A81 Combining Metric and Morphological Traits for Sex Estimation: A Pilot Study Using the Innominate

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Learning Overview: The goal of this presentation is to inform attendees about the potential impact of combining metric and morphological data types into a single statistical model for sex estimation using pilot data from the innominate.

Impact Statement: This presentation will impact the forensic science community by presenting a new statistical model that combines metric and morphological data for sex estimation using the innominate and comparing this model to commonly used metric-only and morphological-only methods.

The estimation of osteological sex is a crucial component in the construction of the "biological profile" from a set of unidentified skeletal remains. Traditionally, sex estimation methods have focused exclusively on the use of either metric (e.g., FORDISC®, DSP2) or morphological (e.g., MorphoPASSE) data.[1-3] Surveys of forensic anthropologists have shown that the majority of practitioners use multiple sex estimation methods based on both metric and morphological data. However, there is significant divergence in how the results from different methods are combined into a final estimation of sex and expression of statistical confidence. If results of the methods do not agree, forensic anthropologists may give preference to one method over another, provide a final estimation based on personal experience, or take an average of all methods.[4]

While the long-term goal of this research is to develop a novel method for sex estimation that can accommodate metric and morphological data from multiple skeletal elements, this pilot study focuses on the integration of these data types using the innominate. The innominate is the most sexually dimorphic bone in the human skeleton; however, the most commonly used morphological features (e.g., ventral arc, subpubic concavity, etc.) are not captured by the most commonly used measurements (innominate height and breadth) and vice versa. Two experienced observers collected metric and morphological data from the innominate in a sample of 19 females and 16 males (n = 35) from the Southeast Texas Applied Forensic Science Facility Skeletal Collection. Metric data included the measurements defined by Brůžek et al. for DSP2, excluding greater sciatic notch height (IIMT).[2] Morphological data included the Ventral Arc (VA), Subpubic Concavity (SPC), and Medial aspect of the Ischiopubic Ramus (MIPR) from the MorphoPASSE program, as well as the shape of the greater sciatic notch, presence of a composite arc, pubis shape, and subpubic angle.[3,5-7].

Sex estimation was tested using four statistical models: DSP2 (using only metric data), MorphoPASSE (using only morphological data for the VA, SPC, MIPR), a Random Forest (RF) model (using all metric and morphological data), and a Feed-Forward Neural Network (FFNN) model (using all metric and morphological data). Using a decision threshold of PP > 0.95, the FFNN model had the optimal performance, combining high accuracy and low sex-bias, while remaining highly inclusive of the sample. MorphoPASSE and the RF model achieved perfect accuracy for both observers, while one female was misclassified by DSP for both observers. However, while these three models produced high accuracy levels, the implementation of a decision threshold reduced the sample from the initial full set of 35 individuals to as low as 23 individuals. Using the FFNN, Observer 1 achieved perfect accuracy for 32 individuals meeting the decision threshold (18F/14M), and Observer 2 achieved 97.2% accuracy with all 35 individuals meeting the decision threshold, with one female being misclassified as male.

While existing sex estimation methods using the innominate are highly accurate, this pilot study demonstrates the potential for achieving nearly perfect accuracy with high statistical confidence by combining metric and morphological traits using a FFNN model. This model will continue to be tested using larger samples and data collected from multiple skeletal elements with the long-term goal of creating a freely available program for sex estimation that can integrate metric and morphological data, incorporate traits from the entire skeleton, and accommodate missing data.

References:

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Sex Estimation; Metric and Morphological Data; Neural Network Model