Exploring Sexual Dimorphism of Ancestral Cranial Nonmetric Traits in Modern European Americans

Savannah R. Mills[1], B.A. (srmills@bu.edu) and Sean D. Tallman[1,2], Ph.D. (tallman@bu.edu)
(1) Boston University School of Medicine; Forensic Anthropology Program; Department of Anatomy and Neurobiology
(2) Boston University, Department of Anthropology

Introduction

The estimation of ancestry in forensic anthropological contexts, which can be derived from nonmetric and metric approaches, is a pivotal part of the biological profile. In particular, cranial nonmetric traits are often utilized because they have a long-standing tradition in anthropological studies; they may be present on fragmented skeletal remains; and they may be scored without instrumentation (Hefner, 2007). The continued improvement of ancestry estimation methods and research into the various factors that affect their expression is crucial given the increasing diversity within the U.S. At present, nonmetric ancestry estimation methods are not sex specific; however, it is unknown how sex influences trait expressions. Thus, the present study examines the frequency of nonmetric traits used to estimate ancestry in European American females and males in order to determine if they are sexually dimorphic. It is hypothesized that statistically significant differences exist between females and males for some traits, and that this knowledge will assist in the further standardization of nonmetric traits when utilized in forensic contexts.

Methods and Materials

This study examines **17 nonmetric traits of the cranium and six nonmetric traits of the mandible** following Hefner and Linde (2018) and Berg (2008). The data were collected at the Texas State University, San Marcos, Texas using the donated skeletal collection at the Grady Early Building. A total of **97 females** and **113 males** were chosen based on the state of the mandible and overall structure of the facial bones. Additionally, 10% (f=10; m=11) were scored a second time by the first author to examine intraobserver error.

Chi-square tests were used to determine if there were statistically significant nonmetric trait expression differences between females and males. Subsequently, correspondence analyses (CA) was used to analyze the relationship between each morphoscopic trait that was found to have a significant relationship (*p*-value < 0.05), and both sexes. A one-dimensional PCA plot was generated for each of the significant traits, whereby the plots visualize which ordinal score is associated with females and males. Lastly, Cohen's Kappa analyses were used to determine the intraobserver reliability of each trait.

Results

The results indicate that 14 out of the 23 nonmetric traits have a significant relationship with sex, with a *p*-values less than 0.05 (Table 1). These traits include ANS, INA, NAS, NBC, NBS, OBS, PS, PZT, SPS, CS, LBM, ARS, GAF, and PREI. One-dimensional PCA plots were generated in order to visualize which ordinal scores for the statistically significant traits were more closely associated with females and males. Figures 1 – 6 demonstrate PCA plots for traits PZT, SPS, INA, ARS, GAF, and NBS. These plots illustrate which ordinal scores occurred more in females and males given their location along the diagonal line. Along each spectrum within the plots, the ordinal score's location is determined by the number of times it was scored on females or males. Thus, the location will be either closer to 1.0 for the male percentage or closer to 1.0 for the female percentage. Using Cohen's Kappa to analyze the intraobserver error, it was found that 13 of the 23 morphoscopic traits had "substantial" to "almost perfect" agreement when rescored following Landis and Koch (1997) (Table 1).

Posterior Zygomatic Tubercle (PZT)

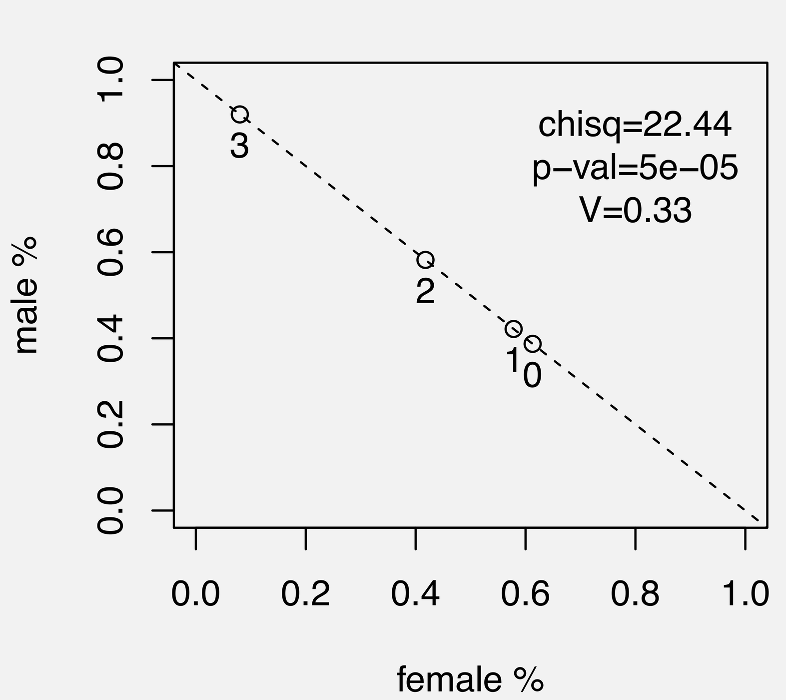

Figure 1. *One-dimensional plot for PZT and sex.*

Supranasal Suture (SPS)

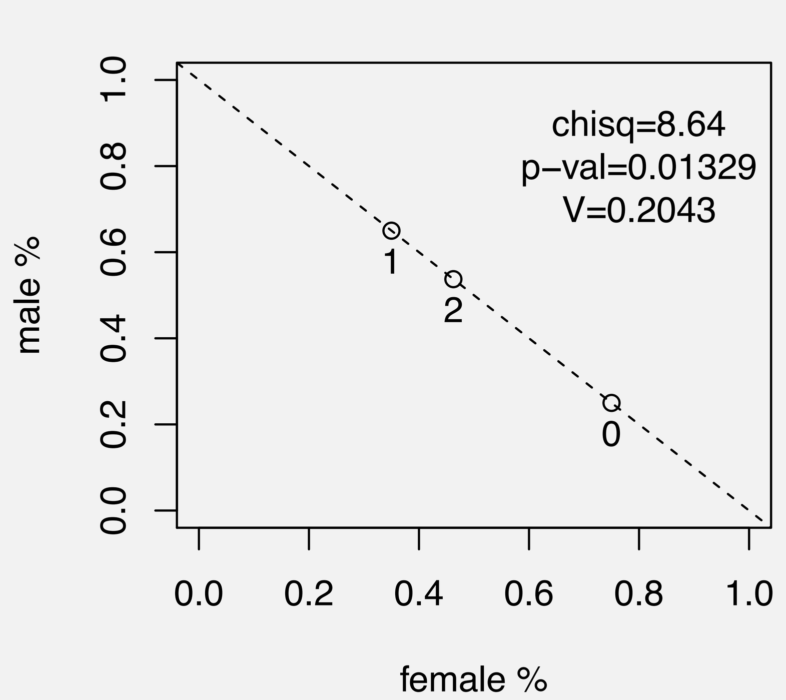

Figure 2. *One-dimensional plot for SPS and sex.*

Inferior Nasal Aperture (INA)

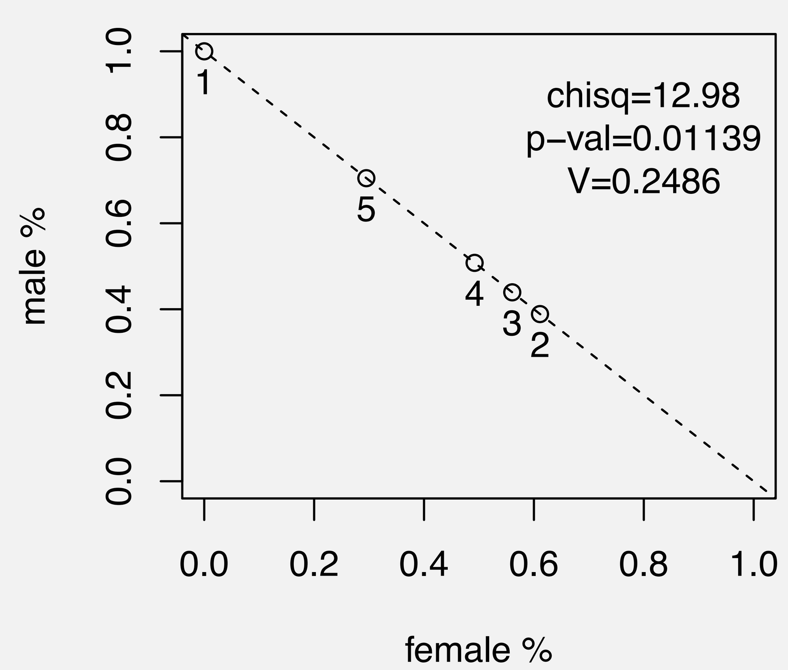

Figure 3. *One-dimensional plot for INA and sex.*

Ascending Ramus Shape (ARS)

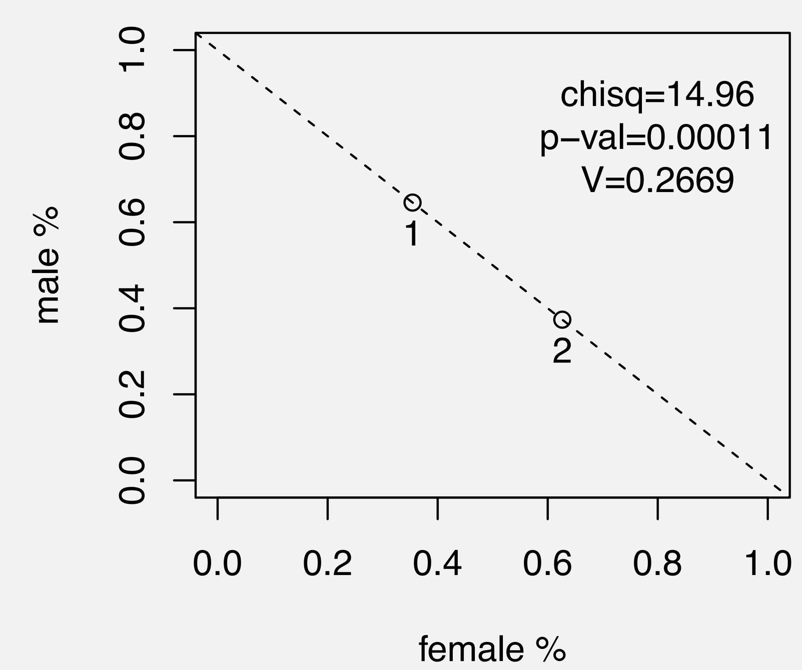

Figure 4. *One-dimensional plot for ARS and sex.*

Table 1 – *Statistically Significant Nonmetric Traits.*

Trait	Ordinal Scoring System	*p*-value	Intraobserver Error
Anterior Nasal Spine (ANS)	1 – slight; 2 – intermediate; 3 - marked	0.03629	Substantial (0.73)
Inferior Nasal Aperture (INA)	1 – marked slope; 2 – moderate slope; 3 – abrupt; 4 – weak sill; 5 – pronounced sill	0.01639	Substantial (0.80)
Nasal Aperture Shape (NAS)	1 – narrow; 2 – intermediate; 3 – broad	0.01136	Moderate (0.56)
Nasal Bone Contour (NBC)	0 – low & rounded; 1 – oval; 2 0 broad plateau; 3 – narrow plateau; 4 – triangular	0.02101	Moderate (0.50)
Nasal Bone Shape (NBS)	1 – straight; 2 - superior pinch; 3 – lateral bulge; 4 - triangular	0.000114	Moderate (0.53)
Orbital Shape (OBS)	1 – rectangular; 2 – circular; 3 – rhombic	0.002293	Fair (0.29)
Palate Shape (PS)	1 – elliptical; 2 – parabolic A; 3 – parabolic B; 4 - hyperbolic	0.002179	Moderate (0.55)
Posterior Zygomatic Tubercle (PZT)	0 – absent; 1 – weak; 2 – moderate; 3 – marked	0.0000259	Substantial (0.71)
Supranasal Suture (SPS)	0 – obliterate; 1 – unfused; 2 – closed by visible	0.01062	Fair (0.34)
Chin Shape (CS)	1 – blunt; 2 – pointed; 3 – square; 4 – rocker	0.00001066	Almost Perfect (0.83)
Lower Border of the Mandible (LBM)	1 – straight; 2 – undulating; 3 – partial rocker; 4 – rocker	0.007774	Moderate (0.43)
Ascending Ramus Shape (ARS)	1 – pinched; 2 – wide	0.0001943	Substantial (0.63)
Gonial Angle Flare (GAF)	0 – absent; 1 – inverted; 2 – slight; 3 – medium; 4 – everted	< 0.00001	Substantial (0.77)
Posterior Ramus Edge Inversion (PREI)	0 – absent; 1 – slight; 2 – medium; 3 – turned	0.0004809	Substantial (0.78)

Gonial Angle Flare (GAF)

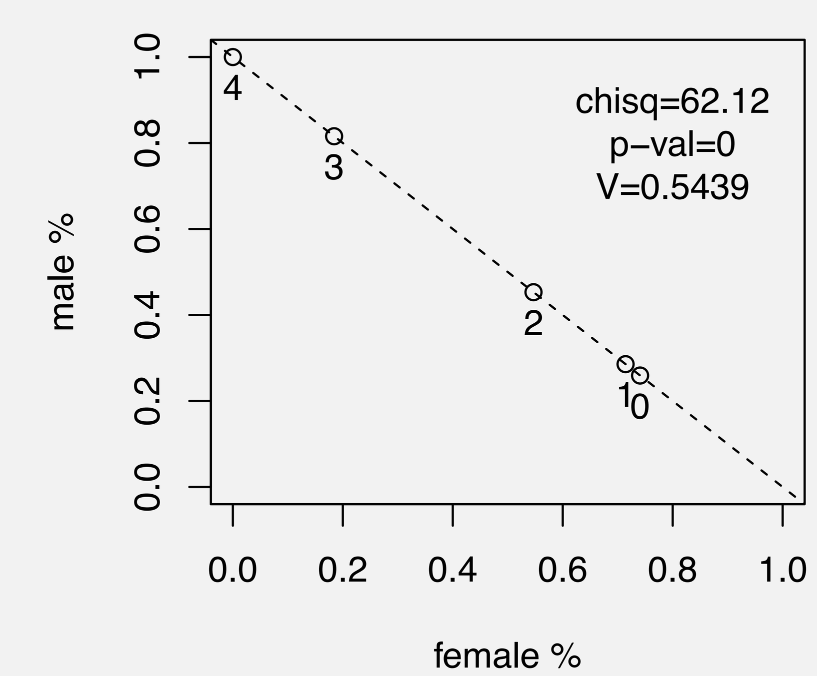

Figure 5. *One-dimensional plot for GAF and sex.*

Nasal Bone Shape (NBS)

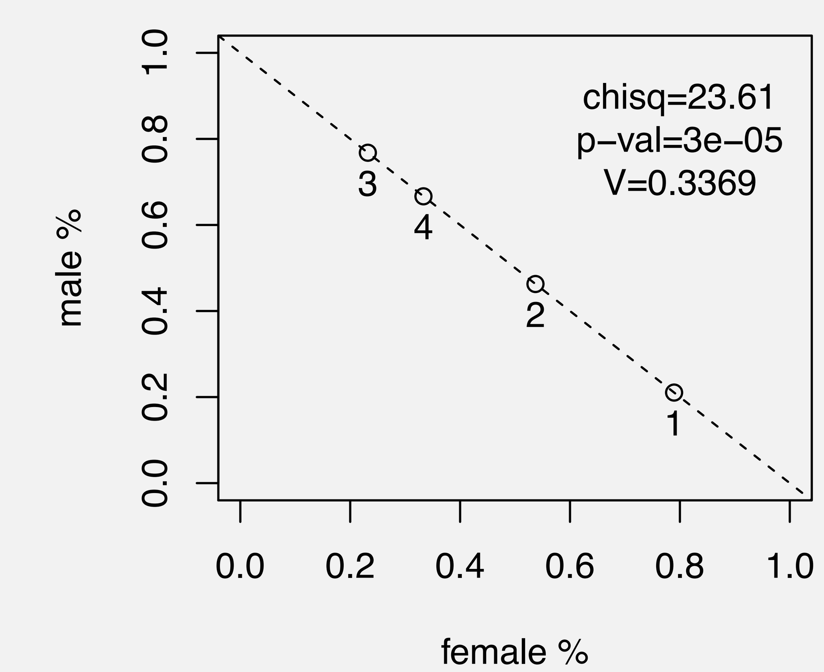

Figure 6. *One-dimensional plot for NBS and sex.*

Discussion and Conclusions

The current study found that 14 nonmetric traits exhibit sexual dimorphism, specifically nine of the 17 cranial nonmetric traits and five of the six mandibular nonmetric traits. This emphasizes that the mandible is highly sexually dimorphic and could potentially affect ancestry estimation if used within this population group. Given that past research has typically pooled males and females to develop nonmetric methods, the results presented here indicate the need for further research into the effects of sex on nonmetric trait expression.

Comparing the present results to those in Tallman (2016), several cranial and mandibular traits were found to be affected by sex; however, these traits varied between Tallman (2016) and the current study. Tallman (2016) found that the CS, PZT, PREI, GAF, ARS, and PS are sexually dimorphic traits, similar to this study's findings; whereas, the INA, NAS, NBC, SPS, and OBS were not found to be sexually dimorphic traits in Tallman (2016). This suggests there may be population differences in sexually dimorphic expressions. Atkinson and Tallman (2019) similarly found sex differences in nonmetric trait expressions in modern Japanese and Thai and archaeological Native American groups; however, the inclusion of sex into logistic regression equations failed to improve classification accuracies.

Overall, the degree of sexual dimorphism between the 14 nonmetric traits is due to several factors: muscle attachment sites (OBS, PS, PZT, SPS, CS, LBM, ARS, GAF, PREI), and size and shape differences (ANS, INA, NAS, NBC, NBS, OBS). Ultimately, these factors dictate the formation and appearance of these traits. These results emphasize that pooling females and males together when estimating ancestry for such populations groups as European Americans may potentially influence the outcome of the estimation. However, future researchers will investigate whether the inclusion of sex into nonmetric methods does, in fact, impact the outcome.

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