

Regression-based Prediction of Stature From Humeral and Femoral Segment Lengths Among Nigerian School Children

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Abstract

Background

Accurate stature estimation is important in forensic anthropology, clinical practice, and anthropometric research when direct height measurement is impractical. Because anthropometric relationships vary across populations, population-specific prediction models are required.

Objective

To develop regression equations for estimating stature from humeral and femoral segment lengths among school-aged children in Southwestern Nigeria.

Methods

A cross-sectional study was conducted among 85 apparently healthy children aged 6–12 years attending Achievers University Primary School, Owo, Nigeria, comprising 44 males and 41 females. Standing height was measured using a stadiometer, while humeral and femoral segment lengths were obtained using standard anthropometric techniques. Pearson's correlation and multiple linear regression analyses were used to assess associations and develop sex-specific stature-prediction equations.

Results

Mean stature was 128.80 ± 8.15 cm in males and 130.10 ± 10.14 cm in females. Stature was significantly correlated with age, humeral length, and femoral segment length in both sexes ($p < 0.001$). Among males, age showed the strongest correlation with stature ($r = 0.723$), whereas femoral segment length showed the strongest correlation among females ($r = 0.838$). Regression models explained 75.4% of the variance in male stature ($R^2 = 0.754$) and 88.3% in female stature ($R^2 = 0.883$).

Conclusion

Age, humeral length, and femoral segment length are useful predictors of stature among Nigerian children aged 6–12 years. The developed sex-specific equations provide preliminary population-specific tools for stature estimation, with potential applications in forensic anthropology, clinical assessment, and anthropometric research. External validation in larger and geographically diverse Nigerian populations is recommended.

1.0 INTRODUCTION

Stature is an important anthropometric characteristic used to describe human body size and proportions and has applications in clinical medicine, forensic anthropology, nutrition, ergonomics, sports science, and biological anthropology (Fawehinmi et al., 2025; Tanko et al., 2020). In forensic investigations, stature forms an important component of the biological profile used in the identification of unknown human remains, particularly when direct measurement of body height is impossible because of fragmentation, decomposition, burning, or dismemberment (Lee et al., 2024; Chu & Stull, 2025). In paediatric practice, stature is also an essential indicator of growth and nutritional status and contributes to the assessment of children whose standing height cannot be measured directly (World Health Organization [WHO], 2006).

Stature can be estimated from several anatomical measurements, including dimensions of the skull, vertebral column, pelvis, hands, feet, and long bones. Among these, the long bones of the appendicular skeleton are particularly useful because their dimensions are closely related to overall skeletal growth and body height. The femur is frequently employed because of its substantial contribution to lower-limb length and its strong relationship with stature, while the humerus provides a useful alternative when lower-limb skeletal elements are unavailable or compromised (Spradley, 2016; Cardoso, 2024). Studies of Nigerian populations have likewise demonstrated significant relationships between long-bone dimensions and stature, supporting their application in regression-based anthropometry (Fawehinmi et al., 2013; Adetona et al., 2024).

Regression equations may vary considerably across populations because of differences in sex, ancestry, geographical location, body proportions, growth patterns, and other biological factors. Consequently, population-specific equations are preferable to direct application of equations developed in unrelated populations (Kamnikar et al., 2024; Lee et al., 2024; Spradley, 2016). Nigerian studies have demonstrated such population variation, with differences in anthropometric relationships reported across ethnic and geographical groups (Fawehinmi et al., 2013; Tanko et al., 2020; Usman et al., 2024; Fawehinmi et al., 2025). These findings emphasise the importance of developing population-specific regression equations rather than applying equations derived from unrelated populations.

Population specificity is particularly important in children because stature and skeletal proportions change continuously throughout growth. Age-related changes in longitudinal bone growth, sex-specific maturation, nutritional status, and the timing of puberty can alter the relationship between long-bone dimensions and stature. Consequently, regression equations developed in adults or other age groups may not provide appropriate estimates for children. Recent anthropological research has consequently emphasised the importance of age- and population-appropriate approaches to subadult stature estimation (Cardoso, 2024; Murray et al., 2024; Chu & Stull, 2025).

In Nigeria, research on stature estimation has examined variables including femoral dimensions, tibial length, upper-arm length, arm span, foot length, and other anthropometric parameters, but much of the available evidence concerns adolescents and adults. Studies have demonstrated significant relationships between these anthropometric variables and stature and have highlighted variation in

stature-prediction equations across Nigerian populations (Didia et al., 2009; Enakpoya et al., 2024; Oghenemavwe et al., 2024; Okon et al., 2024; Adetona et al., 2024; Tanko et al., 2020; Usman et al., 2024; Fawehinmi et al., 2025). These findings reinforce the importance of developing population-specific regression equations. Although these studies demonstrate the usefulness of anthropometric regression for stature estimation, published evidence specifically addressing the combined use of humeral and femoral segment lengths among Nigerian school-aged children remains limited, particularly in Southwestern Nigeria. This represents an important gap because locally derived paediatric equations could provide useful reference tools for anthropometric assessment and forensic applications.

Therefore, this study aimed to develop sex-specific regression equations for estimating stature from age, humeral length, and femoral segment length among apparently healthy school-aged children attending Achievers University Primary School, Owo, Ondo State, Nigeria. Specifically, the study assessed the relationships between stature and these anthropometric variables and developed regression models for stature estimation within the study population. It was hypothesised that age, humeral length, and femoral segment length would demonstrate significant positive associations with stature and provide useful predictors for population-specific stature estimation.

2.0 MATERIALS AND METHODS

2.1 Study Design

This study employed a cross-sectional descriptive design to investigate the relationship between stature and selected anthropometric parameters and to develop regression equations for predicting stature from humeral and femoral segment lengths among school-aged children.

2.2 Study Area

The study was conducted at Achievers University Primary School, Owo, Ondo State, Nigeria. The school, established in 2017, is located within the main campus of Achievers University along Km 1, Idasen/Uteh Road, Owo. It is a co-educational institution with an estimated population of approximately 120 pupils. Owo is located in the northern part of Ondo State, Southwestern Nigeria, and is predominantly inhabited by people of Yoruba ethnicity.

2.3 Study Population

The study population comprised apparently healthy male and female pupils aged 6–12 years enrolled at Achievers University Primary School during the study period.

2.4 Sample Size and Sampling Technique

A total of 85 children, comprising 44 males and 41 females, participated in the study. Participants were selected using a simple random sampling technique from eligible pupils who met the inclusion criteria and whose parents or legal guardians provided informed consent.

2.5 Eligibility Criteria

2.5.1 Inclusion Criteria

Participants were eligible for inclusion in the study if they were between 6 and 12 years of age, enrolled at Achievers University Primary School, apparently healthy at the time of data collection, and had written informed consent provided by their parents or legal guardians.

2.5.2 Exclusion Criteria

Participants were excluded from the study if they had congenital or acquired skeletal deformities, a previous history of fractures or injuries involving the upper or lower limbs, medical conditions known to affect skeletal growth or stature, or were unable to maintain the appropriate anatomical position required for accurate anthropometric measurements.

2.6 Anthropometric Measurements

Anthropometric measurements were obtained using standardized procedures to ensure consistency and minimize measurement error. All measurements were taken with participants barefoot and wearing light clothing. Each measurement was obtained twice, and the average of the two readings was used for statistical analysis.

2.7 Measurement of Standing Height

Standing height was measured using a calibrated portable stadiometer and recorded to the nearest 0.1 cm. Participants stood erect on a flat surface with their heels together, knees fully extended, arms hanging freely by their sides, and head positioned in the Frankfort horizontal plane. The movable headpiece of the stadiometer was lowered gently until it touched the vertex of the head before the measurement was recorded.

2.8 Measurement of Humeral Length

Humeral length was measured on the right upper limb using a flexible anthropometric measuring tape. The measurement was taken from the lateral margin of the acromion process to the lateral epicondyle of the humerus with the arm relaxed in the anatomical position. Measurements were recorded to the nearest 0.1 cm.

2.9 Measurement of Femoral Segment Length

Femoral segment length was measured on the right lower limb using a flexible anthropometric measuring tape. The measurement extended from the superior aspect of the greater trochanter to the lateral femoral condyle with the participant standing in the anatomical position. Measurements were recorded to the nearest 0.1 cm.

2.10 Quality Assurance

Prior to data collection, all measuring instruments were inspected and calibrated according to the manufacturers' recommendations. Measurements were obtained by trained investigators using a standardized protocol to minimize observer variation. Duplicate measurements were performed for each participant, and the mean value was used for subsequent statistical analyses.

2.11 Statistical Analysis

Data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) version 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all study variables and expressed as mean $\pm$ standard deviation (SD).

Pearson's product-moment correlation analysis was performed to determine the strength and direction of the relationships between stature and the predictor variables (age, humeral length, and femoral segment length). Multiple linear regression analysis was subsequently employed to develop gender-specific predictive equations for estimating stature. The coefficient of determination (R^2) was used to evaluate the predictive performance of each regression model. Statistical significance was established at a probability level of $p < 0.05$.

3.0 Results

3.1 Participant Characteristics

A total of 85 apparently healthy school children aged 6–12 years participated in the study, comprising 44 males (51.8%) and 41 females (48.2%). Descriptive statistics for stature, age, humeral length, and femoral segment length, stratified by sex, are presented in Table 1.

The mean stature was 128.80 ± 8.15 cm among males and 130.10 ± 10.14 cm among females. Mean age was comparable between males (7.93 ± 1.48 years) and females (7.80 ± 1.49 years). Mean humeral length was 27.93 ± 2.42 cm in males and 28.27 ± 2.54 cm in females. Females had a higher mean femoral segment length (41.15 ± 5.24 cm) than males (36.77 ± 3.35 cm).

Table 1
Descriptive statistics of study variables by sex

Variable	Sex	n	Mean $\pm$ SD	Median
Stature (cm)	Male	44	128.80 $\pm$ 8.15	129.50
	Female	41	130.10 $\pm$ 10.14	129.00
Age (years)	Male	44	7.93 $\pm$ 1.48	8.00
	Female	41	7.80 $\pm$ 1.49	8.00
Humeral length (cm)	Male	44	27.93 $\pm$ 2.42	28.00
	Female	41	28.27 $\pm$ 2.54	28.00
Femoral segment length (cm)	Male	44	36.77 $\pm$ 3.35	37.00
	Female	41	41.15 $\pm$ 5.24	42.00
Note: SD = standard deviation.				

3.2 Correlation Between Stature and Anthropometric Variables

Pearson's correlation analysis showed significant positive correlations between stature and age, humeral length, and femoral segment length in both sexes (Table 2).

Among males, age demonstrated the strongest correlation with stature ($r = 0.723$, $p < 0.001$), followed by humeral length ($r = 0.617$, $p < 0.001$) and femoral segment length ($r = 0.544$, $p = 0.0001$). Among females, age ($r = 0.839$, $p < 0.001$) and femoral segment length ($r = 0.838$, $p < 0.001$) showed very strong positive correlations with stature, while humeral length was also strongly correlated with stature ($r = 0.755$, $p < 0.001$).

Table 2
Pearson's correlation coefficients between stature and predictor variables by sex

Predictor variable	Male (n = 44)	p-value	Female (n = 41)	p-value
Age (years)	0.723	< 0.001	0.839	< 0.001
Humeral length (cm)	0.617	< 0.001	0.755	< 0.001
Femoral segment length (cm)	0.544	0.0001	0.838	< 0.001
Note: Values are Pearson's correlation coefficients (r). All correlations were positive and statistically significant.				

3.3 Multiple Linear Regression Analysis

3.3.1 Male Participants

A multiple linear regression model incorporating age, humeral length, and femoral segment length was statistically significant among male participants ($F_{(3,40)} = 40.830$, $p < 0.001$) and explained 75.4% of the variance in stature ($R^2 = 0.754$; Table 3).

As shown in Table 4, age and humeral length were significant independent predictors of stature. Age was positively associated with stature ($B = 3.139$, $SE = 0.458$, $t = 6.855$, $p < 0.001$), as was humeral length ($B = 1.351$, $SE = 0.301$, $t = 4.485$, $p < 0.001$). Femoral segment length had a positive regression coefficient but did not reach statistical significance after adjustment for age and humeral length ($B = 0.419$, $SE = 0.223$, $t = 1.880$, $p = 0.067$).

Table 3
Analysis of variance for the multiple linear regression model predicting stature among male participants

Source	Sum of squares	df	Mean square	F	p-value
Regression	2155.321	3	718.440	40.830	< 0.001
Residual	703.839	40	17.596	—	—
Total	2859.159	43	—	—	—

Model summary

$R^2 = 0.754$.

Table 4
Multiple linear regression coefficients for prediction of stature among male participants

Predictor	B	SE	t	p-value
Constant	50.738	8.484	5.980	< 0.001
Age (years)	3.139	0.458	6.855	< 0.001
Humeral length (cm)	1.351	0.301	4.485	< 0.001
Femoral segment length (cm)	0.419	0.223	1.880	0.067
Note: B = unstandardized regression coefficient; SE = standard error.				

3.3.2 Female Participants

Among female participants, the multiple linear regression model was statistically significant ($F_{(3,37)} = 93.103$, $p < 0.001$) and explained 88.3% of the variance in stature ($R^2 = 0.883$; Table 5).

Age, humeral length, and femoral segment length were all significant independent positive predictors of stature (Table 6). Age was positively associated with stature ($B = 2.793$, $SE = 0.556$, $t = 5.024$, $p < 0.001$),

as was humeral length ($B = 1.235$, $SE = 0.288$, $t = 4.285$, $p < 0.001$) and femoral segment length ($B = 0.707$, $SE = 0.163$, $t = 4.328$, $p < 0.001$).

Table 5
Analysis of variance for the multiple linear regression model predicting stature among female participants

Source	Sum of squares	df	Mean square	F	p-value
Regression	3630.656	3	1210.219	93.103	< 0.001
Residual	480.953	37	13.001	—	—
Total	4111.610	40	—	—	—

Model summary

$R^2 = 0.883$.

Table 6
Multiple linear regression coefficients for prediction of stature among female participants

Predictor	B	SE	t	p-value
Constant	44.316	6.571	6.744	< 0.001
Age (years)	2.793	0.556	5.024	< 0.001
Humeral length (cm)	1.235	0.288	4.285	< 0.001
Femoral segment length (cm)	0.707	0.163	4.328	< 0.001
Note: B = unstandardized regression coefficient; SE = standard error.				

3.4 Sex-Specific Regression Equations for Stature Prediction

Based on the multiple linear regression analyses, separate sex-specific equations were derived for estimating stature from age, humeral length, and femoral segment length.

For males:

$$\text{Stature (cm)} = 50.738 + 3.139(\text{Age}) + 1.351(\text{Humeral length}) + 0.419(\text{Femoral segment length})$$

For females:

$$\text{Stature (cm)} = 44.316 + 2.793(\text{Age}) + 1.235(\text{Humeral length}) + 0.707(\text{Femoral segment length})$$

The male model explained 75.4% of the observed variance in stature, whereas the female model explained 88.3%. Although femoral segment length was significantly correlated with stature in both

sexes, it contributed independently to the multivariable model only among females. These equations therefore provide sex-specific, sample-derived prediction models for stature among the school-aged children studied. Their applicability to other Nigerian populations should be confirmed through external validation.

4.0 DISCUSSION

This study demonstrated significant positive relationships between stature and age, humeral length, and femoral segment length among Nigerian school children aged 6–12 years. The sex-specific regression models explained 75.4% of the variation in male stature and 88.3% in female stature, indicating that age and long-bone measurements provide useful predictors of stature in this population. Similar evidence has demonstrated the value of long-bone dimensions for estimating stature in children, although the strength of these relationships varies according to age, sex, and population (Smith, 2007; Murray et al., 2024; Chu & Stull, 2025).

Age showed a strong positive correlation with stature in both males and females and remained a significant independent predictor in both regression models. This finding is consistent with the progressive increase in stature during childhood resulting from longitudinal skeletal growth. Murray et al. (2024), in a study specifically examining stature estimation from long-bone lengths in children, similarly demonstrated strong relationships between skeletal dimensions and stature and emphasized the importance of accounting for developmental differences in juvenile populations. The slightly greater mean stature and skeletal measurements observed among females in the present study may reflect sex-related differences in growth and maturation, although the absence of pubertal-status data prevents a definitive interpretation.

Humeral length was significantly correlated with stature in both sexes and remained an independent predictor in both regression models. This finding supports the use of the humerus as a practical indicator of overall skeletal size. Murray et al. (2024) reported strong predictive relationships between humeral length and stature among children, while Usman et al. (2024) demonstrated the usefulness of multiple anthropometric regression models for stature estimation in Nigerian and Indian populations. Although the latter study involved adults, it reinforces the importance of population-specific regression coefficients.

Femoral segment length demonstrated a moderate association with stature in males and a very strong association in females. However, femoral segment length was independently significant only in females. This difference highlights the distinction between simple correlation and multivariable prediction: although femoral segment length was related to stature in males, it provided limited additional information after age and humeral length were included in the model. Shared variation among the predictors and the relatively small sample may have contributed to this finding. Previous Nigerian research has also demonstrated significant femur–stature relationships and the importance of population-specific equations (Fawehinmi et al., 2013; Adetona et al., 2024).

The explanatory performance of the regression models was substantial, particularly among females. Comparable Nigerian studies have demonstrated the usefulness of regression-based anthropometry for stature estimation among adolescents and adults (Tanko et al., 2020; Usman et al., 2024; Fawehinmi et al., 2025). However, the R^2 values obtained in the present study should not be interpreted as evidence of external predictive accuracy because the equations were developed and evaluated using the same sample. Recent stature-estimation research has emphasized the importance of independent validation before regression equations are applied to populations beyond the original study sample (Murray et al., 2024; Chu & Stull, 2025).

The findings have potential applications in forensic anthropology and clinical anthropometry. In forensic contexts, population-specific equations may assist in estimating stature when complete remains or direct measurements are unavailable. In clinical settings, segmental measurements may provide an alternative when standing stature cannot be obtained. However, anthropometric relationships are influenced by population characteristics, sex, age, nutritional status, growth patterns, and secular changes; consequently, equations developed in one population should not automatically be transferred to another. Evidence from Nigerian populations, including differences in femur–stature relationships among ethnic groups, further supports the need for locally derived equations (Fawehinmi et al., 2013; Tanko et al., 2020; Fawehinmi et al., 2025).

A major strength of this study is the development of sex-specific stature-prediction equations using age and readily measurable humeral and femoral segment lengths in Nigerian school children. Nevertheless, the relatively small sample, recruitment from a single school and geographical location, and absence of pubertal-status assessment limit generalisability. In addition, external validation was not performed. Larger multicentre studies involving children from different regions and ethnic backgrounds in Nigeria are therefore needed to validate and, where necessary, refine these equations before wider clinical or forensic application.

Overall, age and humeral length were significant independent predictors of stature in both sexes, whereas femoral segment length provided additional predictive value only among females. The findings provide preliminary population-specific regression models for stature estimation among Nigerian children aged 6–12 years and contribute to the limited Nigerian literature on juvenile stature prediction.

5.0 CONCLUSION

This study demonstrated significant positive associations between stature and age, humeral length, and femoral segment length among school-aged children in Owo, Nigeria. Sex-specific regression models showed substantial explanatory power, with age and humeral length independently predicting stature in both sexes, while femoral segment length provided additional predictive value among females. The resulting equations therefore provide preliminary population-specific models for estimating stature from readily obtainable anthropometric measurements.

These findings may have applications in paediatric anthropometry, clinical assessment, and forensic identification where direct measurement of stature is impractical. However, the relatively small sample size, single-school setting, and absence of external validation limit the generalisability of the equations. Larger multicentre studies involving children from different geographical regions and ethnic groups in Nigeria are recommended to validate and refine these models before wider application.

Abbreviations

B

Unstandardized regression coefficient

R²

Coefficient of determination

SD

Standard deviation

SE

Standard error

SPSS

Statistical Package for the Social Sciences

WHO

World Health Organization

Declarations

Ethical Compliance Statement: This study was conducted in accordance with the ethical principles for research involving human participants and the institutional research protocol of Achievers University. Ethical approval was obtained from the Achievers University Research Ethics Committee prior to commencement of the study. Permission was also obtained from the management of Achievers University Primary School, Owo. Written informed consent was obtained from the parents or legal guardians of all participating children, and participation was voluntary. The study was conducted in accordance with the principles of the Declaration of Helsinki, with confidentiality and anonymity of participants maintained throughout.

Author Contribution

OAE: Conceptualization, Data collection and acquisition, writing original draft, data analysis & interpretation, review & editing, final approval. ETT: Data collection and acquisition, Writing original draft, data analysis & interpretation, review & editing, final approval. AFT: Writing original draft, data analysis & interpretation, review & editing, final approval. OTV: Writing original draft, data analysis & interpretation, review & editing, final approval. LEO: Writing original draft, data analysis & interpretation, review & editing, final approval. IBO: Writing original draft, data analysis & interpretation, review & editing, final approval,

and supervising the work.UTO: Writing original draft, data analysis & interpretation, review & editing, final approval.

Data Availability

All data supporting the findings of this study are available within the paper.

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