Application of the Pureepatpong and Thummar Equations to Estimate Stature from Ulna Length in Early-Adult Madurese Individuals

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ABSTRACT
Stature is a fundamental anthropometric indicator used in nutritional assessment and pharmacokinetic calculations; however, direct measurement is often challenging in intensive care settings or among individuals with skeletal deformities. Estimation based on ulna length offers a practical alternative. Although numerous formulas have been proposed, none have been specifically developed or tested for the Madurese ethnic group. This study aimed to estimate stature from ulna length among early-adult Madurese individuals. An analytical observational design with a cross-sectional approach was employed. A total of 34 students aged 18–29 years from the Faculties of Medicine, Nursing, and Pharmacy at Universitas Muhammadiyah Malang were selected using purposive sampling. Stature was measured using a microtoise, whereas ulna length was assessed using a sliding caliper. Data were analyzed using univariate statistics, independent t-tests, and linear regression. The findings demonstrated significant differences between actual stature and estimated values generated by existing formulas, with the Pureepatpong equation yielding estimates closest to actual measurements compared with the Thummar formula. Ulna length showed a significant association with stature. In conclusion, ulna-based measurement is a valid method for estimating stature in early-adult Madurese individuals. The Pureepatpong formula exhibited superior accuracy and is therefore recommended for application in this population.
Keywords: stature estimation; ulna length; early adulthood; Madurese ethnicity; anthropometry

INTRODUCTION
Stature is widely recognized as one of the most essential anthropometric indicators used in nutritional assessment, body mass index calculation, and pharmacokinetic considerations in clinical practice [1]. Direct measurement of stature is typically performed in a standing position using standardized equipment; however, in certain circumstances; such as among patients admitted to intensive care units (ICUs), individuals with musculoskeletal disorders, spinal deformities, or limited mobility obtaining an accurate standing height becomes difficult or even impossible. These constraints underscore the need for alternative methods that are both practical and reliable for estimating stature in diverse clinical contexts [2-4].

One of the most frequently utilized alternatives is the estimation of stature based on ulna length [4]. The ulna is considered advantageous because its length demonstrates a relatively stable relationship with overall stature and can be measured more easily than other long bones, particularly in patients who are unable to stand upright [5,6]. Consequently, ulna-based measurement has emerged as a promising solution not only in clinical settings but also in forensic applications where rapid and non-invasive stature estimation is required.

Despite its practicality, the accuracy of ulna-based stature estimation is strongly influenced by population characteristics, including sex, age, and ethnicity [5]. Numerous estimation formulas developed across different countries have produced variable results when applied to populations other than those for which they were originally derived [7]. This variability highlights the potential for substantial estimation bias when non-population-specific formulas are used, thereby limiting their applicability in settings where ethnic or demographic differences are pronounced.

To date, no ulna-based stature estimation formula has been specifically developed or validated for individuals of Madurese ethnicity. This gap is noteworthy, as anthropometric differences among ethnic groups in Indonesia may significantly affect the accuracy of stature estimation methods [7]. Given the distinct anthropological profile of the Madurese population, reliance on formulas derived from other ethnic groups may lead to systematic errors and reduce clinical utility.

Therefore, the present study aims to evaluate and compare the accuracy of existing ulna-based stature estimation formulas and to examine the relationship between ulna length and stature among early-adult individuals of Madurese ethnicity. The findings of this research are expected to provide a scientific foundation for the use of ulna length as a more accurate alternative method for stature estimation tailored to local population characteristics. Moreover, the study seeks to contribute to improved practices in clinical assessment, nutritional evaluation, and forensic identification, particularly in contexts where direct measurement of stature is not feasible.

METHODS
This study employed an analytical observational design with a cross-sectional approach and was conducted at Campus 2 of Universitas Muhammadiyah Malang, Malang City, East Java, in March 2025. The research focused on early-adult individuals of Madurese ethnicity. The target population consisted of students from the Faculties of Medicine, Nursing, and Pharmacy at Universitas Muhammadiyah Malang, enrolled between 2021 and 2024. A total of 34 respondents were selected using purposive sampling based on predefined inclusion and exclusion criteria [8]. The inclusion criteria comprised individuals aged 18–25 years, born to both a Madurese father and mother, and willing to participate in the study. Exclusion criteria included the presence of bone abnormalities or any condition that could interfere with accurate measurement of stature or ulna length.

The study variables included ulna length as the independent variable and actual stature as the dependent variable, along with estimated stature derived from the Thummar and Pureepatpong formulas as comparative variables. Stature was measured using a microtoise, with respondents standing upright without footwear, maintaining the Frankfort horizontal plane, and positioning the measuring bar to touch the vertex of the head (Figure 1) [2,3]. Ulna length was measured using a sliding caliper from the olecranon to the styloid process following standardized anthropometric procedures (Figure 2 [9]. All measurements were performed by the same researcher to minimize inter-observer bias and ensure consistency.

Data analysis consisted of univariate procedures to describe respondent characteristics, independent samples t-tests to compare actual stature with estimated values, and linear regression analysis to examine the relationship between ulna length and stature. The significance level was set at $p < 0.05$.

Figure 1. Measurement of actual stature

Figure 2. Measurement of ulna length

RESULTS

This study involved a total of 34 early-adult respondents of Madurese ethnicity, consisting of 25 females (73.5%) and 9 males (26.5%). The mean age of male participants was 19.78 ± 1.20 years, which was slightly younger than that of female participants, whose mean age was 20.36 ± 1.55 years. Consistent with general anthropometric patterns, males demonstrated greater ulna length (27.20 ± 1.34 cm) compared with females (23.25 ± 1.70 cm), a difference that aligned with their higher actual stature (173.44 ± 5.75 cm for males versus 158.02 ± 5.23 cm for females).

Stature estimation using the Thummar formula produced values lower than actual stature for both sexes, yielding mean estimates of 165.51 ± 4.92 cm for males and 142.89 ± 9.05 cm for females. In contrast, the Pureepatpong formula generated estimates that more closely approximated actual stature, with mean values of 168.22 ± 5.11 cm for males and 149.61 ± 6.08 cm for females. These findings indicate that the Pureepatpong equation provides a more accurate estimation of stature than the Thummar formula across both sex groups.

Independent samples t-test revealed significant differences ($p < 0.05$) between actual stature and estimated values for both formulas among female respondents. However, the Pureepatpong formula demonstrated superior accuracy, reflected in a smaller mean difference compared with the Thummar formula (−8.41 cm vs. −15.13 cm). Among male respondents, only the Thummar formula showed a statistically significant difference ($p = 0.006$), whereas the Pureepatpong formula did not reach statistical significance ($p = 0.058$), despite producing estimates that were closer to actual stature (−7.93 cm vs. −5.23 cm). Taken together, these results indicate that the Pureepatpong formula consistently yields more accurate stature estimates than the Thummar formula.

Regression analysis further demonstrated a significant relationship between ulna length and stature across all groups. The following regression equations were obtained: 1) males: stature = 73.163 + 3.686 × ulna length ($R^2 = 73.9\%$); 2) females: stature = 116.983 + 1.765 × ulna length ($R^2 = 32.8\%$); 3) combined sample: stature = 86.868 + 8.380 × ulna length ($R^2 = 71.8\%$).

These results confirm that ulna length is significantly associated with stature, with a stronger predictive relationship observed among males compared with females. The higher coefficient of determination (R^2) in males suggests that ulna length serves as a more robust indicator of stature in this group, whereas additional factors may influence stature estimation among females.

DISCUSSION

Stature is a fundamental parameter across multiple disciplines, including forensic science, anthropology, clinical medicine, and nutrition. In many circumstances, direct measurement of stature is not feasible, necessitating the use of alternative methods such as estimation based on ulna length [10]. Ulna length demonstrates a significant correlation with stature, indicating that individuals with longer ulnae generally exhibit greater overall height [11]. This relationship forms the basis for numerous anthropometric models that utilize ulna length as a practical proxy for stature estimation.

The present study found that male participants exhibited longer ulna lengths than female participants, consistent with well-established sex-based differences in skeletal dimensions [12]. Similar findings have been reported in studies conducted in India and Nepal, where stronger correlations between ulna length and stature were observed among males. These differences are likely attributable to hormonal influences and variations in the rate of skeletal maturation [10–12]. Testosterone promotes longitudinal bone growth in males, whereas estrogen accelerates epiphyseal fusion in females, resulting in comparatively shorter long bones [1,11].

This observation aligns with the theoretical framework suggesting that estrogen expedites epiphyseal maturation, leading to earlier cessation of growth in females. Consequently, females tend to exhibit shorter ulna lengths than males of the same age group [13]. Research further indicates that estrogen exerts its effects on bone growth through estrogen receptors (ERs) located within the growth plate [14]. Experimental studies in female mice have shown that blockade of ERβ results in substantial increases in long-bone growth, whereas blockade of ERα slows growth [13]. These findings suggest that activation of ERβ by estrogen contributes to earlier epiphyseal closure, providing a biological explanation for the shorter ulna lengths observed among female respondents in this study.

In addition, estrogen suppresses the expression of key growth-related factors such as IGF-1 and Indian Hedgehog (Ihh), both of which play critical roles in chondrocyte proliferation and long-bone elongation [13]. Thus, the overall effect of estrogen on long-bone development is to accelerate epiphyseal maturation and terminate growth earlier, reinforcing the observed sex-based differences in ulna length.

Conversely, testosterone exerts a more complex influence on long-bone growth in males. It acts directly through androgen receptors and can also be aromatized into estradiol, which mediates additional growth effects [15]. As a result, males experience a longer growth period before epiphyseal closure. In this study, male respondents demonstrated greater mean stature than females, consistent with the role of testosterone in prolonging the growth phase by enhancing chondrocyte proliferation within the growth plate [16]. Testosterone also increases IGF-1 expression, further stimulating long-bone elongation. Elevated IGF-1 levels in males contribute to greater ulna length and overall stature compared with females [17]. Together, testosterone and IGF-1 form a synergistic mechanism that enables males to achieve greater adult height.

Ulna length exhibits a significant association with stature and can be used as an alternative method for height estimation [18,19]. Although variations exist among estimation formulas, the Pureepatpong equation demonstrated superior accuracy compared with the Thummar formula in this study. Two primary regression formulas; Thummar and Pureepatpong were applied to estimate stature from ulna length among early-adult Madurese individuals [20,21]. Both formulas have been used in previous studies involving Asian populations, including those in India and Thailand [19].

The findings revealed that the Thummar formula consistently underestimated stature in both males and females, whereas the Pureepatpong formula produced estimates closer to actual measurements. This pattern aligns with prior research indicating that the accuracy of stature estimation formulas is highly dependent on the population and ethnicity from which the regression model was derived [22]. For example, studies in Nepal have reported stronger correlations between ulna length and stature among males, which may explain the larger deviations observed in female estimates [10].

Despite the relative accuracy of the Pureepatpong formula, the present study indicates that ulna-based stature estimation still exhibits limitations when applied to the Madurese population. Although Pureepatpong provided more accurate estimates than Thummar, substantial discrepancies remained, particularly among female respondents. These deviations highlight the need for population-specific regression models that account for unique anthropometric characteristics.

The observed inaccuracies; such as underestimations ranging from 5 to 15 cm across formulas underscore the necessity of developing a Madurese-specific prediction model. The regression coefficients obtained in this study ($R^2 = 0.739$ for males and $R^2 = 0.328$ for females) indicate a strong relationship for males but suggest that additional variables may influence stature among females. These findings support the importance of population-specific equations and standardized measurement protocols [21].

Ethnic variation also contributes to differences in regression coefficients (ranging from 1.765 to 5.617), demonstrating that stature estimation formulas must be adapted to local anthropometric characteristics [20]. Southeast Asian populations, including the Madurese, possess distinct body proportions, long-bone ratios, and stature profiles compared with African or European populations. Measurement techniques, including posture, instrument calibration, and operator training, further influence accuracy. For Madurese-specific studies, the use of calibrated digital instruments and standardized anthropometric training is strongly recommended [7].

Ulna-based estimation methods hold significant value in clinical medicine and nutrition, particularly for assessing nutritional status in patients whose stature cannot be measured directly [7]. Ulna length also serves as an alternative for calculating BMI and monitoring growth in children and adolescents, with reported accuracy reaching 88.1% [18]. In forensic science, ulna length aids in identifying individuals in cases involving incomplete remains, as numerous studies have demonstrated strong correlations between ulna length and stature [23]. The average stature of Madurese males (173.44 cm) and females (158.02 cm) can be estimated using ulna-based regression models [10]. This study also contributes to anthropological knowledge by highlighting sex- and ethnicity-based differences in ulna length and emphasizing the importance of developing population-specific regression models [12,19]. In sports science, stature plays a role in athlete selection and training program development [22]. Stature estimation also assists in dietary planning, exercise prescription, and musculoskeletal rehabilitation by informing predictions of posture and biomechanical alignment [24,25].

This study has several limitations, including a relatively small sample size, an unequal distribution between male and female participants, and the use of purposive sampling, which may introduce selection bias. The study was conducted at a single location and limited to university students, restricting generalizability. Additionally, other factors influencing stature; such as nutritional status, physical activity, and genetic background were not assessed, and measurement bias remains possible. Future research should involve larger and more balanced samples, multiple study sites, and a broader range of variables to enhance the accuracy and applicability of ulna-based stature estimation models.

CONCLUSION

Based on the findings of this study, ulna length is a valid predictor of stature, demonstrating a consistent relationship that supports its use as an alternative estimation method for early-adult individuals of Madurese ethnicity. The Pureepatpong formula produced estimates closer to actual stature than the Thummar formula and is therefore more suitable for this population. Accordingly, ulna-based stature estimation; particularly when using population-appropriate formulas may be considered a practical alternative in clinical and forensic applications.

Ethical consideration, competing interest and source of funding

-This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Muhammadiyah Malang (KEPK-FKUMM), with ethical clearance certificate number 00031/EA/2025/0029213573.
-No conflict of interest related this research.
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