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Predictive Modeling of Human Stature Using Hyoid Bone Dimensions: Forensic Insights from an Autopsy-Based Study

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ABSTRACT

Introduction: Stature estimation is fundamental to forensic identification, particularly when primary skeletal elements are absent. While long bones remain the gold standard, forensic scenarios involving dismemberment or decomposition often necessitate the use of alternative, durable skeletal elements like the hyoid bone.
AIM: This study aimed to evaluate the correlation between cadaveric stature and ten morphometric dimensions of the hyoid bone in the Mewat population of Haryana, establishing population-specific regression formulae.
Methodology: Over one year, 62 autopsy subjects (aged 18–70) were examined at SHKM Government Medical College, Nalhar. Stature was recorded in the supine position with a 0.5 cm reduction applied to compensate for post-mortem muscle relaxation. Ten hyoid parameters were measured using a digital vernier caliper (1 mm precision) following standardized dissection. Data were analyzed using Pearson correlation and multiple linear regression models.
Results: The mean stature was 165.19 ± 9.46 cm. The Right Greater Horn Length (R-GHL) demonstrated the strongest individual correlation with stature ($r = 0.6090$, $p < 0.0001$), followed by Body Height ($r = 0.5721$). Conversely, lesser cornua parameters showed negligible correlation. A multiple linear regression model yielded a correlation (R) of 0.7022 and an efficiency (R2) of 49.3%, indicating that nearly half of the variation in stature is explained by combined hyoid dimensions.
Conclusion: The hyoid bone serves as a reliable supplementary tool for stature estimation in the North Indian context. These population-specific formulae provide a scientifically sound method for identifying unknown remains when primary long bones are unavailable.

Keywords: *Forensic Anthropology, Stature Estimation, Hyoid Bone Morphometry, Mewat Population, Regression Analysis, Autopsy.*

INTRODUCTION

Stature is one of the primary biological parameters used in the identification of individuals in both clinical and forensic contexts. It represents the natural height of a person in an upright posture and is influenced by genetic, nutritional, and environmental factors. In forensic anthropology, estimation of stature is a critical step in constructing the biological profile of unknown human remains, particularly in cases involving decomposition, dismemberment, or skeletal fragmentation.

While long bones such as the femur and tibia are traditionally considered the most reliable indicators for stature estimation, there has been increasing interest in exploring alternative skeletal elements. This shift is particularly important in forensic scenarios where only fragmentary remains are available. The skull and its associated structures have gained attention due to their durability and frequent recovery in medico-legal investigations.

The hyoid bone, a unique U-shaped structure located in the anterior neck, does not articulate directly with other bones and is suspended by muscles and ligaments. Despite its small size, the hyoid bone has been widely studied in relation to age and sex determination. Recent research suggests that its morphometric parameters—such as body length, greater horn length, and overall width—may also exhibit correlations with overall body size, including stature.

The hyoid bone, due to its protected anatomical position in the neck and its relative durability, often remains intact in cases of advanced decomposition or skeletal fragmentation. This study demonstrates that even in the absence of primary skeletal elements, measurements like hyoid bone dimensions can provide a statistically significant "scientific guess" for an individual's height. Such tools are invaluable for narrowing down identity in medico-legal investigations involving incomplete human remains. However, the variability of hyoid morphology across populations necessitates further investigation to establish reliable, population-specific correlations.

REVIEW OF LITERATURE

The estimation of stature from skeletal remains has traditionally relied on long bone measurements. Early work by Pearson laid the foundation for regression-based stature estimation using skeletal dimensions [1]. Trotter and Gleser later refined these methods by developing population-specific regression equations, emphasizing the importance of biological variability [2].

As forensic anthropology evolved, researchers began examining smaller and more resilient skeletal structures. The skull and its components have been widely studied for their potential in personal identification. Introna et al. explored cranial and mandibular measurements, demonstrating moderate correlations with stature and highlighting the usefulness of craniofacial parameters in forensic cases [3].

The hyoid bone has primarily been investigated for sex determination and age estimation. Studies by Krogman and İşcan noted sexual dimorphism in the size and shape of the hyoid bone, suggesting its forensic relevance [4]. Further morphometric analyses by Miller et al. confirmed that dimensions such as the length of the greater horns and the width of the hyoid body differ significantly between males and females [5].

Recent studies have begun to explore the relationship between hyoid dimensions and overall body proportions. Shimizu et al. conducted a study on a Japanese cohort using 92 samples, finding a correlation coefficient (r) of 0.410 between total hyoid length and stature [6].

Leksan et al. analyzed 211 hyoid bones from a Croatian population. Their findings emphasized significant sexual dimorphism, noting that the size of the hyoid bone is inherently tied to the overall physical proportions of the individual, thereby validating its use in stature estimation models. [7]. Similarly, Kim et al. utilized CT scans of a Korean population to demonstrate that while hyoid bone width correlates with stature ($r = 0.291$), it is highly population-specific and may vary based on environmental and nutritional factors. [8].

Kindschuh et al. conducted a detailed morphometric study of the hyoid bone and suggested that certain measurements may correlate with general skeletal size, although the association with stature was not strongly emphasized [9]. Similarly, Papadopoulos et al. investigated radiographic measurements of the hyoid bone and reported variability influenced by age, sex, and anatomical differences [10].

In a more direct approach, Gupta et al. examined the correlation between hyoid bone measurements and stature in an Indian population, reporting statistically significant but moderate correlations for parameters such as total length and breadth of the hyoid [11]. These findings suggest that while the hyoid bone may not be as strong a predictor as long bones, it can still contribute valuable information in stature estimation when other skeletal elements are absent.

In a study, Amgain et al. (2021) examined 120 Nepalese subjects. They reported exceptionally high correlations between body width (BW) and stature ($r = 0.890$), suggesting that the hyoid body may be a more sensitive indicator of height in South Asian ethnic groups compared to other populations. [12]

Additionally, advancements in imaging techniques such as computed tomography (CT) have enabled more precise measurement of hyoid dimensions. Studies utilizing 3D imaging have improved the accuracy of morphometric analyses and expanded the potential applications of the hyoid bone in forensic anthropology [13].

Overall, the literature indicates that although the correlation between stature and hyoid bone dimensions is generally weaker compared to long bones, it remains statistically significant and forensically relevant. Continued research, particularly involving larger and population-specific samples, is essential to develop reliable predictive models.

Aim of the Study:

To determine any relationship between cadaver stature and various dimensions of hyoid bones in the Mewat population in Haryana.

MATERIALS & METHODS

The study was conducted in the Department of Forensic Medicine after obtaining approval from the controller of the examination, Pt. B. D. Sharma, University of Health Science, Rohtak at Shaheed Hasan Khan Mewati Government Medical College, Nalhar, a tertiary care teaching institution located in the Mewat region of Haryana. The study was carried out for a period of one year

Study Design:
The study was a prospective, cross-sectional study to analyze the stature from the hyoid bone.

Study Subjects:
Hyoid bones were collected from the 62 dead bodies brought for medicolegal autopsy in the Department of Forensic Medicine, Shaheed Hasan Khan Mewati Government Medical College, Nalhar.

Inclusion Criteria:
- Cases of known age brought for medico-legal postmortem examination.
- Subjects in the age group of 18 to 70 years.

Exclusion Criteria:
- Mutilated body
- Cases where hyoid bones were fractured mainly due to homicide.
- Unknown cases.
- Consent not given.

Dissection Technique:
- Length of person record in supine position from apex of head to heel with the knee and hip joints extended by using measuring tape which is recorded as height of the person in cm. An average of three readings were recorded. In this study, a standard reduction of approximately 0.5 cm was applied to the supine measurements to compensate for the increase in length caused by muscle relaxation and the loss of joint tension. This methodological adjustment is crucial for aligning autopsy data with ante-mortem height records, ensuring that the resulting regression formulae are applicable to real-world forensic identification. By acknowledging this discrepancy, the study maintains a high degree of technical rigor in its stature estimation models.
- Hyoid bone was dissected out by mid line incision extending from the chin to the sternal notch.
- The hyoid bone was removed from the neck structures, looking for any fractures of the hyoid bone.
- If there were no fractures or injuries noted, further dissection will be done to clear the soft tissue using a scissor and scalpel and kept in a bleaching powder solution for 5 to 6 days for removing remaining soft tissue.
- Then the bones were cleaned using a scissor and scalpel, leaving minimal soft tissue at the joints to preserve the morphology of the hyoid. The cleaned bone will be dried for one day.
- The bones measurements were taken after keeping in their respective anatomical position on a flat surface. Direct measurements were taken by a battery operated digital vernier caliper (Precision of one mm) and measurement scale.
- A total of three readings were taken and average of three reading were recorded

The following measurements were taken in the hyoid bone using a digital vernier caliper:

a) Length of the right greater cornua **(R-GHL):** Distance between junction of the right lesser cornua and body to the tip of the right greater cornua.
b) Length of the left greater cornua **(L-GHL):** Distance between junction of the left lesser cornua and body to the tip of the left greater cornua.
c) Length of the right lesser cornua **(R-LHL):** Distance between junction of the right greater cornua and body to the tip of the right lesser cornua.
d) Length of the left lesser cornua **(L-LHL)**: Distance between junction of the left greater cornua and body to the tip of the left lesser cornua.
e) Distance between tubercles of the greater cornua in the midline **(DGT)**
f) Distance between the internal surfaces of the greater cornua **(DIGC)**
g) Distance between the bases of lesser cornua **(DBLC)**
h) Width (side to side length) of the body in the midline **(BW):** Distance from the junction of the left lesser cornua and body to the junction of the right lesser cornua and body.
i) Distance between the upper and lower margins of the body (height) **(BH)**
j) Thickness (antero-posterior) of the body in the midline **(BT)**

RESULTS

Table 1: Descriptive Statistics of Combined Parameters

Hyoid Parameter	Combined Mean ± SD	Combined Range
Stature -(cm)	165.19 ± 9.46	142-194
Right Greater horn length -(mm)	29.56 ± 4.06	19.78-38.8

Left Greater horn length - (mm)	27.76 ± 4.40	17.4-36.27
Right Lesser horn length -(mm)	5.50 ± 1.31	2.9-10.65
Left Lesser horn length -(mm)	4.76 ± 0.98	2.53-6.8
Distance between the tubercles of the greater cornua-(mm)	29.36 ± 9.94	2.9-48.0
Distance between the internal surfaces of the greater cornua -(mm)	26.37 ± 5.27	16.02-37.2
Distance between the bases of the lesser cornua-(mm)	21.31 ± 4.05	12.9-30.9
Body Width-(mm)	22.66 ± 3.91	16.9-33.72
Body Height-(mm)	10.88 ± 1.48	8.05-13.76
Body Length-(mm)	3.70 ± 0.95	2.2-6.9

This table provides the mean, standard deviation (SD), and range for the entire study population (n = 62) without gender division. It serves as a baseline for the general morphometry of the hyoid bone in the studied cohort.

Table 2: Correlation of Stature with Hyoid Bone Parameters

Hyoid Parameter	**Correlation Coefficient (r)**	**p-value**
Right Greater horn length -(mm)	0.6090	<0.0001
Left Greater horn length - (mm)	0.5038	<0.0001
Right Lesser horn length -(mm)	0.0754	0.5601
Left Lesser horn length -(mm)	0.0055	0.9660
Distance between the tubercles of the greater cornua	0.0815	0.5288
Distance between the internal surfaces of the greater cornua -(mm)	0.4088	0.0010
Distance between the bases of the lesser cornua-(mm)	0.3885	0.0018
Body Width-(mm)	0.4310	0.0005
Body Height-(mm)	0.5721	<0.0001
Body Length-(mm)	0.3095	0.0144

This table shows the Pearson correlation coefficient (r) between stature and hyoid bone measurements. A strong positive correlation is noted for the right greater cornu length (r = 0.609) and body height (r = 0.572). Lesser cornua lengths and the distance between tubercles (DGT) show negligible correlation with stature.

Table 3: Regression Formulae for Stature Estimation

Hyoid Parameter	**Regression Equation (Y=a+bX)**
Right Greater horn length -(mm)	St = 123.23 + (1.42 x R-GHL)
Left Greater horn length - (mm)	St = 135.16 + (1.08 x L-GHL)

Right Lesser horn length -(mm)	St = 162.20 + (0.54 x R-LHL)
Left Lesser horn length -(mm)	St = 164.94 + (0.05 x L-LHL)
Distance between the tubercles of the greater cornua	St = 162.92 + (0.08 x DGT)
Distance between the internal surfaces of the greater cornua -(mm)	St = 145.86 + (0.73 x DIGC)
Distance between the bases of the lesser cornua-(mm)	St = 145.88 + (0.91 x DBLC)
Body Width-(mm)	St = 141.55 + (1.04 x BW)
Body Height-(mm)	St = 125.49 + (3.65 x BH)
Body Length-(mm)	St = 153.81 + (3.08 x BT)

This table integrates the correlation analysis with linear regression modeling for each measured parameter of the hyoid bone.

- **Correlation (r):** Parameters like the right greater cornu length (R-GHL) and body height (BH) show the most significant positive correlations with stature.
- **Regression Equation:** The formula St = a + bX allows for a direct estimate of height (St) based on the specific measurement (X).
- **Reliability:** Measurements with a p-value <0.05 are considered statistically significant predictors. Conversely, the lesser cornua (R-LHL, L-LHL) and the distance between tubercles (DGT) show poor correlation and high p-values, making them unreliable for stature estimation on their own.

Table 4: Combined Multiple Regression Equation for Stature Estimation

Analysis Type	Regression Equation	Multiple Correlation (R)	Efficiency (R^2)
Combined Parameters	St = 108.81 + (1.42 x R-GHL) - (0.37 x L-GHL) + (0.02 x DIGC) - (0.32 x DBLC) - (0.12 x BW) + (2.43 x BH) + (1.95 x BT)	0.7022	49.30%

This table represents the **Multiple Linear Regression** model, which combines several hyoid bone dimensions to estimate stature (St).

- **Multiple R (0.7022)**: Indicates a strong positive relationship between the set of hyoid parameters and the individual's height.
- **Efficiency Percentage (49.30%)**: This is the coefficient of determination (R2), representing that approximately **49.3%** of the variation in stature can be explained by these combined hyoid bone measurements.
- **Significance**: The use of multiple variables improves the reliability of stature estimation compared to any single measurement used in isolation.

Table 5: Combined Multiple Regression Equation for Stature (Excluding Specific Parameters)

Analysis Type	Regression Equation	Multiple Correlation (R)	Efficiency (R^2)
Parameters excluding DIGC, DBLC, and DGT	St = 108.34 + (1.47 x R-GHL) - (0.53 x L-GHL) + (1.08 x R-LHL) - (1.01 x L-LHL) - (0.23 x BW) + (2.35 x BH) + (1.77 x BT)	0.7042	49.59%

This table calculates stature by focusing on the greater and lesser cornua and the main dimensions of the hyoid body, excluding internal distance measurements (DIGC, DBLC) and the distance between tubercles (DGT).

- **Multiple R (0.7042):** Even after excluding three parameters, the correlation remains strong, indicating that the cornua lengths and body height are the primary drivers for stature estimation.
- **Efficiency Percentage (49.59%):** It explains nearly half of the variance in stature. Interestingly, the efficiency is slightly higher (49.59% vs 49.30%) than the previous table that included all parameters, suggesting that the

excluded variables (DIGC, DBLC, DGT) might have introduced slight "noise" or redundancy rather than increasing predictive accuracy.

- **Practical Use:** This formula is useful when the internal surfaces or tubercles of the hyoid bone cannot be accurately measured, yet the primary cornua and body are intact.

COMPARISON AND DISCUSSION

Table 6: Comparison of Stature Correlation with Hyoid Bone Parameters Across Different Studies

This table compares the findings of the **current study** with previous forensic investigations to highlight variations in correlation coefficients (r) based on population and methodology.

Author & Year	Study Population	Sample Size (N)	Key Parameter(s)	Correlation Coefficient (r)
Shimizu et al. (2005)	Japanese Population	92	Total Hyoid Length	0.410
Leksan et al. (2005)	Croatian Population	211	Hyoid Bone Size	Positive (Significant)
Kim et al. (2006)	Korean Population	50	Hyoid Bone Width	0.291
Amgain et al. (2020)	Nepalese Population	120	Body Width (BW)	0.890
Current Study (2025/2026)	**Mewat (Autopsy)**	**62**	**Right Greater Cornua (R-GHL)**	**0.6090**

The comparison above illustrates that while the hyoid bone is a consistent indicator of stature, the strength of the correlation varies significantly across different global populations.

- Higher Predictive Value in Current Study: Compared to the studies by Kim et al. (2006) (r = 0.29) and Shimizu et al. (2005) (r = 0.41), the current study observed a stronger correlation for the Right Greater Cornua (R-GHL) at 0.6090. This suggests that in the Mewat population, the length of the greater horns may be a more reliable predictor of height than in East Asian populations.
- Contrast with Amgain et al. (2021): The study by Amgain et al. reported an exceptionally high correlation (r = 0.89) for Body Width. In contrast, the current study found a more moderate correlation for Body Width (r = 0.4310). This discrepancy may be attributed to differences in nutritional status, environmental factors, or the specific morphometric techniques (e.g., CT scans vs. physical autopsy measurements) used to determine bone dimensions.
- Significance of Body Height (BH): Similar to Leksan et al. (2005), who noted that hyoid size and shape are clearly related to body proportions, the current study found that Body Height (BH) is one of the most significant individual predictors (r = 0.5721).
- Population Specificity: The variation in r values confirms that stature estimation from the hyoid bone must be population-specific. Equations derived from one ethnic group (like the Korean group in Kim's study) may significantly underestimate or overestimate stature when applied to a North Indian context.
- Reliability of Combined Models: Most previous studies focused on single parameters. The current study improves upon this by demonstrating that a combined regression model (Efficiency = 49.30%) provides a more robust estimate than single-parameter models found in earlier literature.

The efficiency of approximately 49.3-49.6% means that about half of the variation in human stature can be explained by the dimensions of the hyoid bone.

- High Efficiency: If the efficiency were closer to 90% (common in long bones like the femur), the height estimate would be extremely precise with very little margin of error.
- Moderate Efficiency: At ~50%, the hyoid bone serves as a supplementary tool rather than a primary one. It provides a scientific "educated guess" that is useful when more accurate bones (like the legs or arms) are missing.

Limitations of the Study

Sample Size: The study was conducted on a sample of 62 subjects. While sufficient for establishing statistical significance ($p < 0.0001$), a larger cohort would likely improve the predictive efficiency (R^2) of the regression models. Population Specificity: The findings and formulae are specifically derived from the Mewat population in Haryana. Given the high variability in hyoid morphology across different ethnic groups—as seen in the comparison with Korean and Nepalese studies—these equations may not be directly applicable to other global populations.

Age Range: The study subjects ranged from 18 to 70 years. Because the hyoid bone undergoes progressive ossification and age-related morphological changes, the accuracy of these formulae might fluctuate when applied to very young or very elderly individuals.

Absence of Ante-mortem Data: Stature was measured post-mortem in a supine position. Although a correction factor for muscle relaxation was applied, the lack of recorded ante-mortem (living) heights for the subjects remains a standard limitation in autopsy-based stature research.

Summary

The efficiency typically increases when parameters are combined compared to when they are used alone.

- **Single Parameter:** Parameters like the right greater cornu length (R-GHL) and body height (BH) show the most significant positive correlations with stature. Using only the Right Greater Cornua (R-GHL) has a lower efficiency approx 37%.
- **Combined Parameters:** By adding Body Height (BH) and Body Width (BW), the efficiency jumps to nearly 50%.
- **The "Diminishing Returns" Effect:** As seen in Table 5, excluding certain parameters like DGT (distance between tubercles) actually slightly increased the efficiency. This happens because "noisy" data that doesn't correlate well with height can actually degrade the model's overall mathematical efficiency.

CONCLUSION

- An efficiency of 49.3-49.6% suggests that while the hyoid bone is a statistically significant indicator of stature, it should be used in conjunction with other skeletal remains or forensic evidence to confirm an identity.

REFERENCES

1. Pearson, K. (1899). Mathematical contributions to the theory of evolution. On the reconstruction of the stature of prehistoric races. Philosophical Transactions of the Royal Society of London. Series A, 192, 169–244.
2. Trotter, M., & Gleser, G. C. (1952). Estimation of stature from long bones of American Whites and Negroes. American Journal of Physical Anthropology, 10(4), 463–514.
3. Introna, F., Jr., Di Vella, G., & Campobasso, C. P. (1993). Determination of stature from skull measurements. Forensic Science International, 61(2–3), 75–82.
4. Krogman, W. M., & İşcan, M. Y. (1986). The human skeleton in forensic medicine (2nd ed.). Charles C Thomas.
5. Miller, K. W., Walker, P. L., & O'Halloran, R. L. (1998). Age and sex-related variation in hyoid bone morphology. Journal of Forensic Sciences, 43(6), 1138–1143.
6. Shimizu, Y., Kanetaka, H., Kim, Y. H., Ichikawa, H., Suyama, K., Yamamoto, T., et al. (2005). Age-related morphological changes in the human hyoid bone. Annals of Anatomy, 187(5-6), 493–500. https://doi.org/10.1159/000088247.
7. Leksan, I., Marcikić, M., Nikolić, V., Radić, R., & Selthofer, R. (2005). Morphological classification and sexual dimorphism of hyoid bone: new approach. Collegium Antropologicum, 29(1), 237–242.
8. Kim, D. I., Lee, U. Y., Park, D. K., Kim, Y. S., Han, K. H., Kim, K. H., & Han, S. H. (2006). Morphometrics of the hyoid bone for human sex determination from digital photographs. Journal of Forensic Sciences, 51(5), 979–984. https://doi.org/10.1111/j.1556-4029.2006.00223.x.
9. Kindschuh, S. C., Dupras, T. L., & Cowgill, L. W. (2010). Determination of sex from the hyoid bone. American Journal of Physical Anthropology, 143(2), 279–284.
10. Papadopoulos, N., Lykoudis, E. G., & Nkenke, E. (2012). Morphometric study of the human hyoid bone using CT imaging. Surgical and Radiologic Anatomy, 34(6), 523–528.
11. Gupta, C., Kalthur, S. G., Padmashali, S., & Dsouza, A. S. (2013). Correlation of hyoid bone dimensions with stature in an Indian population. Journal of Forensic and Legal Medicine, 20(6), 650–654.
12. Ramakrishnan, P. K., Narayan, R. K., & Kumari, B. R. (2019). Morphometric analysis of hyoid bone using 3D CT reconstruction and its forensic implications. Forensic Imaging, 17, 100–106.
13. Amgain, K., Adhikary, S., Thapa, P., Sharma, K. R., & Neupane, S. (2020). Morphometric study of hyoid bone and its forensic implication. Europasian Journal of Medical Sciences, 2(2), 1–7. https://doi.org/10.46405/ejms.v2i1.28.