Metric and Non-Metric Assessments of Sex:

Accuracy, Correlation and Corroboration

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Introduction

Sex estimation is a vital component of biological profile estimation during forensic identification of skeletonized or badly decomposed unknown individuals. While there is a recent trend in the forensic anthropological community toward the use of more metric methods, non-metric methods continue to be routinely employed because of their relative ease of use, their perceived reliability, and because they are frequently "passed-down-knowledge." Because of the aforementioned factors, non-metric methods are often still utilized for biological profile estimation, in conjunction with metric assessments, particularly with the human skull and pelvis. The skull has historically been the most studied portion of the skeleton for both ancestral and sex related differences, while the pelvis, specifically the innominates and the pubic bone, is widely regarded as the best indicator of sex due to the sexual dimorphism related to childbirth and locomotion in females.

In a study examining the relationship between metric and non-metric traits in crania, Chevrund *et al.* (1979) posited that due to the nature of growth in the crania, that metric and non-metric traits should have the same developmental basis and therefore contribute to one another. Chevrund *et al.* found moderate to high correlations between cranial non-metric traits and metrics. Due to the high correlation, Chevrund *et al.* recommended that metrics and non-metrics be used in conjunction with one another in skeletal analyses.

Recently, however, members of several anthropology organizations (AAA, AAFA, AAPA, ASHB, CAPA) were asked to participate in an online survey entitled "Current Practices in Sex Estimation for the Adult Skeleton" (Klales 2011). Question number 20 in this survey asked whether participants preferred to use non-metric methods, metric methods, or both for sex estimation. Thirty seven percent (n=51) of participants preferred to use one method or the other for sex estimation and in these instances, nonmetric methods were 2.4 times more likely to be preferred to metric methods. Because of the disparity in sex estimation techniques utilized within the discipline, it is important to constantly evaluate the accuracy of each method, while also assessing how techniques can be used as corroboration for one another.

Materials

Non-metric and metric data were collected from all forensic cases with positively identified individuals conducted from 2009 to present at the Department of Applied Forensic Sciences at Mercyhurst University in Erie, PA. Sample sizes varied for each method because of differential degrees of preservation and damage between cases. The non-metric methods utilized for sex estimation include: (1) the Walker (2008) method for sex estimation of the crania using the expressions of the nuchal crest, the mastoid processes, the supra-orbital margin of the orbits, the supra-orbital ridge, and the mental eminence (Figure 1); and (2) the Klales *et al.* (*in review*) method for estimating sex using ordinal scoring and expressions of the subpubic concavity, the medial aspect of the ischio-pubic ramus, and the ventral arc of the pubic bone as modified from the Phenice (1969) method (Figure 2). In addition to non-metric techniques, standard osteometric measurements of the crania and innominate were also collected for each individual, or case, based on the parameters outlined in Moore-Jansen *et al.* (1994).

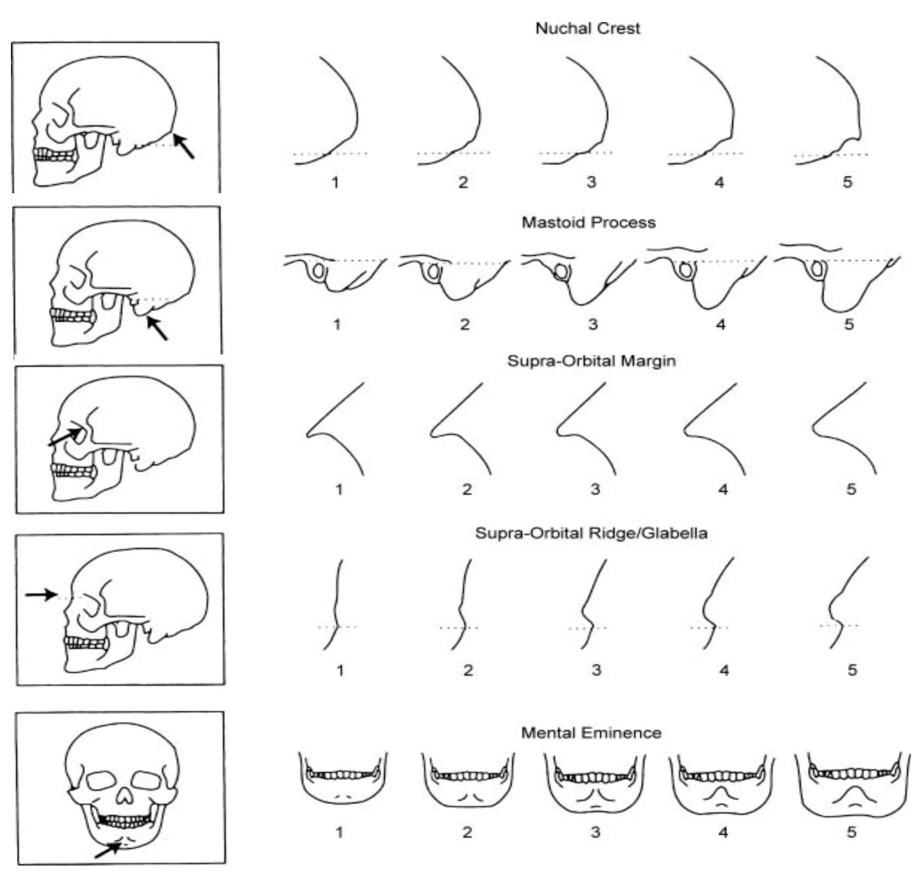

Figure 1. Cranial traits and their associated scores (taken from Buikstra and Ubelaker 1994 and used by Walker 2008)

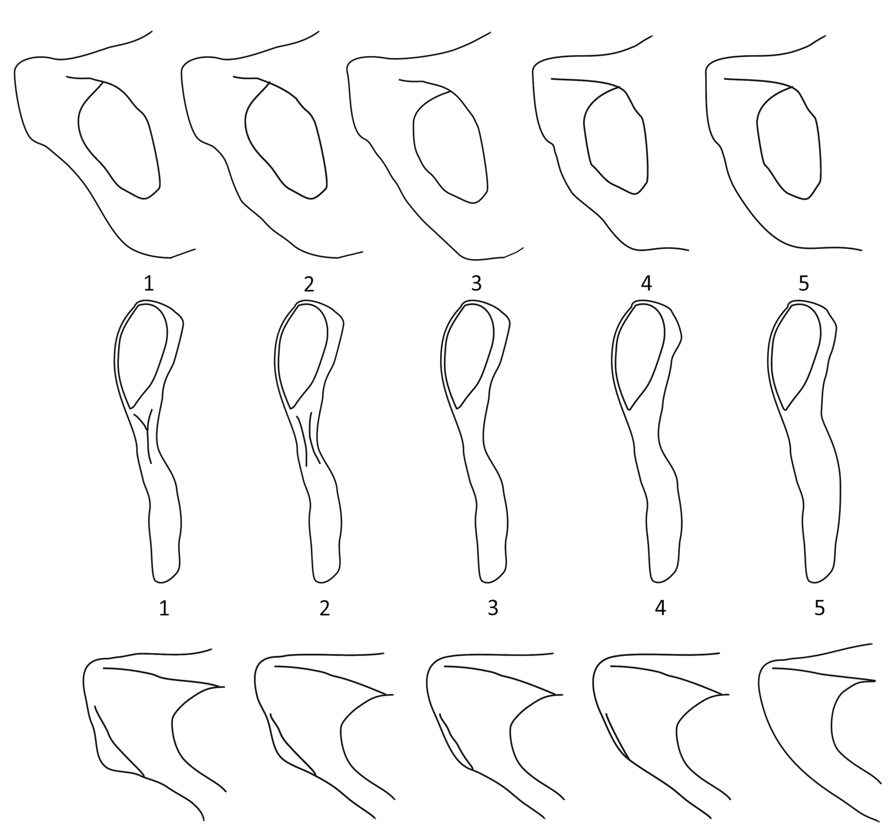

Figure 2. Pubic bone traits and their associated scores (taken from Klales *et al. in review*)

Methods

Craniometric measures were analyzed through Fordisc 3.0 (Jantz and Ousley 2005). Variables used in each analysis were forward stepwise selected and limited to 1/3rd the number of the smallest sample size, as recommended by the Fordisc 3.0 help file. Fordisc 3.0 offers an estimation of both sex and ancestry for each analysis. For the purposes of this study, only the assignment of sex was recorded.

Classification accuracies were calculated for each of the non-metric methods and also for the craniometric measures. This was undertaken in order to evaluate how well the metric assessment corroborates with the results attained using non-metric methods and vice versa.

Lastly, polyserial correlation matrices were then used to examine the relationship between standard craniometric measures and non-metric trait expressions. Polyserial correlations were necessary because ordinal data was compared to quantitative data. Correlations between the ordinal variables were calculated using Spearman's rank correlation coefficient.

Results

Both Fordisc 3.0 and the Walker (2008) method estimated sex 100% correctly, while the Klales *et al.* (*in review*) method misidentified one individual in the study sample resulting in a 90.9% classification accuracy (Table 1).

Only variables that demonstrated strong correlations (greater than or equal to 0.7) were reported. The Walker cranial traits had the following strong correlations with the craniometrics:

- Nuchal Crest: biasterionic breadth, basion-bregma height, bicondylar breadth, chin height, bigonial breadth, height at the mental foramen, mastoid height, maximum cranial breadth, and bizygomatic breadth.
- Mastoid Process: biauricular breadth, basion-bregma height, bicondylar breadth, frontal chord, chin height, height at mental foramen, maximum cranial breadth, and bizygomatic breadth.
- Supra-Orbital Margin: biauricular breadth, foramen magnum breadth, breadth at mental foramen, and bizygomatic breadth.
- Supra-Orbital Ridge/Glabella: biasterionic breadth, bicondylar breadth, chin height, palate breadth, bigonial width, and mastoid height.
- Mental Eminence: biasterionic breadth, frontal chord, chin height, height at mental foramen, palate breadth, and orbital breadth.

Table 1. Documented sex and classification through each method.

Case	ID Sex	Walker	Klales *et al.*	FD3 Cranio	FD3 Pelv
1	F	F	F	F	F
2	F	F	F	F	F
3	F	F	N/A	F	N/A
4	F	F	F	F	F
5	F	F	F	F	F
6	F	F	N/A	F	N/A
7	F	F	F	F	F
8	F	F	F	F	F
9	M	M	M	M	M
10	M	M	M	M	M
11	M	M	**F**	M	**F**
12	M	M	M	M	M
13	M	M	M	M	M
14	M	M	M	M	M
%		100	90.9	100	90.9

The Klales *et al.* traits had strong correlations with the following osteometrics of the innominate:

- Subpubic Concavity: innominate height and pubis length.
- Medial Aspect of the Ischio-Pubic Ramus: innominate height and pubis length.
- Ventral Arc: innominate height and pubis length.

Additionally, there were strong correlations within and between the non-metric methods presented below. A correlation matrix with all of the non-metric traits is presented in Table 2.

- Nuchal Crest: subpubic concavity.
- Mastoid Process: glabella, medial aspect of the ischio-pubic ramus.
- Supra-Orbital Margin: glabella, medial aspect of the ischio-pubic ramus, and ventral arc.
- Supra-Orbital Ridge/Glabella: mastoid, supra-orbital margin, medial aspect of the ischio-pubic ramus, and ventral arc.
- Mental Eminence: medial aspect of the ischio-pubic ramus.
- Subpubic Concavity: nuchal crest and ventral arc.
- Medial Aspect of the Ischio-Pubic Ramus: mastoid process, supra-orbital margin, glabella, mental eminence, and ventral arc.
- Ventral Arc: supra-orbital margin, glabella, subpubic concavity, and medial aspect of the ischio-pubic ramus.

Discussion

Both the Walker (2008) method and the craniometrics were 100% accurate in their sex estimations, while the Klales *et al.* (*in review*) method and pelvic measures both misclassified the same individual. While only analyzing a small sample size, the utility of all the methods examined is exemplified by high classification accuracies.

Table 2. Correlation matrix with all of the non-metric traits. Values with strong significance are in green (values with correlations >/= 0.7).

Trait	Nuchal	Mastoid	Orbit	Glabella	Mental	Subpubic	Med.Asp.	Ventral
Nuchal	1.00	0.28	0	0.36	0.14	**0.70**	0.21	0.45
Mastoid	0.28	1.00	0.43	**0.75**	0.50	0.20	**0.86**	0.61
Orbit	0	0.43	1.00	**0.76**	0.43	0.64	**0.72**	**0.85**
Glabella	0.36	**0.75**	**0.76**	1.00	0.57	0.59	**0.78**	**0.84**
Mental	0.14	0.50	0.43	0.57	1.00	0.23	**0.74**	0.27
Subpubic	**0.70**	0.20	0.64	0.59	0.23	1.00	0.42	**0.82**
Med.Asp.	0.21	**0.86**	**0.72**	**0.78**	**0.74**	0.42	1.00	**0.72**
Ventral	0.45	0.61	**0.85**	**0.84**	0.27	**0.82**	**0.72**	1.00

Bizygomatic breadth and biauricular breadth showed strong correlations with all of the non-metric traits except for the Walker traits supra-orbital ridge/glabella and the mental eminence. The lack of strong correlation between the aforementioned breadth measurements and glabella and the mental eminence was expected because both of those traits are unlikely influenced by lateral expansion of the skull. Innominate height and pubis length were both strongly correlated with each of the pelvic nonmetric traits.

Many of the the non-metric traits showed strong correlations with one another (Table 2). Of the Walker traits, glabella has most highly correlated with other cranial traits and with the innominate traits. The nuchal crest was only strongly correlated with subpubic concavity. The relatively low degree of correlation between the nuchal crest and other non-metric traits might be a product of small sample size, or an effect of the populations from which the traits were derived (Walker 2008).

The medial aspect of the ischio-pubic ramus showed the most strong correlations with the other non-metric traits. The subpubic concavity had the least strong correlations with the other non-metric traits. The strong correlations between ventral arc and the medial aspect of the ischio-pubic ramus with the cranial non-metric traits make them suitable estimators of sex.

Conclusions

There are several strong correlations between standard osteometric measures and non-metric traits. The changes in size are clearly linked, to some degree, to the changes in shape. However, the non-metric traits have many strong correlations with one another suggesting that the morphology, as described by Walker (2008) and Klales *et al.* (*in review*), of the skull and pelvis are also sexually dimorphic. Because of the high degree of correlations between all of the metric and non-metric variables, it is suggested that both metric and non-metric methods be employed in skeletal anlaysis for corroboration and improved accuracy, especially in instances of fragmentary remains when not all measures can be obtained.

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