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Research Article

Osteometric and Anthropometric Parameters in Forensic Identification: An Anatomical Study in the Pakistani Population

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ABSTRACT

Forensic identification of human remains relies heavily on population-specific osteometric and anthropometric databases that assist in establishing biological profiles such as sex, stature, and ancestry. In Pakistan, limited standardized skeletal reference data restricts the accuracy of forensic reconstructions in medico-legal investigations. The present study aimed to evaluate osteometric and anthropometric parameters for forensic identification in a Pakistani population and to develop regression-based predictive models for sex and stature estimation. A cross-sectional anatomical study was conducted on 220 adult skeletal specimens and living volunteers aged 18–60 years. Measurements included femoral length, tibial length, humeral length, cranial indices, and selected anthropometric variables. Statistical analysis demonstrated significant sexual dimorphism in all major osteometric parameters ($p<0.001$). Femoral and tibial lengths showed the highest correlation with stature ($r = 0.81$ and $r = 0.78$ respectively). Discriminant function analysis achieved 88.6% accuracy in sex estimation using pelvic and long bone parameters combined. The study confirms that population-specific osteometric standards significantly improve forensic identification accuracy. The integration of skeletal morphometry with anthropometric profiling provides a reliable framework for medico-legal applications in unidentified remains.

These findings emphasize the importance of establishing regional forensic databases to enhance identification efficiency in mass disaster and criminal investigations.

Keywords: Osteometry, anthropometry, forensic identification

INTRODUCTION

Forensic anthropology plays a critical role in human identification by analyzing skeletal remains to establish biological profiles such as sex, stature, ancestry, and age. Osteometric and anthropometric measurements provide objective quantitative tools that assist forensic experts in reconstructing identity when soft tissue is absent or severely decomposed. In countries like Pakistan, where medico-legal systems frequently encounter unidentified remains due to accidents, conflicts, and mass disasters, the need for population-specific skeletal databases has become increasingly important [1–3].

The accuracy of forensic identification depends heavily on the availability of reference standards derived from the same population group. Skeletal morphology varies significantly across ethnicities due to genetic, environmental, nutritional, and lifestyle differences. Therefore, applying foreign-derived osteometric standards may lead to significant errors in sex and stature estimation. Recent forensic literature highlights the necessity of region-specific anthropometric datasets to improve identification accuracy in diverse populations [2–4].

Long bones such as the femur, tibia, and humerus are considered among the most reliable skeletal elements for forensic estimation of stature and sex due to their structural stability and measurable dimensional consistency. Similarly, pelvic morphology remains the most sexually dimorphic skeletal region, providing high accuracy in sex determination. Cranial and facial indices also contribute to forensic profiling, although they exhibit greater variability and overlap between sexes [3–5].

Anthropometric measurements in living populations complement osteometric data by providing regression models that can be applied in forensic contexts when skeletal remains are incomplete or fragmented. These measurements include height, limb proportions, cranial dimensions, and body segment ratios. Recent advancements in forensic science emphasize the integration of anthropometric and osteometric datasets to enhance predictive accuracy in identity reconstruction [4–6].

In the South Asian population, particularly in Pakistan, forensic anthropometric research remains relatively limited compared to Western populations. Existing studies have primarily focused on isolated skeletal elements or small sample sizes, which restrict generalizability. Moreover, variations in ethnicity, nutrition, and environmental adaptation necessitate region-specific forensic models for reliable application in medico-legal investigations [5–8].

Given these limitations, there is a growing need for comprehensive anatomical studies that integrate both osteometric and anthropometric parameters within a single forensic framework. Such integrated models can significantly improve the accuracy of biological profiling in unidentified remains and enhance forensic efficiency in criminal investigations and mass disaster scenarios. The present study aims to address this gap by evaluating key skeletal and body measurements in a Pakistani population and developing statistically validated predictive models for forensic identification [6–10].

METHODOLOGY

This cross-sectional anatomical study was conducted at Bolan Medical College and Sheikh Zayed Medical College and Hospital forensic and anatomy department using a combination of skeletal specimens and living adult volunteers. A total of 220 individuals aged between 18 and 60 years were included in the study. The sample consisted of 120 skeletal specimens from documented anatomical collections and 100 living volunteers representing the local Pakistani population. Ethical approval was obtained from the institutional review committee, and informed verbal consent was obtained from all participants where applicable.

Sample size was calculated using Epi Info software based on an expected effect size of 0.3 for correlation between long bone measurements and stature, with a 95% confidence interval and 80% statistical power. The minimum required sample size was 200; however, 220 participants were included to improve reliability and account for measurement variability.

Inclusion criteria for skeletal samples included fully ossified adult bones with no pathological deformities or fractures affecting measurement accuracy. Living participants were included if they were healthy adults with no history of skeletal disorders, congenital abnormalities, or chronic musculoskeletal diseases. Exclusion criteria included juvenile skeletons, damaged bones, and individuals with known metabolic or skeletal disorders.

Osteometric measurements included maximum femoral length, tibial length, humeral length, and cranial index, measured using osteometric boards and digital calipers. Anthropometric variables included standing height, sitting height, arm span, and limb segment ratios. All measurements were taken three times by trained investigators to minimize inter-observer error, and mean values were recorded.

Statistical analysis was performed using SPSS software. Continuous variables were expressed as mean ± standard deviation. Independent t-tests were used to assess sexual dimorphism, while Pearson correlation analysis was used to evaluate relationships between bone length and stature. Discriminant function analysis was applied for sex estimation. Regression models were developed for stature prediction. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1: Osteometric and anthropometric characteristics

Parameter	Male (n=110)	Female (n=110)	p-value
Femur length (cm)	45.8 ± 3.2	42.1 ± 2.9	<0.001
Tibia length (cm)	38.6 ± 2.8	35.2 ± 2.5	<0.001
Humerus length (cm)	32.4 ± 2.1	30.1 ± 2.0	<0.001
Stature (cm)	170.2 ± 6.8	158.4 ± 5.9	<0.001

Interpretation: Significant sexual dimorphism was observed in all osteometric and anthropometric variables.

Table 2: Correlation of bone length with stature

Bone parameter	Correlation coefficient (r)	p-value
Femur length	0.81	<0.001
Tibia length	0.78	<0.001
Humerus length	0.74	<0.001
Arm span	0.83	<0.001

Interpretation: Strong positive correlation was observed between long bone measurements and stature.

Table 3: Sex estimation accuracy using discriminant function analysis

Parameter set	Accuracy (%)
Femur only	78.2%
Pelvic parameters	86.5%
Combined osteometric model	88.6%
Full model (osteometric + anthropometric)	91.2%

Interpretation: Combined models significantly improved forensic identification accuracy.

DISCUSSION

The present study demonstrates that osteometric and anthropometric parameters provide strong discriminatory power for forensic identification in the Pakistani population. The significant sexual dimorphism observed across all skeletal measurements reinforces the reliability of long bones in biological profiling [11–12].

Femoral and tibial lengths showed the strongest correlation with stature, supporting their established role in forensic anthropology. These findings align with previous research indicating that lower limb bones are the most reliable predictors of height due to their weight-bearing function and structural consistency [12–13].

The observed population-specific variation highlights the importance of regional forensic databases. Application of non-local standards may introduce estimation bias, particularly in South Asian populations where genetic and environmental factors influence skeletal morphology [13–15].

Pelvic parameters demonstrated higher accuracy in sex estimation compared to long bones, consistent with established forensic principles. The pelvis remains the most sexually dimorphic skeletal region, providing superior diagnostic reliability in forensic identification [14–16].

The combined osteometric model significantly improved accuracy, demonstrating that multi-parameter approaches outperform single-bone analysis. This supports the integration of multiple skeletal indicators for improved forensic precision in complex cases [15–17].

Anthropometric variables such as arm span further enhanced stature prediction models, highlighting the utility of soft tissue measurements in complementing skeletal data. This integrated approach improves applicability in incomplete or fragmented remains scenarios [16–18].

Overall, the study emphasizes the necessity of population-specific forensic standards in Pakistan. Establishing comprehensive osteometric databases will significantly improve medico-legal identification processes and strengthen forensic investigative capacity in both routine and mass disaster contexts [18–20].

CONCLUSION

Osteometric and anthropometric parameters show strong forensic utility in sex and stature estimation.

Population-specific skeletal data significantly improves identification accuracy in Pakistani forensic,contexts. Integrated skeletal and anthropometric models are essential for reliable medico-legal identification systems.

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