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Relationship Between Femur Length and Body Height Among Junior High School Students at SMP Methodist Antiokhia Pancurbatu

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Abstract
Femur length is widely used to estimate stature, but most evidence comes from adults, and few studies address early adolescents. This cross-sectional analytical study examined the relationship between femur length and body height among 394 junior high school students at SMP Methodist Antiokhia Pancurbatu, Deli Serdang, selected by total sampling. Femur length was measured twice from the greater trochanter to the femoral condyle and averaged; height was measured with a stadiometer. Data were non-normal (Kolmogorov–Smirnov), so Spearman correlation was used, and simple linear regression produced an estimation equation. Mean femur length was 35.44 ± 6.57 cm and mean height 150.05 ± 9.14 cm. Femur length correlated strongly with height ($\rho = 0.617$, $p < 0.001$) and explained 37.9% of its variance. The equation was height = 119.72 + 0.86 × femur length (SEE 7.21 cm). The equation suits adolescents only.
Keywords: Femur Length, Body Height, Stature Estimation, Adolescents, Forensic Anthropometry

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INTRODUCTION

Body height is an important anthropometric parameter in forensic, clinical, and public health practice. It is used not only as an indicator of growth and nutritional status but also in identifying individuals, especially when the body is incomplete or height cannot be measured directly. Anthropometric data also support the monitoring of growth in children and adolescents, which helps detect health problems early. Direct measurement is often impossible, for example in forensic investigations, mass casualty events, or after amputation. In such cases certain body parts, mainly the long bones such as the femur, tibia, ulna, and humerus, are measured to estimate height. The femur is the longest bone in the human body and contributes most to height, so it is often treated as a fairly accurate indicator of a person's stature. Several studies report a strong correlation between height and femur length. In a Japanese population, maximum femur length was closely related to height ($R^2 = 0.842$) and was the most reliable of the femoral measurements (Kira et al., 2023). Hoermann et al. (2023) likewise found that the femur is among the most reliable long bones for anthropometric analysis and forensic identification, with correlations of r = 0.82 in men and r = 0.77 in women. Among the Sangihe ethnic group in Indonesia, femur length and height were also fairly strongly correlated in both sexes (Tanudjaja & Pasiak, 2022).

Most of these studies, however, focus on adults, university students, or specific ethnic groups. Few have examined early adolescents, particularly junior high school students. Adolescence is marked by a growth spurt of the long bones, so the relationship between femur length and height at this age may differ from that seen in adults. Results from adult populations cannot simply be assumed to represent adolescents who are still growing. Sex, race, ethnicity, nutritional status, and other demographic variables also shape the relationship between femur

length and height. Because of anthropometric characteristics, environmental influences, and genetic variation, equations derived from one population cannot always be applied accurately to another. Local studies are therefore still needed to obtain anthropometric data that fit the characteristics of the community concerned. Students of SMP Methodist Antiokhia Pancurbatu are early adolescents in a period of active growth, which makes them a relevant population for anthropometric research. To date, no study has examined the relationship between femur length and height in these students or in adolescents in Deli Serdang Regency. This study was therefore conducted to supply local anthropometric data for anatomy, forensic anthropology, and the evaluation of adolescent growth. Its general aim was to determine whether femur length is related to body height. The specific aims were to measure femur length, to measure height, to analyze the relationship between the two, to establish the strength of their correlation, and to determine whether femur length can serve as a predictor of height.

Previous Studies

Table 1 summarizes six earlier studies on the relationship between femur length and height. Two come from international or forensic settings and four from Indonesian populations.

Table 1. Summary of Previous Studies on Femur Length and Body Height

Study	Population or context	Main findings
Kira et al. (2023)	Japanese population	Maximum femur length was very closely related to height (R^2 = 0.842) and was the most reliable of the femoral measurements
Hoermann et al. (2023)	Anthropometric and forensic identification	The femur was among the most reliable long bones; correlation with height was r = 0.82 in men and r = 0.77 in women
Tanudjaja and Pasiak (2022)	Sangihe ethnic group, Indonesia	Femur length and height were fairly strongly correlated in both men and women
Kaintako et al. (2023)	Papuan ethnic students, Tomohon, Indonesia	Positive correlation of moderate strength (r = 0.569)
Rizkah et al. (2022)	Toraja people, Indonesia	Height estimation was developed from femur length
Putri Shella and Gafar Parinduri (2025)	Medan, Indonesia	Height estimation was developed from femur length

Three points stand out. First, every study found a positive association between femur length and height, which supports the femur as the preferred bone for stature estimation. Second, the strength of association varies. Adult series report strong coefficients (r = 0.77 to 0.82) and a very high explained variance (R^2 = 0.842), while an Indonesian student sample reported a moderate coefficient (r = 0.569). Differences in population, age range, ethnic background, and measurement method are the usual explanations (Pankaj Kumar et al., 2023). Third, the studies cover adults, university students, and specific ethnic groups, and none addresses early adolescents in Deli Serdang. Adolescents are still growing and their epiphyseal plates have not closed, so the findings of adult studies may not transfer. The present study was designed to fill this gap.

RESEARCH METHODS

Design and setting

This was an analytical observational study with a cross-sectional design, in which femur length and height were measured at the same time. The design suits the evaluation of the correlation between height (the dependent variable) and an anthropometric variable (femur

length) in a defined population, because it describes the status of both variables at a single point in time. The study took place at SMP Methodist Antiokhia Pancurbatu.

Population and sample

The population was all students of SMP Methodist Antiokhia Pancurbatu. Every member of the population who met the inclusion and exclusion criteria was included, using total sampling. This approach was chosen because the population was manageable and complete data could be obtained, which was expected to make the data more accurate and representative. A total of 394 students were included. Inclusion criteria were active enrollment at the school, willingness to participate, and no abnormality or history of injury of the lower limb that could affect femur measurement. Students were excluded if they were absent on the day of data collection, were unwilling to take part, or had a history of trauma, deformity, or disorder of the thigh bone that could compromise measurement accuracy.

Variables and measurement

Femur length was the independent variable and body height the dependent variable. Table 2 gives their operational definitions. Femur length was measured on the living subject by palpating the greater trochanter and the femoral condyle and measuring the distance between them with a tape measure or anthropometer. Each measurement was taken twice and averaged. Height was measured once with a stadiometer, with the student standing upright without footwear and the head in the Frankfurt plane. In this plane an imaginary line from the lower orbital margin to the external auditory meatus is parallel to the floor.

Table 2. Operational Definitions of the Study Variables

Variable	Operational definition	Measurement	Instrument	Scale
Femur length	Length of the thigh bone from the greater trochanter to the femoral condyle	Measured twice, mean value used	Tape measure or anthropometer	Ratio (cm)
Body height	Height of the respondent standing upright without footwear	Measured once, standard procedure (Frankfurt plane)	Stadiometer	Ratio (cm)

Data analysis

Analysis proceeded in four steps: descriptive statistics, a normality test, a correlation test, and simple linear regression. Normality was first planned with the Shapiro–Wilk test, but because the sample exceeded 50 the Kolmogorov–Smirnov test was used. A significance value above 0.05 indicated a normal distribution. Pearson correlation was to be used for normally distributed data and Spearman correlation otherwise. Correlation strength was read as very weak (0.00–0.199), weak (0.20–0.399), moderate (0.40–0.599), strong (0.60–0.799), or very strong (0.80–1.000), and a p-value below 0.05 was considered significant. Simple linear regression was then used to build the height estimation equation and to obtain the coefficient of determination (r^2) and the standard error of estimate (SEE).

RESEARCH RESULTS AND DISCUSSION

This section reports data from 394 students who met the inclusion and exclusion criteria, followed by a discussion of the findings against earlier work.

Characteristics of respondents

Respondents came from two school units labeled SMP Methodist 1 (198 students, 50.3%) and SMP Methodist 2 (196 students, 49.7%). Boys numbered 198 (50.3%) and girls 196

(49.7%), as shown in Table 3. This balanced sex composition is a methodological advantage because it limits the bias that could arise from sex differences in bone growth, so the femur-height relationship can be taken to represent both sexes proportionally.

Table 3. Frequency Distribution of Respondent Characteristics (N = 394)

Characteristic	Category	n	%
School	SMP Methodist 1	198	50.3
	SMP Methodist 2	196	49.7
Sex	Male	198	50.3
	Female	196	49.7

Descriptive statistics

Mean femur length was 35.44 ± 6.57 cm (range 20.0 to 51.0 cm, median 36.00 cm), and mean height was 150.05 ± 9.14 cm (range 130.0 to 176.0 cm, median 150.00 cm). Both medians lie close to their means, which indicates data spread fairly evenly around the center. The coefficient of variation (SD divided by mean) was 6.1% for height, which is homogeneous, but 18.5% for femur length. The wide femur range partly reflects biological variation during growth and partly the likely variation in external measurement, since palpating the femur on a living person is harder than measuring height. This point returns under the limitations.

Table 4. Femur Length and Body Height by Sex, Mean ± SD (cm)

Group	n	Femur length	Body height
All respondents	394	35.44 ± 6.57	150.05 ± 9.14
Male	198	36.98 ± 7.06	151.76 ± 10.44
Female	196	33.88 ± 5.63	148.33 ± 7.23

Boys had a longer mean femur than girls (36.98 versus 33.88 cm, a difference of about 3.10 cm) and were taller (151.76 versus 148.33 cm, a difference of about 3.43 cm). Boys also showed more spread in both variables.

Normality test

Because the sample exceeded 50, the Kolmogorov–Smirnov test was used. Both variables had significance values below 0.05 (Table 5), so neither was normally distributed in the strict statistical sense. The result needs careful reading. The statistic for height (0.052) was small, meaning its distribution closely resembles a normal curve, while the statistic for femur length (0.172) was larger and reflected a broader spread. Skewness and kurtosis were within the commonly accepted limits for near-normal data (|skewness| < 2 and |kurtosis| < 7). Femur length was somewhat platykurtic, a flat and wide distribution that fits its high coefficient of variation and a population of adolescents at different stages of growth. Normality tests are also very sensitive in large samples, where small deviations can yield significant p-values. Since the assumption of normality was not met, the Spearman test was used for correlation, and simple linear regression was used for the estimation equation because it is robust at n = 394.

Table 5. Kolmogorov–Smirnov Normality Test (n = 394)

Variable	Statistic	Sig.	Skewness	Kurtosis	Conclusion
Femur length	0.172	<0.001	0.218	−1.045	Not normal
Body height	0.052	0.011	0.231	−0.513	Not normal

Correlation and regression

Femur length correlated significantly with height ($\rho = 0.617$, $p < 0.001$; Table 6). The positive coefficient means that height rose as femur length increased, and by the interpretation guideline the strength is strong. The null hypothesis was therefore rejected and the alternative hypothesis accepted. Regression gave $r^2 = 0.379$, so femur length accounted for about 37.9% of the variation in height and the remaining 62.1% was due to other factors.

Table 6. Spearman Correlation and Simple Linear Regression of Height on Femur Length

Parameter	Value
Spearman coefficient (ρ)	0.617
Significance (2-tailed)	<0.001
Interpretation	Significant, positive, strong
Coefficient of determination (r^2)	0.379
Regression equation	Height = 119.72 + 0.86 × femur length
Standard error of estimate	7.21 cm

Respondents and sex differences

The respondents were early adolescents in a period of active growth. The long bones, including the femur, are still lengthening through epiphyseal plates that have not closed, which makes this age group highly relevant to anthropometric study of growth (Rizkah et al., 2022). The mean height of 150.05 cm and mean femur length of 35.44 cm reflect body dimensions that are still developing. Boys had longer femurs and were taller than girls. This sexual dimorphism agrees with the literature, which states that males generally have larger long bones and greater height because of sex hormones and different growth patterns during puberty (Pankaj Kumar et al., 2023; Rizkah et al., 2022). Testosterone promotes larger bone growth before the epiphyseal plates close. The sex difference in femur length (3.10 cm) was comparable to the difference in height (3.43 cm), a first coherent sign that longer femurs go with greater height, later confirmed by the correlation test. The greater spread among boys (SD 7.06 cm for femur and 10.44 cm for height, against 5.63 and 7.23 cm in girls) probably reflects more varied pubertal stages in boys at junior high age, some of whom have entered the growth spurt while others have not.

The relationship between femur length and height

Femur length and height were positively and strongly related ($\rho = 0.617$, $p < 0.001$). This answers the research question directly: height rises as the thigh bone lengthens. The relationship has clear anatomical and physiological grounds. Anatomically, the femur is the longest and strongest bone in the body and contributes most to overall length (Rizkah et al., 2022). Standing height is the sum of several vertical segments: the skull, the vertebral column, the pelvis, the femur, the tibia, and the foot. The lower limb, dominated by the femur and tibia, makes the largest proportional contribution, and because the femur is the longest bone in this chain its contribution is the most prominent. Variation in femur length therefore directly shapes variation in height. Physiologically, the growth of the femur and of the whole skeleton is governed by the same systemic hormones, mainly growth hormone, insulin-like growth factor-1, thyroid hormone, and sex hormones, all acting on the epiphyseal plates (Pankaj Kumar et al., 2023). Because the femur and the rest of the skeleton grow under the same control, they move in coordination, which produces a strong correlation.

The coefficient of determination ($r^2 = 0.379$) shows that femur length explained 37.9% of the variation in height. This is large for a single predictor, given that height is the sum of many

skeletal segments and is influenced by genetic, hormonal, and environmental factors. The remaining 62.1% is explained by other segments such as the tibia, spine, and pelvis, and by genetic, nutritional, hormonal, and environmental factors (Rizkah et al., 2022). Because these segments do not always grow in exactly the same proportion in every person, part of the variation in height stays unexplained by the femur alone, which is why r^2 is not close to 1. Height remains a multifactorial trait that no single bone can fully explain.

Femur length as a predictor of height

Simple linear regression gave the equation height = 119.72 + 0.86 × femur length, with a standard error of estimate (SEE) of 7.21 cm. Each additional centimeter of femur length was associated with 0.86 cm more height. This ability has practical value in forensic anthropology. In mass disasters, accidents, mutilation cases, or the identification of incomplete remains, height cannot be measured directly, so estimation from long bones is needed (Pankaj Kumar et al., 2023; Putri Shella & Gafar Parinduri, 2025). The femur is the first choice for three reasons. It contributes much to height, it is sturdy and therefore more likely to be found intact than fragile bones, and its length is stable once the epiphyseal plates close in adulthood. Among the femur, tibia, humerus, and ulna, it gives the highest estimation accuracy (Pankaj Kumar et al., 2023). The equation can serve as an initial reference for height equations for local adolescents. Caution is needed, however. An SEE of 7.21 cm leaves a margin of error that cannot be ignored. This is expected because the femur explains only part of the variation in height, and estimation accuracy also depends on the precision of femur measurement. The equation should be seen as an aid to approximation, not an absolute determinant of height. It is also specific to the adolescents studied and needs adjustment for adults or for other ethnic groups, as anthropometric research has stressed (Hendra Pamuji Pamukti & Dirwan Suryo Soularto, 2022).

Comparison with previous studies

The result is consistent with earlier Indonesian studies. Kaintako et al. (2023) found a moderate positive correlation (r = 0.569) among Papuan students in Tomohon, and the present coefficient (ρ = 0.617) is slightly higher and falls in the strong category. Tanudjaja and Pasiak (2022) found a fairly strong correlation among the Sangihe in both sexes, in line with this study. Rizkah et al. (2022) among the Toraja and Putri Shella and Gafar Parinduri (2025) in Medan both developed height estimates from femur length, which confirms the femur as a reliable predictor across populations. Differences in coefficients between studies can come from population characteristics, age range, ethnic background, and the method and precision of measurement (Pankaj Kumar et al., 2023). Reported coefficients range from moderate to strong. Studies of adults that measure bone directly or radiographically generally find higher correlations because bone length has stabilized and measurement is more precise. Studies of growing adolescents that use external measurement tend to give more variable correlations. Against that background, ρ = 0.617 in adolescents measured externally is fairly good. It suggests that the basic femur-height relationship is robust enough to be detected despite the limits of the measurement method.

Limitations

Four limitations should be kept in mind. First, femur length was measured externally on living subjects by palpating the greater trochanter and the femoral condyle, which is harder and more error prone than direct or radiographic measurement because anatomical points under soft tissue can vary between examiners and between sessions. The high variation in femur

length (coefficient of variation 18.5%, range 20 to 51 cm) suggests such variation in procedure. Measurement error of this kind generally weakens a correlation, so the true relationship may be stronger than observed. Second, the cross-sectional design describes one point in time and cannot establish cause and effect. Third, the students were still growing with open epiphyseal plates, so the equation is specific to this population and does not automatically apply to adults. Fourth, nutritional status, pubertal stage, and genetic factors were not controlled, and the study covered one school environment with a particular ethnic background, so generalization needs care. Future studies should use more standardized measurement, such as radiography or a uniform external protocol with trained examiners and repeated measures, control for confounders such as nutritional status and Tanner stage, build separate equations for boys and girls, use broader populations, and consider a longitudinal design.

CONCLUSION

Femur length was strongly and significantly related to body height among students of SMP Methodist Antiokhia Pancurbatu. Five conclusions follow from the findings.

1. Mean femur length was 35.44 ± 6.57 cm and mean height 150.05 ± 9.14 cm. Boys had longer femurs (36.98 cm) and greater height (151.76 cm) than girls (33.88 cm and 148.33 cm).
2. Femur length and height were positively, strongly, and significantly correlated ($\rho = 0.617$, $p < 0.001$), so the alternative hypothesis was accepted.
3. Femur length explained about 37.9% of the variation in height ($r^2 = 0.379$); the rest is explained by other bone segments and by genetic, nutritional, hormonal, and environmental factors.
4. Femur length can predict height with the equation height = 119.72 + 0.86 × femur length, with a standard error of estimate of 7.21 cm. Each additional centimeter of femur is associated with 0.86 cm more height.
5. The equation is specific to the adolescent population studied and must be adjusted before use in adults or in other ethnic groups.

The equation can be an initial reference for height estimation in Indonesian adolescents, but its SEE means it is an approximation, not an exact value. Further research should use standardized or radiographic femur measurement, control for nutritional status and pubertal stage, derive separate equations for boys and girls, and draw on broader and more diverse populations.

The novelty of this study lies in the development of a population-specific stature estimation model based on femur length among early adolescents, an age group that remains relatively underrepresented in anthropometric research compared with adult populations. Unlike previous forensic anthropometric studies that predominantly investigate the relationship between long bone dimensions and stature in adults, this research provides empirical evidence of this association within an adolescent population through direct anthropometric measurements involving 394 junior high school students. Its principal contribution is the establishment of a population-specific regression equation linking femur length to body height, supported by correlation analysis, coefficient of determination, and standard error of estimate to characterize the predictive capacity of the model. By extending the application of femoral anthropometry to early adolescent populations, this study contributes to a more age-sensitive approach to stature estimation and provides preliminary evidence relevant to forensic anthropology and clinical anthropometry. Furthermore, the findings highlight the importance of considering age-related growth characteristics and population specificity when developing anthropometric prediction models, rather than directly applying generalized equations derived from adult populations. The proposed equation also

provides a foundation for further external validation across different adolescent populations to assess its predictive accuracy and broader applicability.

BIBLIOGRAPHY

Cavaignac, E., Li, K., Faruch, M., et al. (2017). Three-dimensional geometric morphometric analysis reveals ethnic dimorphism in the shape of the femur. Journal of Experimental Orthopaedics, 4(1). https://doi.org/10.1186/s40634-017-0088-2

De Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, 85(9), 660–667. https://doi.org/10.2471/BLT.07.043497

Kaintako, M., Marhta, D., Kaseke, M., George, D., & Tanudjaja, N. (2023). Hubungan tinggi badan dengan panjang tulang femur pada mahasiswa etnis Papua di Tomohon Kelurahan Kakaskasen III (Vol. 1).

Kira, K., Chiba, F., Makino, Y., et al. (2023). Stature estimation by semi-automatic measurements of 3D CT images of the femur. International Journal of Legal Medicine, 137(2), 359–377. https://doi.org/10.1007/s00414-022-02921-y

Kokati, D. B., B. R., J., & Pinjar, M. J. (2025). Stature estimation from fragments of femur in South Indian population. Cureus. https://doi.org/10.7759/cureus.78877

Kumar, P., Shahnawaz, K., & Varma, G. (2014). Study of estimation of stature by the length of femur. Journal of Evolution of Medical and Dental Sciences, 3(12), 3166–3172. https://doi.org/10.14260/jemds/2014/2261

Lai, P. S., Mohamad Noor, M. H., & Abdullah, N. (2021). Stature estimation study based on pelvic and sacral morphometric among Malaysian population. Bulletin of the National Research Centre, 45(1). https://doi.org/10.1186/s42269-021-00601-2

Ningsih, A. W., Istarini, A., & Miftahurrahman, M. (2026). Body height estimation using femoral length among the 2022–2024 cohort of medical and health sciences students at Jambi University. Jurnal Kedokteran Diponegoro (Diponegoro Medical Journal), 15(3), 252–261. https://doi.org/10.14710/dmj.v15i3.54744

Pamukti, H. P., & Soularto, D. S. (2022). Korelasi antara tinggi badan dan panjang tungkai bawah perkutan pada mahasiswa ras Jawa usia pertumbuhan.

Pomeroy, E., Stock, J. T., & Wells, J. C. K. (2021). Population history and ecology, in addition to climate, influence human stature and body proportions. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-020-79501-w

Putri, S. R., & Parinduri, A. G. (2025). Determination of height based on estimated femur length in Medan City. Buletin Farmatera, 10. http://jurnal.umsu.ac.id/index.php/buletin_farmatera

Rizkah, S., Anwar, M., Hamzah, P. N., et al. (2022). Penentuan estimasi tinggi badan berdasarkan panjang tulang femur pada masyarakat yang bersuku Toraja.

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. Indian Journal of Dermatology, 61(3), 261–264. https://doi.org/10.4103/0019-5154.182410

Simon, S., Fischer, B., Rinner, A., et al. (2023). Body height estimation from automated length measurements on standing long leg radiographs using artificial intelligence. Scientific Reports, 13(1). https://doi.org/10.1038/s41598-023-34670-2

Soekanto, A., Mudzadadil, I., & Sani, A. (2023). The relationship of os. femur with height influenced by gender, race, and nutrition for medical student in Faculty of Medicine University Wijaya Kusuma Surabaya. Anatomica Medical Journal, 6(2). http://jurnal.umsu.ac.id/index.php/AMJ

Surdam, Z., Makmun, A., Nulanda, M., Indarwati, R. P., & Ardiansyah, H. (2022). Estimasi tinggi badan berdasarkan panjang tulang femur pada mahasiswa suku Bugis Universitas Muslim Indonesia. Jurnal Ilmiah Universitas Batanghari Jambi, 22(3), 1684. https://doi.org/10.33087/jiubj.v22i3.2704

Tanudjaja, G. N., & Pasiak, T. (2022). Hubungan tinggi badan dengan panjang tulang femur pada etnis Sangihe di Madidir Ure.