A re-evaluation of the power of “standard” measurements in estimating sex and sex-specific ancestry from the innominate and sacrum

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Introduction

The development of a biological profile is critical for the analysis of skeletal remains in both bioarchaeology as well as forensic anthropology. In 1994, Buikstra and Ubelaker produced: “Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History.” This publication has set the current practices of most skeletal data collection. However, since 1994 new methods have been developed and should be compared to our current “standard” practices in order to refine our data collection protocols. The pelvic girdle is often cited as the most sexually dimorphic region of the body (Flander 1978), while the innominate is often cited as the single most sexually dimorphic bone (Stewart 1979).

However, the pelvis is also formed by the sacrum which has received little positive attention in terms of sexual dimorphism in modern human skeletal remains (Steyn and Iscan 2008). Due to recent developments in the field of osteometrics, microscribe digitizers are improving the way practitioners can collection and analyze data. Unfortunately 3D digitizers are not currently available for widespread application, thus new methods must also be backwards compatible to 2D linear measurements. The goal of this study is to use 3D data collected on both the innominate and sacrum and extract appropriate 2D landmarks for wider utility. The 2D linear measurements have been analyzed (Klales et al. 2009; Vollner et al. 2011) to determine their value for sex estimation as well as sex-specific ancestry estimation.

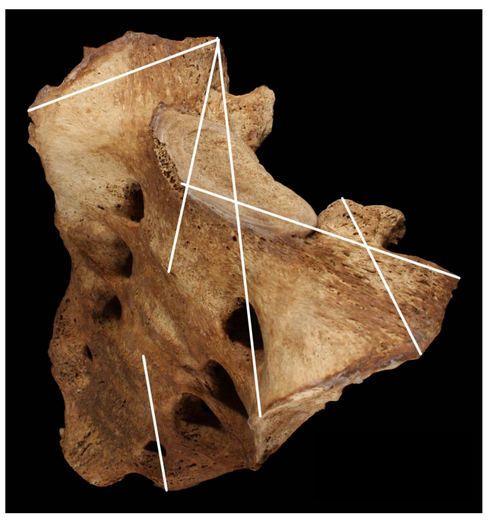

Figure 1. Six new sacral measurements for sex estimation.

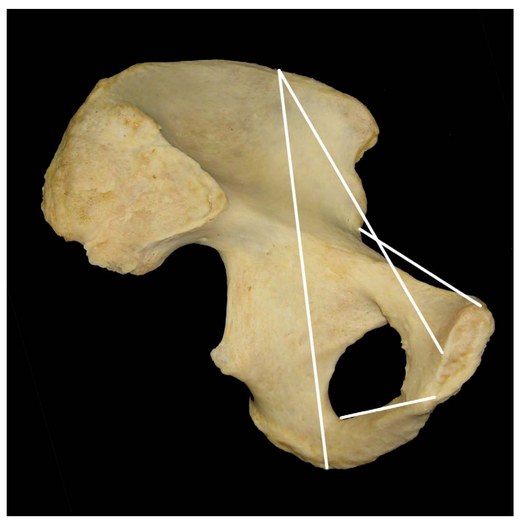

Figure 2. Four of five new innominate measurements for sex estimation.

Materials and Methods

A sample of 136 innominates and 163 sacra of European and African American males and females from the Hamann-Todd Collection housed at the Cleveland Museum of Natural History were utilized to capture three-dimensional landmark data. Individuals were included if they were at least 19 years of age and did not appear to suffer from any apparent pathological conditions. Twenty-one previously defined landmarks were digitally collected for each innominate and 23 previously defined landmarks were digitally collected for each sacrum (Klales et al. 2009; Vollner et al. 2011).

The extraction of the linear 2-D data created a dataset of 210 measurements for each innominate and 253 measurements for each sacrum. These measurements were analyzed through a forward step-wise (F = 0.05 to enter, F = 0.10 to remove) discriminant function analysis (FSDFA) to determine the measurements needed for the highest level of accuracy possible for the estimation of sex (2 groups) and ancestry/sex (4 groups) for both innominates as well as sacra.

These measurements were then compared against the Standards (Buikstra and Ubelaker 1994) measurements for the innominate as well as the sacrum. The innominate measurements were slightly different as the point inside the acetabulum was not digitized however, the resulting measurements still encompass the same variation as the ischio-pubic index. The sacral “Standards” measurements utilized included: Anterior Height and Anterior Superior Breadth.

Table 1. Classification matrix for new innominate measurements compared to classification matrix for ‘standard’ measurements.

		Predicted for New Measurements			**Predicted for Stds Measurements**		
		Males	Females	Total	Males	Females	Total
Count	Males	**70**	1	71	**66**	5	71
	Females	0	**65**	65	4	**61**	65
%	Males	**98.60%**	1.40%	**99.00%**	**93.00%**	7.00%	**93.40%**
	Females	0.00%	**100.00%**		6.10%	**93.80%**	

Results

The forward stepwise discriminant function analysis selected seven innominate measurements to producing a 99% cross-validated accuracy (CVA) for sex (Table 1) and five measurements with a 83% CVA for ancestry/sex estimation (Table 2). Using only the “Standards” measurements we were able to produce a 93% CVA for sex estimation (Table 1) and a 61.3% CVA for sex/ancestry estimation (Table 2).

The FSDFA selected six new sacral measurements producing an 89% CVA for sex estimation (Figure 1 and Table 3) and eight measurements with a 65.6% CVA for ancestry/sex estimation (Table 4). The data collected was unable to reproduce all three sacral “Standards” measurements however, utilizing only anterior height and anterior superior breadth sex was estimated at 53.4% CVA (Table 3) and 38% CVA for ancestry/sex (Table 4).

Table 2. Classification matrix for new sacral measurements compared to the classification matrix for ‘standards’ measurements for sex estimation.

		Predicted for New Measurements			**Predicted for Stds Measurements**		
		Males	Females	Total	Males	Females	Total
Count	Males	**76**	9	85	**44**	41	85
	Females	9	**69**	78	35	**43**	78
%	Males	**89.40%**	10.60%	**89.00%**	**51.80%**	48.20%	**53.40%**
	Females	11.50%	**88.50%**		44.90%	**55.10%**	

Table 3. Classification matrix for new innominate measurements compared to the classification matrix for ‘standards’ measurements for sex-specific ancestry estimation.

		Predicted for New Measurements					**Predicted for Stds Measurements**				
		Af Am F	Af Am M	Eu Am F	Eu Am M	Total	Af Am F	Af Am M	Eu Am F	Eu Am M	Total
Count	Af Am F	**28**	0	4	1	33	**16**	1	15	1	33
	Af Am M	0	**29**	0	6	35	1	**21**	2	11	35
	Eu Am F	6	0	**26**	0	32	7	2	**23**	0	32
	Eu Am M	0	5	1	**30**	36	1	9	2	**24**	36
%	Af Am F	**84.80%**	0.00%	12.10%	3.00%	**83.00%**	**48.50%**	3.00%	45.50%	3.00%	**61.30%**
	Af Am M	0.00%	**82.90%**	0.00%	17.10%		2.90%	**60.00%**	5.70%	31.40%	
	Eu Am F	18.80%	0.00%	**81.30%**	0.00%		21.90%	6.30%	**71.90%**	0.00%	
	Eu Am M	0.00%	13.90%	2.80%	**83.30%**		2.80%	25.00%	5.60%	**66.70%**	

Table 4 Classification matrix for new sacrum measurements compared to the classification matrix for ‘standards’ measurements for sex-specific ancestry estimation.

		Predicted for New Measurements					**Predicted for Stds Measurements**				
		Af Am F	Af Am M	Eu Am F	Eu Am M	Total	Af Am F	Af Am M	Eu Am F	Eu Am M	Total
Count	Af Am F	**35**	14	2	1	52	**9**	11	19	13	52
	Af Am M	8	**13**	2	3	26	3	**7**	7	9	26
	Eu Am F	2	0	**19**	5	26	4	1	**14**	7	26
	Eu Am M	2	7	10	**40**	59	4	17	6	**32**	59
%	Af Am F	**67.30%**	26.90%	3.80%	1.90%	**65.60%**	**17.30%**	21.20%	36.50%	25.00%	**38.00%**
	Af Am M	30.80%	**50%**	7.70%	11.50%		11.50%	**26.90%**	26.90%	34.60%	
	Eu Am F	7.70%	0%	**73.10%**	19.20%		15.40%	3.80%	**53.80%**	26.90%	
	Eu Am M	3.40%	11.90%	16.90%	**67.80%**		6.80%	28.80%	10.20%	**54.20%**	

Discussion/Conclusions

The new linear measurements utilized in this analysis show an increase in accuracy compared to the “Standards” measurements for the estimation of sex as well as ancestry/sex. However, the number of measurements taken on both the innominate and sacrum have also increased. This may factor into the amount of time a researcher must spend collecting measurement data, however the outcome is significantly improved.

References

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