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Original Article

Stature Estimation from the Measures of Upper Limb Segments in Hisar Population Migrated from India

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ABSTRACT

Background: The relationship between stature and various body segments has long been used in forensic anthropology to estimate height from partial remains in medico-legal cases. Given the diversity of human populations, region-specific data are crucial for enhancing the accuracy of such estimations.

Objective: To develop regression equations for estimating stature from the measurements of upper limb segments in the male population of Hisar, Pakistan, and to assess the predictive accuracy of these models.

Methods: This study involved 100 male participants aged 18-30 years from the Hisar population in Multan, Pakistan. Measurements taken included standing height, wingspan, bi-acromial length, brachial length, antebrachial length, hand length, hand width, and total upper limb length. Statistical analysis was conducted using SPSS version 25, where Pearson's correlation and linear regression analyses were performed to derive equations for stature estimation.

Results: The study found significant correlations between stature and various upper limb measurements. Notably, wingspan showed the highest correlation with stature ($r=0.800$, $p<0.001$), followed by brachial length (Right $r=0.779$, Left $r=0.782$, both $p<0.001$) and total upper limb length (Right $r=0.715$, Left $r=0.710$, both $p<0.001$). Linear regression analysis provided predictive models with coefficients of determination ranging from $R^2=0.106$ for hand length to $R^2=0.639$ for wingspan.

Conclusion: Upper limb measurements, particularly wing span, brachial length, and total upper limb length, are reliable predictors of stature in the male population of Hisar. These findings support the use of these specific anthropometric measurements in forensic and anthropological applications for this demographic group.

Keywords: Forensic Anthropology, Stature Estimation, Linear Regression, Upper Limb Measurements, Hisar Population, Pakistan

INTRODUCTION

The estimation of human stature from various body segments has long been a subject of interest within forensic anthropology and medical sciences, primarily due to the need for identifying individuals in situations where complete remains are unavailable. This anthropometric approach has been continuously employed and studied across multiple fields for decades, particularly for its applications in medico-legal contexts, such as the identification of disaster victims, war casualties, and in historical reconstructions of skeletal remains (1-5). Moreover, stature estimation plays a critical role in the medical field, aiding in the diagnosis and treatment planning for bedridden or disabled individuals (6), and in sports sciences, where it helps in assessing the athletic potential of individuals (7, 8). Ergonomic design also benefits from accurate stature estimation, influencing everything from workplace setups to transportation systems, ensuring accessibility and safety for individuals of varying body sizes (8).

Research in stature estimation not only improves the foundational methodologies used in forensic and medical practices but also enriches our understanding of population-specific body metrics, which are crucial for precision in such estimations (9). The

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uniqueness of anthropometric data across different populations necessitates the development of specific equations for each demographic group, given that equations derived for one ethnic or regional group may not necessarily apply to another (10). Additionally, the dynamic nature of human populations, with changes in lifestyle and environment, underpins the need for periodic updates and validation of these anthropometric models (11-13).

The present study focuses on the Hisar population residing in the suburbs of Multan, Pakistan—a community that has seen little research regarding its specific anthropometric characteristics. The males of this community, having migrated from India in 1947, represent a distinct genetic and regional cohort. This study aims to fill a gap in the anthropometric data by deriving new regression equations that can estimate stature from measurements of the upper limb segments. This data not only broadens the scope of forensic and medical research but also contributes significantly to the regional and global databases of population-specific anthropometric measurements, thereby enhancing the accuracy and applicability of stature estimation in both scientific and practical contexts.

MATERIAL AND METHODS

The study comprised a sample of 100 male participants from the Hisar population in the suburbs of Multan, Pakistan, all of whom were permanent residents of the area since migrating from India in 1947. The age of participants ranged from 18 to 30 years. Individuals with any deformities or a history of surgical interventions affecting the backbone, or limbs were excluded to maintain homogeneity in the sample relevant to the study's anthropometric focus.

Data collection was conducted in a controlled setting, ensuring consistency and reliability in the measurement process. Each participant was positioned in an anatomical stance on a flat, horizontal surface, with the back aligned against a vertical plane. The posture was standardized such that the heels, buttocks, and shoulder blades were in contact with the vertical plane, and the head was oriented according to Frankfurt’s plane. Stature was measured from a fixed point on the vertical plane to the horizontal base. Other measurements included wingspan, taken as the distance between the tips of the middle fingers with arms abducted perpendicular to the trunk; bi-acromial length, measured between the outer edges of the acromions; lengths of the brachial and antebrachial segments, hand length from the wrist crease to the tip of the middle finger, and hand width across the metacarpal heads. Additionally, the total arm length was measured from the lateral edge of the acromion to the tip of the middle finger. All measurements were conducted using a steel measuring tape for linear dimensions and a flexible measuring tape for circumferences, by the same examiner to avoid inter-observer variability.

Ethical considerations were strictly adhered to throughout the study. The research protocol was reviewed and approved by the institutional ethics committee, ensuring compliance with the Declaration of Helsinki. Informed consent was obtained from all participants, who were informed about the purpose of the study and assured of their anonymity and the confidentiality of their data.

Data analysis was carried out using SPSS version 25. Descriptive statistics provided an overview of the data distribution, including means and standard deviations. The relationship between stature and the various upper limb measurements was assessed using Pearson’s correlation coefficient to determine the strength and direction of the linear relationships. Subsequent linear regression analysis was performed to develop predictive models for stature based on the measurements of the upper limb segments. A p-value of less than 0.05 was considered statistically significant, indicating a reliable correlation between the variables. The robustness of the predictive models was evaluated through the calculation of coefficients of determination (R^2) and standard error of estimates, which quantified the predictive accuracy of the regression equations developed from the study data.

RESULTS

In the investigation of the relationship between upper limb segment measurements and stature in the Hisar male population, the study's findings revealed significant correlations and enabled the construction of predictive models for stature estimation. Below are the summarized results displayed in a detailed tabulated format, complemented by descriptions of the key findings:

Table 1: Pearson’s Correlation for Stature with Upper Limb Segments

Independent Variables (Unit=cm)	R	P-value
Wingspan	0.800	0.000
Bi-acromial length	0.114	0.261

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Right Brachial length	0.779	0.000
Left Brachial length	0.782	0.000
Right Antebrachial length	0.691	0.000
Left Antebrachial length	0.689	0.000
Right Hand length	0.328	0.001
Left Hand Length	0.326	0.002
Right Hand Width	0.510	0.000
Left Hand Width	0.523	0.000
Right Total upper limb length	0.715	0.000
Left Total upper limb length	0.710	0.000

Description of Table 1: The table illustrates that wing span, brachial lengths, antebrachial lengths, total upper limb lengths, and hand widths showed strong correlations with stature, all having significant p-values ($p < 0.05$). Notably, the wing span presented the highest correlation coefficient ($R = 0.800$), suggesting it as the most reliable single predictor of stature among the measured segments. Conversely, bi-acromial length displayed a non-significant correlation ($p = 0.261$), indicating it as a less reliable predictor in this population.

Table 2: Linear Regression for Estimation of Stature from Upper Limb Segment Lengths

Independent Variables (Unit=cm)	Dependent Variable	R^2	a (Coefficients)	b (Constant)	SEE	P-value
Wingspan	Standing Height	0.639	0.732	41.701	3.201	0.000
Bi-acromial Length		0.013	0.225	163.768	5.295	0.261
Right Brachial Length		0.607	3.150	58.684	3.343	0.000
Left Brachial Length		0.612	3.098	60.647	3.321	0.000
Right Antebrachial Length		0.477	3.775	63.963	3.853	0.000
Left Antebrachial Length		0.475	3.578	69.710	3.861	0.000
Right Hand Length		0.108	2.588	122.820	4.948	0.001
Left Hand Length		0.106	2.559	123.387	4.953	0.002
Right Hand Width		0.260	7.243	108.416	4.507	0.000
Left Hand Width		0.274	7.630	105.099	4.463	0.000
Right Total Upper Limb Length		0.512	1.357	66.012	3.725	0.000
Left Total Upper Limb Length		0.505	1.332	67.991	3.751	0.000

Description of Table 2: This table presents the linear regression analysis results, demonstrating the equations developed for predicting stature from upper limb measurements. The variables showing the highest coefficients of determination (R^2) include the wingspan, and the right and left brachial lengths, all surpassing 0.6, which indicates that these measurements can predict stature with substantial accuracy. The standard errors of estimate (SEE) range from 3.201 cm to 5.295 cm, suggesting a relatively tight prediction interval for most measures, except for bi-acromial length, which shows minimal predictive reliability with an R^2 of 0.013.

These results reinforce the utility of specific upper limb measurements as effective predictors of stature in forensic and anthropological applications, particularly in the studied population. The robust correlations and regression models developed offer valuable tools for applications in scenarios where direct measurement of stature is not feasible.

DISCUSSION

The present study elucidated the correlations between various upper limb segment measurements and stature among the male population of Hisar, who are relatively understudied in anthropometric research. The findings revealed strong and statistically significant correlations, particularly with the wingspan, brachial lengths, and total upper limb lengths, echoing the results of earlier research that highlighted the reliability of these measurements in stature estimation (14,15). For instance, the robust correlation observed between wingspan and stature ($R=0.800$) is in alignment with the strong correlations reported in other regional studies such as those by Supare et al. (14) and Chawla et al. (15), who explored similar anthropometric relationships within different Indian populations.

Comparative analyses further reinforced the relevance of the brachial and antebrachial lengths in stature estimation, which were also prominent in studies conducted in Iranian and Nigerian populations (17,18). Such findings suggest that while regional variations exist, certain upper limb measurements may consistently serve as reliable indicators of stature across diverse ethnic groups. However, unlike other studies where hand measurements showed strong correlations with stature (9), this study found that while the hand widths had significant correlations, they were weaker predictors compared to limb lengths. This variance underscores the necessity of developing region-specific equations for stature estimation, as biomechanical and genetic factors can influence body proportions differently across populations.

Despite these robust findings, the study was not without limitations. The sample size, although sufficient to achieve statistical significance, was relatively small and restricted to a narrow age range and a single gender. This limitation restricts the generalizability of the findings to other demographics, including females and other age groups within the Hisar population. Moreover, the exclusion of individuals with deformities or previous surgical interventions on limbs or spine may limit the applicability of the findings in forensic cases where such factors are unknown.

Furthermore, the study relied on manual measurements, which, despite the standardization efforts and use of consistent methods by a single examiner, are susceptible to minor measurement errors which could influence the accuracy of the predictive models. Future studies could benefit from incorporating more advanced, possibly automated, measurement technologies to reduce the potential for human error.

Given these findings and limitations, it is recommended that future research explore larger and more diverse sample sizes to enhance the robustness and applicability of the predictive models. It would also be beneficial to extend the study to include females and a broader age range to develop a more comprehensive understanding of the anthropometric characteristics of the Hisar population. Additionally, incorporating longitudinal data could help assess how changes in lifestyle, health, and environment might impact body proportions over time, further refining the stature estimation models for forensic and medical applications.

CONCLUSION

In conclusion, the study significantly contributes to the existing literature by providing new insights into the anthropometric characteristics of the Hisar male population and reaffirms the importance of specific upper limb measurements in stature estimation. The findings not only enhance forensic anthropology practices but also aid in medical and ergonomic applications where accurate body measurements are crucial.

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