H63 New Statistical Approaches to Sex Estimation: Multi-Stage Discriminant Function Analysis

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After attending this presentation, attendees will understand sex estimation from skeletal remains is based predominantly on overall size, significant shape differences between male and female crania, and that discriminant function analysis (DFA) is a powerful tool for analyzing skeletal data and accuracy can be enhanced through multiple analyses utilizing size and shape variation.

This presentation will impact the forensic community and/or humanity by providing a better understanding of sexual dimorphism expressed by metrics.

Absent the bones of the pelvis, sex estimation from skeletal remains in forensic anthropology is often based predominantly on overall size, so small males and large females are more likely to be misclassified. Because there are different levels of sexual dimorphism and different sizes for the various populations in the world, an incorrect estimation of sex from skeletal remains can drastically affect ancestry assessment and vice-versa. Seriation (e.g., Rogers 2005) is not always an option and will likewise misclassify small males and large females.

Forensic anthropologists have been employing DFA to determine sex from crania for decades. The classic papers by Giles and Elliot in the 1960s provided numerous functions that permitted anthropologists to address questions of sex and ancestry using cranial measurements. More recently, FORDISC uses reference data from numerous human populations to calculate custom discriminant functions suited to a specific case, and some versions included a sex-only function, which combined the male and female samples of American Whites and Blacks. However, as Damann and Byrd (2004) demonstrated, DFA using raw measurements will tend to misclassify small males as female. This is especially true for groups with relatively small crania such as Hispanic males from the Southwest U.S. An incorrect sex assessment in the biological profile may affect the evaluation of ancestry and will hamper a positive identification.

There are various statistical methods for analyzing measurements from males and females, including using sex-centered means, extracting principal components and analyzing all but the first principal component, calculating shape variables (Darroch and Mosimann 1985), and calculating C-scores (Howells 1995). The latter method was recommended by Damann and Byrd (2004). Fordisc 3.0 (Jantz and Ousley 2005) allows the user to transform measurements into shape variables and then perform DFA on them. The flavor of DFA used is a linear discriminant function, though other methods such as quadratic DFA, nearest neighbor analysis, and kernel discriminant analysis can be employed as well.

Using 23 measurements from 171 white males and 100 white females, Fordisc 3.0 was 90% accurate in determining sex, crossvalidated. When shape variables were analyzed, the accuracy dropped to 83%, confirming that size differs between males and females, but also that shape differs significantly between them. More importantly, when the individual classifications were examined, 7 of the 17 males misclassified in the analysis using size and shape were correctly classified when using shape alone; 3 of the 10 females misclassified in the analysis using size and shape were correctly classified when using shape alone. Therefore, a Multi-Stage Discriminant Rule (MDR) utilizing both analyses is: If the size and shape classification of a cranium is male, accept the classification; if the size and shape classification is female, change the assessment to male if it classifies as a male using the shape variables. Following this rule results in classifications that are 94% correct for the white sample. Also, there were no indications of variance-covariance matrix heterogeneity.

While the use of shape variables clearly provides greater accuracy within Whites, there appears to be generalized sex differences that are expressed in relative size and/or shape in all groups: When 274 females and 465 males from several different recent populations were analyzed sex functions were obtained with somewhat reduced accuracy compared to Whites alone. However, results were encouraging using stepwise variable selection, with as few as 12 variables providing classification accuracies of at least 90%, though the most valuable shape variables were largely independent of the most valuable size variables. In looking at how Hispanic individuals classified using stepwise methods on combined recent populations, all 11 females were classified correctly using size and shape; 41 males were classified 90% correctly using size and shape, 83% using shape, and 95% correctly using the MDR.

Most of the metric variation between males and females has been thought to be due to size, but shape is also important. Combining multiple classification tools such as stepwise variable selection, different classification methods, and multiple steps can optimize sex classification accuracy. These tools can also be utilized with data from landmark coordinates and interlandmark distances (nontraditional craniometrics) to further improve sex classification.

References:

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