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BODY HEIGHT ESTIMATION USING FEMORAL LENGTH AMONG THE 2022–2024 COHORT OF MEDICAL AND HEALTH SCIENCES STUDENTS AT JAMBI UNIVERSITY

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ABSTRACT

Background: Estimation of body height using femoral length is widely applied in forensic and clinical anthropometry, particularly when direct height measurement is not possible. Although femoral length is a reliable predictor of stature, the accuracy of estimation models depends on population-specific anthropometric characteristics, highlighting the need for local formulas. **Objective:** This study analyzed the correlation between femur length and body height and developed height estimation models among Jambi University students (2022–2024). **Methods:** This analytical cross-sectional study was conducted at the Faculty of Medicine and Health Sciences, Jambi University, from September to November 2025. Samples were selected using purposive sampling (minimum n = 95, Slovin's formula). Femur length and body height were measured percutaneously using a standardized measuring tape and microtoise. BMI, physical activity level (IPAQ-SF), and anthropometric race were recorded. Data were analyzed using Pearson correlation, One-Way ANOVA, and simple linear regression. **Results:** Femur length was moderately correlated with body height in males (r = 0.599), females (r = 0.598), and the overall sample (r = 0.550; p < 0.001). No significant differences in mean femur length were observed across BMI, physical activity, or anthropometric race groups, and height estimation models were developed. **Conclusion:** Femur length is significantly correlated with body height and can be used for height estimation using gender-specific regression formulas. BMI, physical activity level, and anthropometric race showed no significant differences in mean femur length; further studies with balanced sub-ethnic samples are recommended.

BACKGROUND

Stature is one of the most essential anthropometric parameters in medicine, nutrition, sports medicine, and forensic science. Body height plays an important role in evaluating growth and health status, calculating drug dosage, assessing nutritional status, and planning musculoskeletal rehabilitation[1,2]. Assessment of lower extremity function is an important component of musculoskeletal evaluation, particularly in conditions affecting the locomotor system; therefore, anthropometric measurements of the lower extremities have significant clinical relevance[3].

Anthropometric measurements such as body height and body mass index are widely used as fundamental screening tools to assess nutritional status and health risks across different age groups[4,5]. Early detection programs utilizing height and weight measurements have been shown to play a crucial role in identifying obesity and malnutrition, particularly following lifestyle changes during the COVID-19 pandemic[6]. A community-based screening study in Jambi demonstrated that routine anthropometric assessment is essential for early detection of nutritional problems and long-term health risk prevention[7]. In forensic contexts, stature constitutes a

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key component in human identification, particularly in cases where the body is no longer intact due to trauma, burning, or decomposition, rendering direct height measurement impossible[8,9]. Under such circumstances, estimating stature through body segments that remain measurable becomes crucial, one of the most frequently used being the femur.

The femur is the longest and one of the most robust bones in the human body, making it a useful reference for stature estimation in forensic and anthropometric assessments. Although height estimation using femoral length has been widely utilized, its accuracy remains dependent on the compatibility of the reference population, which may vary according to genetic factors and skeletal morphology[10]. Consequently, predictive models developed from foreign populations cannot be applied directly to the Indonesian population, including residents of Jambi, due to variations in ethnicity and skeletal proportions.

Anthropometric studies based on local Indonesian populations remain limited, and no scientific publication has specifically examined the relationship between femoral length and stature among medical students at the University of Jambi. Meanwhile, the young adult age group (18–22 years) represents a period in which skeletal growth has fully matured, resulting in stable limb proportions and overall stature, making it an ideal population for predictive anthropometric analysis[11]. Therefore, the availability of local anthropometric data from this population holds significant scientific value, particularly for the development of height-estimation models that could be applied clinically and forensically[12,13].

The findings of this study revealed a significant relationship between femoral length and body height, with correlation coefficients categorized as moderate for both the right and left femurs[14]. Moreover, linear regression analysis demonstrated that femoral length has substantial predictive ability for estimating stature. Previous research consistently identifies femoral length as an important predictor of height in young adults. However, findings from recent anthropometric studies show that the differences of BMI, physical activity, and ethnicity on the femur-to-height relationship remain inconclusive, as available evidence has not demonstrated a consistent association across populations[15]. Therefore, further studies involving larger and more diverse samples are needed to clarify whether these additional variables contribute meaningfully beyond femoral length alone[16,17]. This indicates that femoral length can serve as an independent predictor of stature without being influenced by these variables within this population. Overall, this study is important because: (1) it fills the lack of local anthropometric data on young adults in the Jambi region, (2) it provides a scientific basis for stature estimation using femoral length that is more accurate than formulas derived from non-Indonesian populations, and (3) it contributes to applications in forensic identification, human body anthropology, sports medicine, and medical education. The objective of this study was to analyze the relationship between femoral length and body height among students of the 2022–2024 cohort of the Faculty of Medicine and Health Sciences, University of Jambi, and to develop a stature-estimation model based on femoral length that reflects the anthropometric characteristics of the local population.

METHODS/ CASE PRESENTATION

This study is an analytical quantitative research with a cross-sectional design aimed at analyzing the relationship between femur length and body height. The cross-sectional design was chosen because it is suitable for assessing the relationship between anthropometric variables measured at a single point in time without intervention.

The research was conducted from September to November 2025 at the Faculty of Medicine and Health Sciences, Jambi University. The study population consisted of students from the 2022–2024 cohorts. Samples were selected using a purposive sampling technique based on predefined inclusion and exclusion criteria, with a minimum required sample size of 95 respondents.[16] The inclusion criteria were students aged 18–22 years, in good physical condition, and willing to participate. The exclusion criteria included a history of femoral fractures or lower-limb surgery, significant skeletal deformities, chronic diseases affecting bone growth, obesity that prevented proper landmark palpation, refusal to provide informed consent, and incomplete or invalid measurement data.

Data collection included two main variables, femur length and body height, along with additional variables consisting of body mass index (BMI), physical activity level, and anthropometric race. To

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support the calculation of BMI, body weight was measured using a digital weighing scale with the subject wearing light clothing and no footwear, while body height was measured using a microtoise in an upright standing position without footwear. Femur length was measured percutaneously using a standardized measuring tape, following standard anthropometric landmarks from the greater trochanter to the lateral femoral epicondyle. Physical activity level was assessed using the International Physical Activity Questionnaire–Short Form (IPAQ-SF), in which respondents reported the frequency and duration of walking, moderate activities, and vigorous activities performed within the previous seven days. Anthropometric race was obtained through self-report. All anthropometric measurements were performed three times, and the mean value was recorded to minimize measurement

Data analysis was performed using IBM SPSS software. A normality test was carried out to ensure that the data distribution met the requirements for parametric analysis. The relationship between femur length and body height was evaluated using the Pearson correlation test. Simple linear regression analysis was used to assess the predictive ability of femur length on body height and to develop an estimation formula. In addition, a One-Way ANOVA test was conducted to determine whether body mass index (BMI), physical activity level, and race resulted in significant differences in the femur-to-height ratio. A p-value <0.05 was considered statistically significant. Internal validation was performed using a split-sample approach, in which 70% of the data were allocated for model development and 30% for testing.

RESULTS

This section presents the results obtained from the measurement and data analysis of 114 students from the 2022–2024 cohort of the Faculty of Medicine and Health Sciences, Jambi University The results are presented in a logical sequence according to the research.

Frequency Distribution of Research Subject Characteristics

Table 1. Frequency distribution of research subject characteristics

Characteritics	Category	n	%
Gender	Male	40	35,1
	Female	74	64,9
Age (Years)	18	8	7
	19	31	27,2
	20	33	28,9
	21	31	27,2
	22	11	9,6
Body Mass Index	Underweight	15	13,2
	Normal	73	77,2
	Overweight	19	16,7
	Obesity	7	6,1
Physical Activity	Low	19	16,7
	Moderate	66	57,9
	High	29	25,4
Antropometric Race	Caucasoid	2	2
	Mongoloid	111	97,4
	Negroid	1	0,9
	Australoid	0	0

Table 1 presents the frequency distribution of the research subjects based on several key characteristics. The sample was female-dominant (64,9%), with the majority of participants concentrated in 20 years age categories (28,9%). In terms of nutritional status, the largest group had a normal Body Mass Index (BMI) at 77,2%, followed by the overweight (16,7%), underweight (13,2%), and obese (6,1%) categories. Physical activity levels were predominantly moderate (57,9%), with the remaining distributed between high (25,4%) and low (16,7%) levels. The sample exhibited minimal variation in anthropometric race, with 97,4% of respondents categorized as Mongoloid, and the remaining subjects classified as Caucasoid (1,8%) and Negroid (0,9%), with no individuals classified as Australoid.

Descriptive Analysis of Femur Length and Height

Descriptive Analysis of Femur Length

Table 2. Descriptive analysis of femur length

Gender	Min (cm)		Max (cm)		Mean ± SD	
	R	L	R	L	R	L
Male	35	35	50	50	40,940 ± 3,371	40,940 ± 3,371
Female	33	33	47	47	39,747 ± 2,746	39,747 ± 2,746
Overall	33	33	50	50	40,166 ± 3,020	40,166 ± 3,020

R : Right, L : Left

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Table 2 presents the descriptive analysis of femur length based on gender. In males, the minimum and maximum femur lengths ranged from 35 to 50 cm for both right and left sides, with a mean of 40.940 ± 3.371 cm. In females, the femur length ranged from 33 to 47 cm on both sides, with a mean of 39.747 ± 22.746 cm. Overall, the femur length of all subjects ranged from 33 to 50 cm, with an average of 40.166 ± 3.020 cm for both right and left sides.

Descriptive Analysis of Height

Table 3. Descriptive analysis of height

Gender	Minimum (cm)	Maximum (cm)	Mean ± SD
Male	154	184	169,270 ± 6,870
Female	142	171	156,124 ± 6,117
Overall	142	184	160,736 ± 8,953

Table 3 presents the descriptive analysis of height based on gender. In males, the minimum and maximum height ranged from 154 to 184 cm, with a mean of 169.270 ± 6.870 cm. In females, height ranged from 142 to 171 cm, with a mean of 156.124 ± 6.117 cm. Overall, the height of all participants ranged from 142 to 184 cm, with an average of 160.736 ± 8.953 cm

Test of Normality

Table 4. The Shapiro-Wilk normality test for femur length and height

Variable	Group	n	P-Value*
Right Femur Length	Male	40	0,080[1]
	Female	74	0,502[1]
	Overall	114	0,092[1]
Left Femur Length	Male	40	0,080[1]
	Female	74	0,502[1]
	Overall	114	0,092[1]
Height	Male	40	0,469[1]
	Female	74	0,902[1]
	Overall	114	0,084[1]

[1]Normal (p > 0,05); *Shapiro-Wilk Test

Table 4 shows that The Shapiro–Wilk test indicated that all variables met the normality assumption, with p-values above 0.05 across all groups. In the male group, the p-values were 0.080 for both the right and left femur length, and 0.469 for height. In the female group, the p-values were 0.502 for right and left femur length, and 0.902 for height. For the overall sample, the p-values were 0.092 for right and left femur length, and 0.084 for height. These results indicate that the data are normally distributed and are therefore suitable for parametric statistical analysis.

Correlation Analysis of Femur Length and Height

Table 5. The correlation test between femur length and height

Gender	Variable	Correlation with Height		
		r	P-Value	Interpretation
Male	Right Femur	0,599*	<.001[1]	Moderate, significance
	Left Femur	0,599*	<.001[1]	Moderate, significance
Female	Right Femur	0,598*	<.001[1]	Moderate, significance
	Left Femur	0,598*	<.001[1]	Moderate, significance
Overall	Right Femur	0,550*	<.001[1]	Moderate, significance
	Left Femur	0,550*	<.001[1]	Moderate, significance

[1]Significance (p ≤ 0,05); *Pearson Correlation

Table 5 shows the correlation analysis between femur length and height. In males, both right and left femur lengths demonstrated a moderate significant positive correlation with height (r = 0.599; p <0 .001). In females, right and left femur lengths also showed a moderate significant positive correlation with height (r = 0.598; p<0.001). In the overall sample, the correlations between right and left femur lengths and height were positive and significant, with correlation coefficients indicating a moderate strength (r = 0.550; p < 0.001).

Test of Homogeneity of Variances for Cofounding Variable

Table 6. Levene's test for homogeneity of variances right femur length

DV	Confounding (IV)	df 1	df2	F	P-Value*
Right Femur Length	BMI	3	110	1,241	0,298[1]
	Physical Activity	2	111	0,412	0,663[1]
	Anthropometric Race	1	111	0,108	0,743[1]

[1]Homogen (p > 0,05); Levene's Test, DV : Dependent Variable, IV : Independent Variable, BMI : Body Mass Index

Table 6 presents the results of Levene's test for the homogeneity of variances in right femur length across potential confounding variables. The p-values for Body Mass Index (p = 0.298), Physical Activity Level (p = 0.663), and Anthropometric Race (p =

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0.743) were all greater than 0.05, indicating that the variances were homogeneous across all groups. Therefore, there was no violation of the homogeneity assumption for right femur length.

Table 7. Levene's test for homogeneity of variances left femur length

DV	Confounding (IV)	df 1	df 2	F	P-Value*
Left Femur Length	BMI	3	110	1,241	0,298[1]
	Physical Activity	2	111	0,412	0,663[1]
	Anthropometric Race	1	111	0,108	0,743[1]

[1]Homogen (p > 0,05); Levene's Test, DV : Dependent Variable, IV : Independent Variable, BMI : Body Mass Index

Table 7 shows the results of Levene's test for the homogeneity of variances of left femur length across the potential confounding variables. The p-values for Body Mass Index (p = 0.298), Physical Activity Level (p = 0.663), and Anthropometric Race (p = 0.108) were all greater than 0.05, indicating that the variance of left femur length was homogeneous across groups. Therefore, there was no violation of the homogeneity of variances assumption for left femur length.

Analysis of Variance (ANOVA) for BMI, Physical Activity, and Anthropometric Race

Table 8. Analysis of variance (ANOVA) for BMI, physical activity, and anthropometric race on right femur length

Variable	Right Femur	
	F	P-Value*
BMI	0,058	0,982[1]
Physical Activity	0,311	0,733[1]
Anthropometric Race	0,448	0,640[1]

[1]Not Significance (P≥ 0.05), *One-Way ANOVA Test, BMI : Body Mass Index

The table 8 results show that BMI, physical activity, and anthropometric race do not have statistically significant differences in right femur length. This is indicated by the p-values for all three variables being greater than 0.05 (BMI: p = 0.982; Physical Activity: p = 0.733; Anthropometric Race: p = 0.640). These results suggest that variations in body mass index, levels of physical activity, and racial anthropometric classification do not contribute meaningfully to differences in femur length among respondents in this sample. Therefore, right femur length in early adulthood appears to be largely independent of metabolic, lifestyle, and racial factors, supporting the understanding that long-bone length has typically reached full maturation by this age range.

Table 9. Analysis of variance (ANOVA) for BMI, physical activity, and anthropometric race on left femur length

Variable	Left Femur	
	F	P-Value*
BMI	0,058	0,982[1]
Physical Activity	0,311	0,733[1]
Anthropometric Race	0,448	0,640[1]

[1]Not Significance (P≥ 0.05), *One-Way ANOVA Test, BMI : Body Mass Index

The table 9 results indicate that BMI, physical activity level, and anthropometric race show no significant differences in left femur length. This is reflected by the p-values of all variables being greater than 0.05, BMI (p = 0.982), physical activity (p = 0.733), and anthropometric race (p = 0.640), suggesting that there are no meaningful differences in left femur length based on these factors. Therefore, left femur length in early adulthood appears to be largely independent of metabolic status, lifestyle patterns, and racial categorization. This finding supports the understanding that long-bone length has typically reached full biological maturation by this age range, making it less susceptible to external influences such as BMI or physical activity.

Formulation of Height Estimation Model

Table 10. Linear regression models for height estimation based on femur length

Groups	PV	a	b	SEE	P-Value*
Male Height	Right Femur	119,280	1,221	5,572	<.001[1]
	Left Femur	119,280	1,221	5,572	<.001[1]
Female Height	Right Femur	103,219	1,331	4,938	<.001[1]
	Left Femur	103,219	1,331	4,938	<.001[1]
Overall	Right Femur	95,229	1,631	7,510	<.001[1]
	Left Femur	95,229	1,631	7,510	<.001[1]

[1]Significance (p < 0,05); *Linear Regression, PV : Predictor Variable, SEE : Standard Error of The Estimation, a for constant, b for coefficient

Table 10 presents the linear regression models for estimating height based on femur length. In males, both right and left femur lengths produced identical regression models, with a constant value of 119.280 and a coefficient of 1.221 (p< .001). In females, the regression model showed a constant of 103.219 and a

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coefficient of 1.331 for both right and left femur lengths (p< .001). For the overall sample, the constant was 95.229 with a coefficient of 1.631 for both right and left femur lengths (p < .001). All models showed statistically significant relationships, indicating that femur length can be used to estimate height in each group.

Based on the linear regression analysis presented in table 10, the regression equation is defined as:

$$y = a + bx$$

Description:
y : Dependent variable
a : Constant
b : Coefficient of the independent variable
x : Independent variable

For male respondents, the regression equations are shown in Eq. (1) and Eq. (2):

Height = 119.280 + (1.221 × right femur length) (cm) (1)

Height = 119.280 + (1.221 × left femur length) (cm) (2)

For female respondents, the regression equations are shown in Eq. (3) and Eq. (4):

Height = 103.219 + (1.331 × right femur length) (cm) (3)

Height = 103.219 + (1.331 × left femur length) (cm) (4)

For all respondents, the regression equations are shown in Eq. (5) and Eq. (6):

Height = 95.229 + (1.631 × right femur length) (cm) (5)

Height = 95.229 + (1.631 × left femur length) (cm) (6)

Internal validation using a split-sample approach, in which 70% of the data were used for model development and 30% for testing, showed that the training model yielded an R^2 of 0.265 with a standard error of estimate (SEE) of 7.62 cm. The testing dataset demonstrated a higher R^2 of 0.472 with a lower SEE of 6.72 cm, indicating stable model performance and suggesting that the regression equation was not overfitted to the training data.

DISCUSSION

This study examined the association between femur length and stature among medical students at the Faculty of Medicine and Health Sciences, Jambi University, and developed predictive models for height estimation based on femur length. A total of 114 respondents participated, predominantly female (64,9%) and mostly belonging to the Mongoloid anthropometric race (97,4%). This demographic distribution reflects the representation of the student population in the region, which contributes to the contextual relevance of the findings.

The restriction of the study population to a narrow age range (18–22 years) and a predominantly Mongoloid anthropometric group represents a methodological strength rather than a limitation. This homogeneity minimizes biological variability related to skeletal maturation and ethnic proportional differences, allowing the derived regression models to be more population-specific and precise. Consequently, the proposed equations are particularly suitable for stature estimation in young Indonesian adults with similar anthropometric characteristics.

The results demonstrated that males had greater average femur length and height compared to females. This finding is biologically expected and aligns with established knowledge that testosterone promotes epiphyseal growth, long-bone elongation, and muscle mass development to a greater extent in males[14,18]. These results are consistent with previous anthropometric studies conducted in Southeast Asian, European, and North American populations, which similarly reported significantly longer long bones in males than in females due to differences in hormonal regulation, skeletal loading patterns, and growth trajectories[19,20].

Normality testing using the Shapiro–Wilk test showed that all variables were normally distributed, with p-values greater than 0.05 across the male, female, and overall groups. These findings indicate that both femur length and height met the normality assumption regardless of sex stratification, allowing the data to be analyzed using parametric statistical methods such as correlation and linear regression[21].

Correlation analysis identified moderate and significant positive association between femur length and body height in both males ($r = 0.599$) and females ($r = 0.598$), with both correlations reaching high levels of statistical significance ($p < 0.001$). These findings support the key role of the femur in stature estimation, in line with earlier works (e.g., Trotter & Gleser) and more recent anthropometric studies in Southeast Asia,

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such as in Thailand and Malaysia, which identify femoral length (or combined long-bone lengths) as one of the most reliable skeletal predictors of stature[22,23]. In contrast, the combined sample demonstrated only a moderate correlation ($r = 0.550$; $p < 0.001$), likely reflecting sex-specific differences in the proportionality of limb length to total height. This further reinforces the need for sex-specific predictive models rather than universal ones in contexts requiring high precision.

Additionally, ANOVA demonstrated that BMI, physical activity level, and anthropometric race did not significantly influence femur length in this age group. This aligns with the theory of skeletal maturity stating that long-bone length typically reaches its final form at the end of adolescence and is less responsive to lifestyle-related metabolic variations in early adulthood[24,25].

The regression results showed that femur length was a significant predictor of body height in both males and females ($p < 0.001$), following the anthropometric principle that lower-limb proportions relative to stature may differ between sexes[26]. In males, the higher constant value (119.280) reflects their generally greater absolute height, whereas the lower constant in females (103.219) corresponds to their shorter average stature. However, the regression coefficient in females (1.331) was slightly higher than in males (1.221), indicating that each unit increase in femur length contributes marginally more to stature in females . This pattern aligns with modern anthropometric literature suggesting that although males are taller overall, females may exhibit differences in lower-limb proportionality that produce a steeper femur–height relationship[27]. Meanwhile, the combined analysis yielded a larger SEE, indicating heterogeneity in body proportions between sexes, thereby supporting the use of sex-specific models for more accurate height estimation.

Internal validation using a split-sample approach demonstrated comparable predictive performance between the training and testing datasets. This finding indicates that the derived femur-based stature estimation models are stable and not substantially overfitted to the study sample, supporting their applicability within populations with similar anthropometric characteristics.

Despite the robust findings, several limitations must be acknowledged. Although the overall sample size ($n = 114$) met the minimum requirement for regression analysis, the distribution between sexes was unbalanced, with a higher proportion of female participants (64,9%) compared to males (35,1%). This imbalance may influence the stability and generalizability of the regression models, particularly for male populations. In addition, the use of a purposive sampling approach within a single university setting may introduce selection bias and limit external validity. Future studies should involve larger, randomized samples with more balanced sex distributions to further strengthen the applicability of femur-based stature estimation models.

CONCLUSION

This study successfully answered the research question regarding whether femur length can be used to estimate stature in young adults. The findings demonstrated a moderate and statistically significant linear relationship between femur length and height among medical students at Jambi University, where longer femur length corresponded to greater stature. The study also confirmed sex-related differences: males demonstrated longer femur length and a larger regression constant, while females exhibited a higher regression coefficient[29].

The explicit contribution of this manuscript is the establishment of sex-specific and population-specific regression equations for estimating stature from femur length in Indonesian young adults of predominantly Mongoloid race. These equations can be beneficial for applications in clinical anthropometry and forensic identification where full body measurements are unavailable.

However, the generalizability of the results is limited by the single-center sample, narrow age range, and relatively homogeneous ethnic background. Future studies involving larger and multi-ethnic populations are recommended to enhance applicability across broader demographics.

ETHICAL APPROVAL

Ethical approval for this study was obtained from the Ethics Committee of the Faculty of Medicine and Health Science, Jambi University (Ethical Clearance Number: 3032 / UN21.8 / PT.01.04 / 2025).

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CONFLICTS OF INTEREST

There is no conflict of interest related to the materials, methods, and findings in this study.

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AUTHOR CONTRIBUTIONS

Conceptualization, methodology, data collection, formal analysis, and writing—original draft preparation were carried out by Anes Widya Ningsih. Writing—review and editing, supervision, and project administration were provided by dr. Attiya Istarini, Sp.N and dr. Miftahurrahmah, Sp.BA. All authors have read and approved the final manuscript.

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