H72 Sex Estimation From the Clavicle in Modern Americans: Traditional Versus Alternative Approaches

Natalie R. Shirley, MA, University of Tennessee, Department of Anthropology, 250 South Stadium Hall, Knoxville, TN 37996; Brandon*
C. Merkl, MS, University of Tennessee, Department of Mechanical, Aerospace, and Biomedica, 414 Dougherty Engineering Building, Knoxville, TN 37996; and Richard Jantz, PhD, Department of Anthropology, University of Tennessee, Knoxville, TN 37996-0720

The goal of this presentation is to illustrate several approaches to quantifying sexual dimorphism in the human clavicle: linear discriminant functions, neural networks, and curvature analysis with medial axis representation.

This presentation will impact the forensic community by providing discriminant functions for sex estimation from the clavicle in modern Americans. Additionally, this research aims to combine information about size and shape to achieve maximum accuracy in sex estimation and to provide a model for similar analyses of other skeletal elements.

Traditionally, linear discriminant functions are used to discriminate among the sexes. However, neural networks offer the power of multiple non-linear discriminant functions and often provide superior discriminatory capabilities. Furthermore, capturing shape offers an additional method of discriminating sex that, when combined with either of the methods above, can assist in making accurate assessments. This presentation will examine each of these methods and propose the most accurate and precise method for sex estimation.

The William F. McCormick Clavicle Collection at the University of Tennessee contains clavicles from approximately 2,000 individuals from East Tennessee. In order to facilitate rapid data collection from a sample of this size, the entire collection was scanned with computed tomography scanning, and three-dimensional computer models were created. Scanning the bones also enabled the exploration of a number of alternative measurements and way to standardize the curvature analysis. A subset of 1,407 adults was used in this study. The sample was comprised of 53 African Americans and 1,354 Caucasians. Measurements analyzed include maximum length, sagittal midshaft diameter, vertical midshaft diameter, maximum midshaft diameter, minimum midshaft diameter, two diameters from the lateral end, and two diameters from the medial end. Curvature was analyzed by making angular measurements on a medial axis representation of the clavicle shaft.

The sample was analyzed with pooled and separate ancestries, and all discriminant analyses were performed in SAS 9.1 using cross- validation. Overall, the hit ratios were the same with both approaches, but separate discriminant functions are provided for whites and blacks. The best classification rate was 92.22% using maximum length, maximum and minimum midshaft diameters, and maximum and minimum diameters of the lateral end. A simple three-variable model with maximum length and maximum and minimum midshaft diameters discriminated with 91.44% accuracy. The new measurements from the lateral clavicle discriminate 77.72% accurately alone. The medial measurements did not perform well (62.38%) and were omitted from all final models. Maximum and minimum midshaft diameters performed equally as well as sagittal and vertical midshaft diameters; since maximum and minimum midshaft diameters are easier to measure precisely, these measurements offer a way to reduce inter-observer error.

The same sample was subsequently classified using a Feed-Forward Backpropagating Neural Network (NN). A network was constructed using all nine measured variables plus one binary variable indicating side (L = 0, R = 1) as input nodes, followed by a layer of eight hidden nodes, and finally an output layer of two nodes (one per sex). The network was trained using random subsets of the clavicle sample, where 30% were used for training, 30% were used for validation, and 40% were used for testing. Neural networks are ideal for a sample of this size because they are robust to assumptions of normality and equality of variance- covariance matrices. The final testing classification rate was 94.58%, while the overall classification (including the whole sample) was 94.22%. The three-variable model with maximum length and maximum and minimum midshaft diameters resulted in a testing classification rate of 93.48%.

Analysis of curvature was performed using a medial axis representation of the clavicle. The bone models were divided into 8-16 sections perpendicular to the shaft. The midpoint of the section was selected as one vertex of the medial axis. Subsequently, line segments connecting the medial axis points were connected to form an approximation to the shaft curvature. By analyzing the angular deviations between adjacent sections, quantitative shape information is acquired in a compact format. Distinct shape trends between the sexes were noted, but require further analysis before they can be suitably integrated into the classification procedures.

Sex Estimation, Clavicle, Neural Networks

 ** Presenting Author*