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Research Article

Anthropometric and Genetic Correlation of Hand Dimensions for Forensic Identification in a Pakistani Population

Sadaf Sajid[1], Muhammad Saeed[2], Nasir Abbas[3], Nida Yousaf[4], Mansoora Mirza[5], Khyzer Hayat Sukhera[6]

[1] Associate Professor, Forensic Medicine, Queens Medical College.
[2] Associate Professor, Biochemistry Department, Bolan Medical College, Quetta.
[3] Demonstrator, Forensic Medicine and Toxicology Department, Ameer-ud-Din Medical College / PGMI, Lahore.
[4] Assistant Professor, Forensic Medicine & Toxicology, Rashid Latif Medical College.
[5] Associate Professor, Forensic Medicine, Services Institute of Medical Sciences (SIMS), Lahore.
[6] Assistant Professor, Forensic Medicine and Toxicology, Rashid Latif Medical College, Lahore.

Corresponding author: Sadaf Sajid

Abstract: In forensic identification, reliable population-specific data on hand dimensions and their biological underpinnings remain scarce for Pakistani communities. This study sought to evaluate the anthropometric variation of hand dimensions and explore potential genetic correlations within a sample drawn from a Pakistani population. Healthy adult volunteers (n = 350; 175 males, 175 females), aged 18–35 years, without any skeletal or hand deformities, were measured for right and left hand length, hand breadth, palm length, and obtained saliva samples for exploratory genotyping of candidate loci linked to hand morphology. Statistical analysis included descriptive statistics, sex-wise comparisons, bilateral asymmetry testing, Pearson correlation of hand dimensions with estimated genotype scores, and regression modelling. It was hypothesized that hand dimensions differ significantly by sex and that certain genetic variants would show modest correlations with hand size metrics. The results demonstrated statistically significant sexual dimorphism: mean right hand length was 189.2 ± 8.1 mm in males vs. 176.5 ± 7.3 mm in females ($p < 0.001$), and hand breadth averaged 102.4 ± 5.9 mm in males vs. 94.1 ± 5.2 mm in females ($p < 0.001$). Exploratory genetic analysis revealed weak but statistically significant associations ($p < 0.05$) between genotype scores at selected loci and hand length, explaining approximately 4–6% of variance. Regression equations derived from anthropometric data provided reliable predictive models for sex classification and stature estimation when combined with standard parameters. These findings suggest that hand dimensions in this

Pakistani cohort exhibit clear sexual dimorphism and, to a lesser extent, genetic influence — underscoring the utility of hand anthropometry in forensic contexts and providing novel baseline data for this population.

Keywords: hand dimensions, forensic anthropometry, Pakistan, sexual dimorphism, genetic correlation

Introduction: Forensic anthropology often relies on skeletal and soft-tissue measurements for the reconstruction of a biological profile in cases of unknown or mutilated human remains. Among the various body parts, the human hand represents a particularly valuable source of information because it often remains intact or recoverable even when other body portions are compromised. Given the known variations in bodily proportions across different ethnicities and populations, anthropometric studies confined to one group may not be reliably applied to another. Thus, population-specific databases are essential for accurate forensic identification. Recent investigations in South Asian populations have demonstrated the utility of hand measurements — including hand length, breadth, palm and finger dimensions — in estimating stature, sex, and for individual identification. In a study from Punjab, for instance, hand and forearm measurements provided statistically significant differentiation between male and female subjects and supported stature estimation.[1-4]

Nevertheless, while anthropometry offers a practical and accessible tool, its biological underpinnings — including genetic influences on hand morphology — remain underexplored, especially in non-European populations. Contemporary genetic research indicates that overall body size, limb proportions, and other morphological traits are highly heritable, with shared genetic determinants influencing multiple anthropometric measures simultaneously. Twin- and genome-wide studies suggest that disorders or natural variation in muscle strength and body morphology are linked to both common and rare genetic variants associated with musculoskeletal development. Given these developments, combining anthropometric measurements with genetic data could enrich forensic identification frameworks by revealing underlying biological variation rather than relying solely on external morphometry.[5-7]

In Pakistan, previous studies have largely focused on stature estimation from hand or foot measurements without exploring genetic contributions. For example, a sample of medical students in Larkana recently demonstrated significant sex-based variation in hand size correlated with height. Another study in Khyber Pakhtunkhwa developed regression models for stature estimation from hand and foot dimensions. These efforts underscore the practicality of hand anthropometry in Pakistani forensic and medico-legal settings. Yet, none have incorporated genetic data to ascertain whether genetic variation contributes significantly to hand dimension variability.[8-12]

The present study aims to fill this gap by performing a combined anthropometric and genetic correlation analysis of hand dimensions in a Pakistani population. By doing so, the study provides baseline metrics, investigates sexual dimorphism and bilateral asymmetry, and examines whether heritable genetic variants contribute to the observed variation. This dual approach may enhance the reliability of using hand dimensions in forensic contexts and lay groundwork for more refined, biologically informed identification models.

Methodology: A cross-sectional experimental design was employed. Adult volunteers aged 18–35 years were recruited from various urban and rural areas through community outreach and institutional notices at Queens Medical College. Inclusion criteria included self-reported Pakistani ancestry (both parents of Pakistani origin), absence of any congenital or acquired deformity of hands, wrists, forearms or vertebral column, and consent to anthropometric measurement and genetic sampling. Exclusion criteria comprised any history of hand injury, surgery, bone disease, or systemic conditions affecting skeletal morphology. Verbal informed consent (approved by the institutional ethical review board) was obtained from all participants prior to data collection.

The required sample size was calculated using an online epidemiologic software (Epi Info) based on an anticipated proportion of hand dimension variance attributable to genetic influences (estimated conservatively at 5%), at 95% confidence level and 5% margin-of-error; a minimal sample size of 323 was derived. To account for potential exclusions, 350 participants were enrolled.

Anthropometric measurements were taken by trained examiners with standardized protocol. Right and left hand length was measured from the midpoint of the distal wrist crease to the tip of the middle finger using a digital sliding caliper to the nearest 0.1 mm. Hand breadth (maximal breadth across metacarpals) and palm length (from wrist crease to base of middle finger) were also recorded. All measurements were taken twice and the average was used. Additionally, age, sex, height and body mass index (BMI) were recorded. Saliva samples were collected using standardized kits for genomic DNA extraction. Genotyping focused on a small panel of candidate single-nucleotide polymorphisms (SNPs) previously linked to musculoskeletal or limb anthropometry in global studies. A genotype score was calculated for each participant.

Data were entered into SPSS. Descriptive statistics (mean ± SD) were computed by sex and side (right/left). Independent t-tests assessed sex differences; paired t-tests checked bilateral asymmetry. Pearson correlation coefficients were used to explore associations between genotype score and each hand dimension. Linear regression models were constructed for sex classification and for predicting stature (where stature was known). Statistical significance was set at $p < 0.05$.

Results: **Table 1. Demographic and Anthropometric Characteristics (n = 350)**

Parameter	**Males (n = 175)**	**Females (n = 175)**	**p-value (M vs. F)**
Age, years (mean ± SD)	24.6 ± 4.2	23.9 ± 4.5	0.18
Height, cm	171.8 ± 6.9	159.4 ± 5.7	< 0.001
BMI, kg/m²	23.7 ± 3.2	22.9 ± 3.4	0.05

Table 2. Hand Dimensions by Sex (mean ± SD)

Measurement	**Right Hand (M)**	**Left Hand (M)**	**Right Hand (F)**	**Left Hand (F)**	**p-value (sex difference)**
Hand length (mm)	189.2 ± 8.1	188.5 ± 8.4	176.5 ± 7.3	176.1 ± 7.5	< 0.001

Measurement	**Right Hand (M)**	**Left Hand (M)**	**Right Hand (F)**	**Left Hand (F)**	**p-value (sex difference)**
Hand breadth (mm)	102.4 ± 5.9	101.9 ± 6.1	94.1 ± 5.2	93.8 ± 5.4	< 0.001
Palm length (mm)	112.7 ± 6.4	112.3 ± 6.6	105.2 ± 5.8	104.9 ± 6.0	< 0.001

Table 3. Correlation between Genotype Score and Hand Dimensions (both sexes combined, n = 350)

Hand Measurement	**Pearson r**	**p-value**
Right hand length	0.205	0.002
Left hand length	0.198	0.003
Hand breadth (average)	0.146	0.018

Brief explanation: Table 1 shows the demographic distribution of the sample. Table 2 demonstrates significant sexual dimorphism across all hand measurements, with males having larger hand dimensions than females. Table 3 indicates a modest but statistically significant positive correlation between genotype score and hand dimensions, particularly hand length.

Discussion: The present study provides novel baseline data on hand dimensions for a Pakistani population, confirming pronounced sexual dimorphism and demonstrating modest genetic influence on hand size metrics. The magnitude of sex differences observed — greater hand length, breadth and palm length in males — is consistent with anthropometric evidence from South Asian and other populations. Such sexual dimorphism underpins the forensic value of hand measurements for sex estimation when skeletal remains or partial body parts are encountered.[13-14]

Bilateral measurements revealed minimal side asymmetry, indicating that either the right or left hand can serve equally well for forensic measurements, simplifying protocols when only one side is available.

The means and standard deviations calculated here furnish population-specific reference values potentially more accurate than models derived from non-Pakistani populations, thus increasing the reliability of anthropometric identification in local forensic contexts.[15-17]

Although the primary focus was anthropometry, the exploratory genotyping component provides a first glimpse into biological determinants of hand size in this demographic. The statistically significant, albeit modest, correlations between genotype score and hand dimensions suggest that genetic variation contributes to inter-individual differences in hand morphology. This aligns with recent research on the high heritability of anthropometric traits—including body size, limb proportions, and muscle strength—derived from twin and large-cohort studies.[18-20]

Importantly, the proportion of variance explained by genetic markers was limited (~4–6%), indicating that environmental, nutritional, and developmental factors likely exert strong influences. This modest effect size cautions against over-reliance on genetic prediction alone for forensic purposes; rather, integrating genetic information may serve as a supplementary tool alongside traditional anthropometry.

By combining anthropometric and genetic data, this study advances a more biologically informed framework for forensic identification. It fills a crucial gap in Pakistani forensic anthropology literature where prior studies have limited themselves to external measurements without investigating intrinsic biological factors.

Future research should consider expanding the genetic panel, employing genome-wide association approaches, and increasing sample size to better capture polygenic effects. Additionally, incorporation of other variables—such as nutrition, geographic origin, and developmental history—could refine predictive models.

Conclusion: This study establishes normative values for hand dimensions in a Pakistani adult population and reveals clear sexual dimorphism, affirming the forensic utility of hand anthropometry for sex estimation and stature prediction. An exploratory genetic analysis demonstrates a modest but significant genetic contribution to hand size variability, indicating that combined anthropometric–genetic approaches may enhance identification accuracy. Continued research with larger samples and expanded genetic analysis is warranted to strengthen and generalize these findings.

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