Dusadh, Kesth, Suri, and Danuwar are the ethnic people in the ward number 11 (study site). Its total population is 6047 and population of male and female from 20 years to 44 years is 2057 (CBS 2021).

2.2 | Data collection

The study included 200 participants (100 males and 100 females) of the Muslim community aged 20–40 years, representing more than 10% of the population of ward number 11 of Golbazar Municipality. Participants with mentally and physically disabled and those suffering from physical injuries, bone pathologies, or other conditions that might affect the length of their long bones were excluded. In contrast, mentally and physically healthy persons were selected in the study. Verbal consent was obtained from each participant.

To collect data, ulna length was measured as the distance between the tip of the Olecranon process and the styloid process with the elbow fully flexed. Height was measured from the top of the head to the floor while the participants stood upright in the anatomical position with their heads in the Frankfort plane (Illayperuma et al. 2010). The measurements were taken using standard anthropometric instruments in centimeters, according to the procedure specified previously (Vallois 1965). All measurements were made by the same observer using the same equipment to ensure uniformity and reproducibility and to minimize technical and inter-observer errors.

2.3 | Data analysis

After data collection, statistical analysis was conducted using Microsoft Excel to calculate various metrics, including mean, standard deviation, standard error, correlation coefficient, regression coefficient, constant value, and t-test for the correlation coefficient. The analysis was done to assess the regression equation for all participants and each gender and age group. The regression equation took the form of y = a+bx, where,

y = Height, x = Ulna length, a = Intercept, and b = Regression statistic or slope of the line

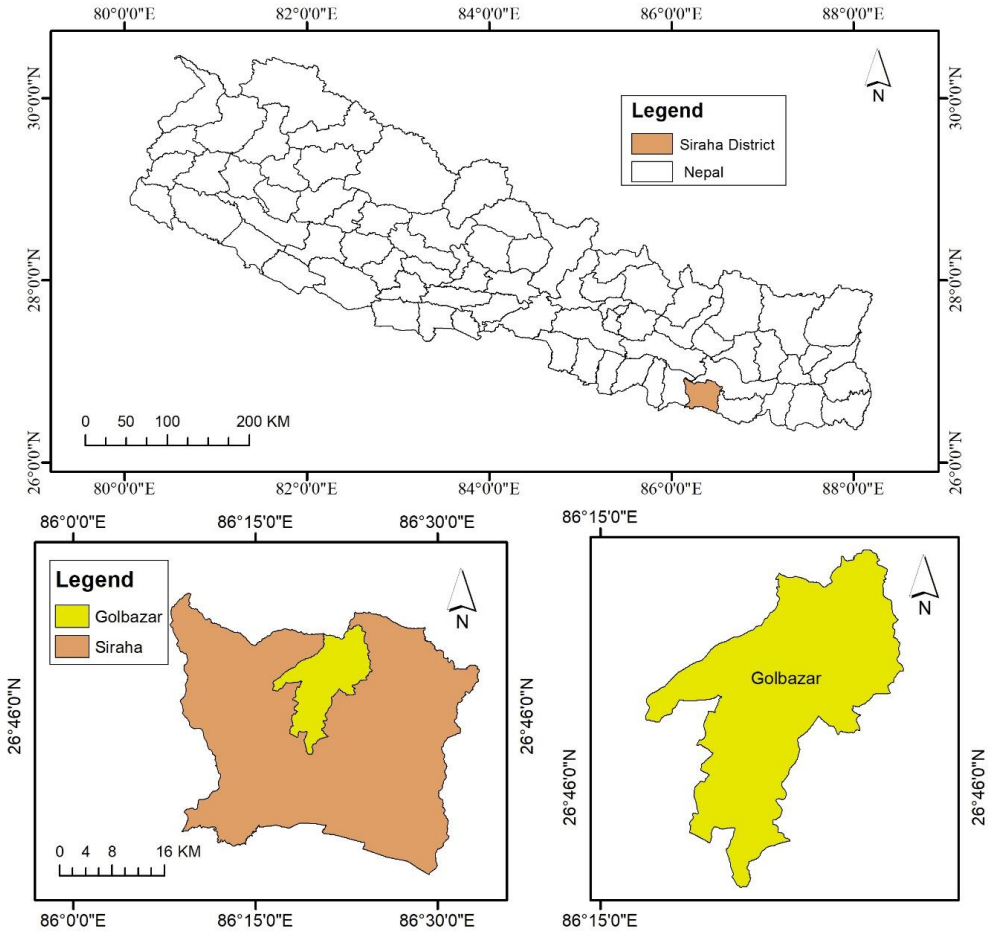

Figure 1. Map of the study area with the Siraha District and Golbazar

3 | Results

In this study, average height of males was higher than females (166.77 ±5.94 cm vs 150.91±7.10 cm) and so was the average length of the ulna (27.85±1.31 cm vs 24.99±3.12 cm). The total population showed an average height of 159.59±9.72 cm and an average ulnar length of 26.53±2.06 and total population. The correlation coefficient (r^2-value) was determined to be 0.63, indicating a positive linear relationship between the two variables. Moreover, regression analysis demonstrated that ulna length accounted for approximately 63% of the variance in height. All data regarding the height and ulna length of males or females or total populations were statistically significant ($p<0.001$). The regression analysis showed that the relationship between ulna length and height was slightly stronger in males than in females (r^2= 0.46 vs 0.36) (Table 1) (Fig. 2A, 2B, 2C).

This study investigated the correlation between height and ulna length in individuals across different age groups. Regression equations were established to estimate height based on ulna length for each age group. The strength of the correlation and the equations varied among the age groups, with stronger correlations observed in the age group of 31–35 years for both males and females. The weaker correlations were observed in the 20–25 and 26–30 years for females and 26–30 years for males (Fig. 3A–3D and 4A–4D).

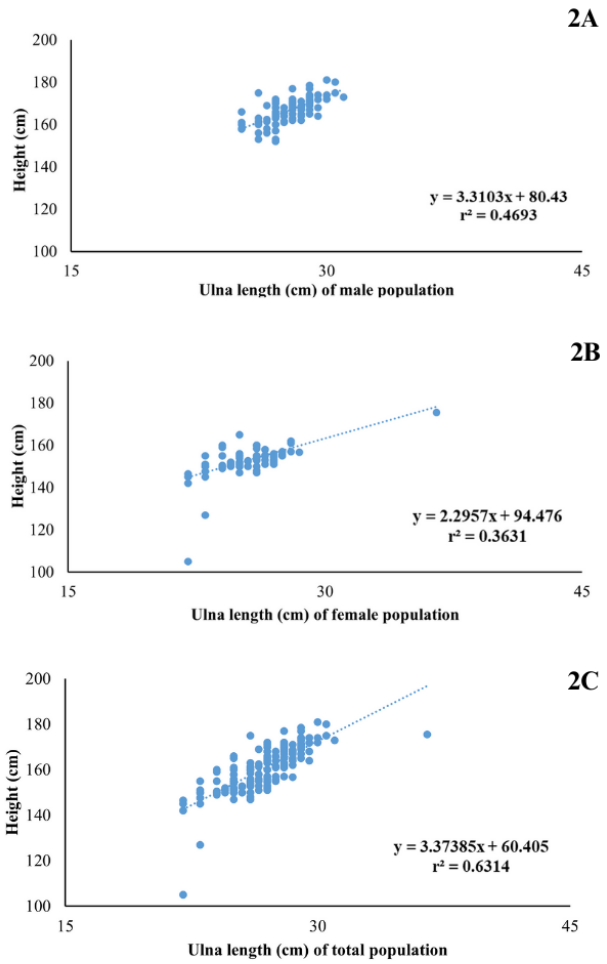

Figure 2. A: Relationship between human height and ulna length in male population (N=100); B: Relationship between human height and ulna length in female population (N=100); C: Relationship between human height and ulna length in total population (N=200).

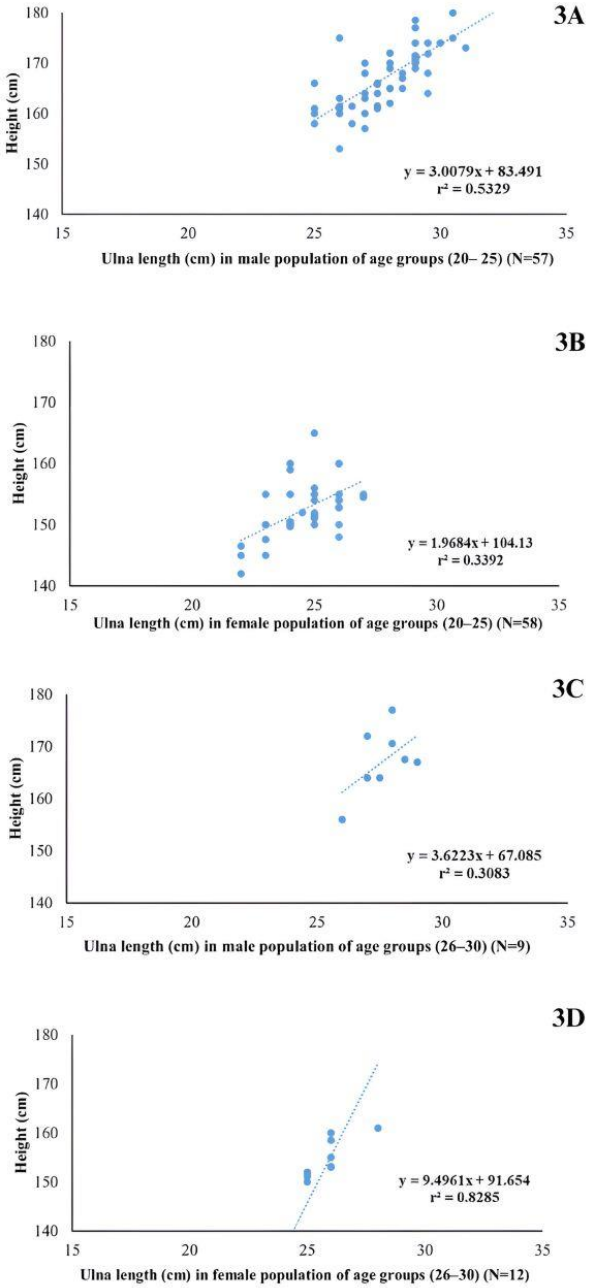

Figure 3. A: Relationship between human height and ulna length in male population of 20–25 years age group (N=57); B: Relationship between human height and ulna length in female population of 20–25 years age group (N=58); C: Relationship between human height and ulna length in male population of 26– 30 years age group (N=9); D: Relationship between human height and ulna length in female population of 26–30 years age group (N=12)

4 | Discussion

The current study is the first of its kind to discuss the ulnar length and height in the Muslim populations of low altitudes, Nepal. The correlation analysis demonstrated a positive

Table 1. Correlation between height and ulna length

Participants	Average height ± SD (cm)	Average ulna length± SD (cm)	r^2	p-value of r^2	Total (n)
Males	166.77 ±5.94	27.85±1.31	0.46	<0.001	100
Females	150.91±7.10	24.99±3.12	0.36	<0.001	100
All	159.59±9.72	26.53±2.06	0.63	<0.001	200

relationship (r^2 = 0.63) between ulna length and height in the overall sample, consistent with previous studies that identified ulna length as a reliable predictor of height (Gauld et al. 2004; Ebite et al. 2008; Borkar 2014; Armah et al. 2017). Regression analysis further supported this relationship by showing that ulna length accounted for approximately 63% of the variation in height. When examining the data by gender, it was found that males had a slightly higher correlation (r^2= 0.46) than females (r^2= 0.36), implying that ulna length may be a more accurate predictor of height in males. Nevertheless, both correlations were statistically significant and indicated a positive association between ulna length and height in both genders.

The regression equations derived from the analysis provided practical formulas for estimating height based on ulna length, with slightly different equations for males: height (y) = 3.103 × Ulna length (x) + 80.42 and females: height (y)=2.29 × Ulna length (x) + 94.47. These equations facilitated a straightforward height estimation using ulna length as the predictor variable (Gul et al. 2020). The study conducted at Nishtar Medical University focused on using ulna length as a reliable and relatively accurate method for estimating an individual's height (Gul et al. 2020). The researchers provided separate regression equations for the entire study group, males, and females: For the whole study group: height = 42.830 + 4.671 × (length of ulna), for males: height = 70.369 + 3.698 × (length of ulna), for females: height = 18.562 + 5.617 × (length of ulna) (Gul et al. 2020). Also, the equations for height estimation from ulna length and found them to be accurate for the study population in Ghana (Banyeh et al. 2022). Interestingly, the height (cm) = 64.7 + 1.7 (arm span) + 2.2 (half arm span) + 2.5 (knee height) equation was used to evaluate the height of the individual in Ethiopia (Digssie et al. 2018). The study found that this equation was a valid proxy indicator of height in the context where height cannot be measured. It can be used to assess the nutritional status of hospitalized and/or bedridden patients, people with skeletal deformities, and the elderly population in Ethiopia. Similar to our results, the regression equations for estimating height from ulna length in the Vietnamese population were height (cm) = 85.61 + (3.16 x ulna length) (males) and height (cm) = 85.80 + (2.97 x ulna length) (females) (Bonell et al. 2017). Furthermore, the regression analysis yielded different equations for each age group, suggesting that the strength of the relationship between ulna length and height varied depending on age. Notably, the age group of 31–35 years exhibited the strongest correlations for both males and females, indicating that ulna length may be instrumental in predicting height for individuals within this age range. Compared to this age group, other age groups like 20–25 years, 26–30 years for females and 26–30 years for males showed weaker correlations. The values of regression equations indicate a low to strong relationship between ulna length and height within each age group (r^2=0.3083–0.8829) and concludes the proportion of variance in height explained

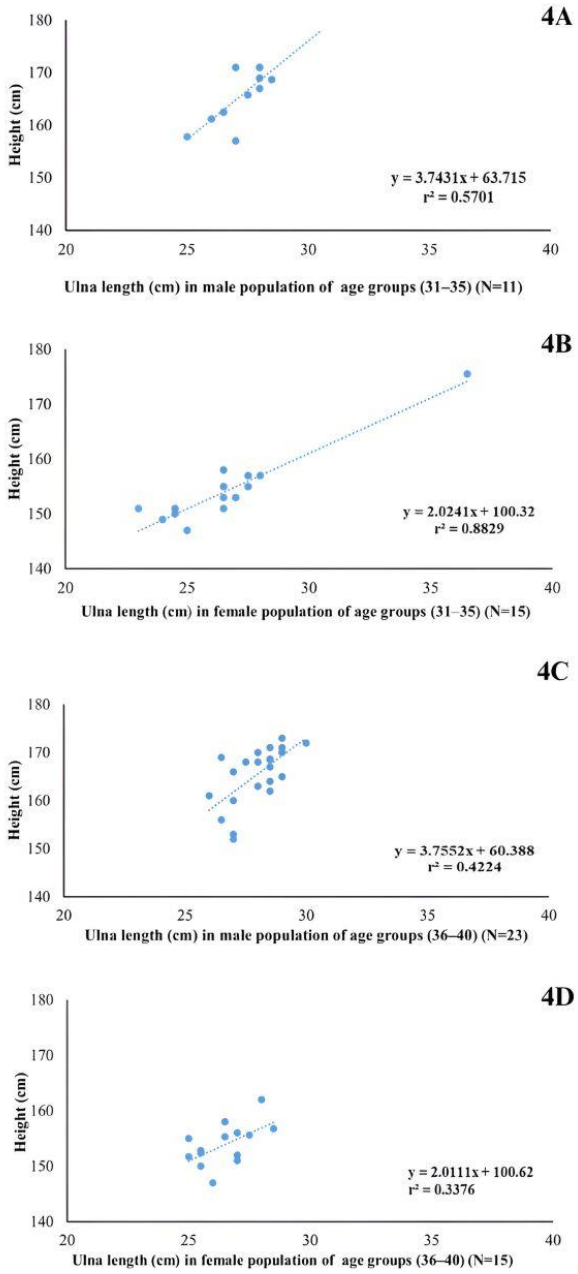

Figure 4. A: Relationship between human height and ulna length in male population of 31–35 years age group (N=11); B: Relationship between human height and ulna length in female population of 31–35 years age group (N=15); C: Relationship between human height and ulna length in male population of 36–40 years age group (N=23; D: Relationship between human height and ulna length in female population of 36–40 years age group (N=15)

by ulna length. The variation in the correlation might be due to the unequal sampling sizes of the current study. In a study conducted by Pandey et al. (2020), it was observed that there

existed moderate positive correlations between height and ulna length among 100 Nepalese youths (male=57 and female=43) of 18-24 years age group. For example, the right ulna exhibited a correlation coefficient (r-value) of 0.473, while the left ulna had a correlation coefficient of 0.491 (Pandey et al. 2020). Similar results were discussed in the earlier reports (Mondal, Malay Kumar et al. 2012; Bonell et al., 2017; Gul et al., 2020). However, level of ossification, mineralization, and nutritional factors may be different in different age groups and these factors should be considered while analyzing the relation of height and ulna length in different age groups. Also, the sex differences in the ulna and tibial lengths in Ghana and several countries (Banyeh et al. 2022), including Nepal might be due to genetic factors.

The research has few limitations. First, the numbers of participants with respect to age groups are not equal. It might have resulted into the different values of correlation coefficient. It is mainly due to the different height ranges of the population. Second, the sampling technique used was purposive. We collected the data only from Muslim populations that represented more than 10% of the total population. The data might not be applicable for all individuals of the heterogenous society. However, we have strictly followed the research methods so that the conclusions here given apply for that homogenous population. The findings suggested that the length of the ulna can serve practical purposes in various fields, including forensic sciences, anthropology, archaeology, clinics, and anatomy. This implies that by measuring the ulna length, one can use the provided regression equations to estimate an individual's height, making it a valuable tool in diverse applications related to human biology and medicine.

Overall, these studies collectively emphasize the positive association between height and ulna length in Muslim populations, highlighting the importance of considering ulna length as a potential indicator of an individual's height.

5 | Conclusions

The height and ulna lengths of individuals in Golbazar Municipality, Siraha District, varied with gender and age. The current study demonstrated a significant positive correlation between ulna length and height, indicating that length can be a possible predictor of human stature. The regression equations derived from this study provide a practical approach for estimating height based on ulna length, particularly within specific age groups. These findings have potential applications in various fields, including forensic anthropology, medical assessments, and growth monitoring.

Acknowledgements

We acknowledge all the local people of Golbazar Municipality for their kind cooperation and support in the field of study. We are grateful to Md Zakiuddin and Md Tabish for providing information and helping us with data collection. We thank the authorities of Golbazar Municipality for their permission to work (Permission No.: 328/2079/080).

Authors' contributions

SS collected the data and analysed them. TRG supervised the work and analysed the data. SS wrote the manuscript draft. Both authors contributed critically to the final version of manuscript and gave final approval for publication.

Conflicts of interest

The authors declare no conflict of interest.

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