The Effects of Cranial and Pelvic Asymmetry on Accurate Sex Classification

Stephanie J. Cole[1], BA Luis L. Cabo[1], MS Alexandra R. Klales[2], PhD

[1]Applied Forensic Sciences, Mercyhurst University; [2]Forensic Anthropology Program, Department of Sociology & Anthropology, Washburn University

Introduction

- Sex estimation is an important parameter of the biological profile
  - Accurate estimation = more accurate sex-specific methods for estimating the other parameters (i.e., ancestry, stature, age)
- Klales et al. (2012) and Walker (2008) use bilateral traits of the pelvis and skull for sex estimation
  - Used in active forensic casework in the U.S. & internationally
- By convention, forensic anthropologists typically use the left side when assessing bilateral traits
- Preferentially selecting the left side could result in fundamental biases and a systematic decrease in classification accuracy for either males or females

Research Goals

- Examine the impact of the frequency, degree, and direction of asymmetry on the original Klales et al. (2012) and Walker (2008) methods
- Put forth recommendations for use of these methods in asymmetric individuals

Materials & Methods

- 2,168 skulls & innominates*

  Hamann-Todd Human Osteological Collection, Terry Anatomical Skeletal Collection, Bass Donated Skeletal Collection, Pretoria Bone Collection, Texas State University Donated Skeletal Collection, Operation Identification, and Mercyhurst University forensic cases (Table 1)

Table 1. Sample demographics.

	Males	Females
Asian	111	66
Black	366	328
Hispanic	106	92
White	643	456
Total	1226	942

- Traits scored using figures and descriptions provided by Klales et al. (2012) and Walker (2008) (Figs. 1-2)
- Frequency, degree, and direction of trait asymmetry were determined
  - Significance of direction tested with x^2
- Classification accuracies compared between symmetric and asymmetric groups for both methods using x^2 (Table 2)
- Intraobserver error tested using Cohen's weighted Kappa
  - n = 100 from Bass sample, n = 100 from Hamann-Todd sample
  - Based on the agreement parameters outlined in Landis & Koch (1977)

* Sample size has been increased by n=858 since abstract submission in August. Results have been updated to reflect the larger sample size.

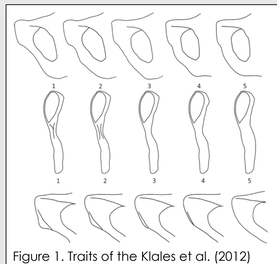

Figure 1. Traits of the Klales et al. (2012) method: subpubic contour (top), medial aspect of ischio-pubic ramus (middle), ventral arc (bottom).

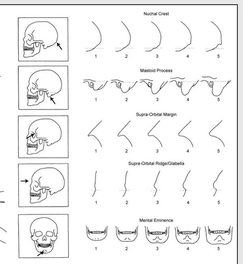

Figure 2. Traits of the Walker (2008) method from Buikstra & Ubelaker (1994).

Table 2. Method equations. Walker Equation 3 has been omitted because it does not contain any bilateral traits.

Method	Equation
Walker Eq.1	Y = -1.375G - 1.185M - 1.151ME + 9.128
Walker Eq.2	Y = -1.568G - 1.459M + 7.434
Walker Eq.4	Y = - 1.629ME - 1.415M + 7.382
Walker Eq.5	Y = -1.007SO + 1.850ME + 6.018
Walker Eq.6	Y = -0.7N -1.559M + 5.329
Klales et al.	Y = 2.726VA + 1.214MA + 1.073SPC – 16.312

Results

- Asymmetry present for all traits for both sexes (Table 3)
  - Examples of asymmetric individuals shown below (Figs. 3-4)

Table 3. Frequency, degree, and direction of trait asymmetry by sex. Direction indicates which side received the higher score. Bolded text indicates statistical significance at p < 0.05.

	Frequency		Degree (+/- 1 score)		Direction	
	Males	Females	Males	Females	Males	Females
Ventral Arc	34.5%	21.6%	86.0%	92.2%	Right	Right
Subpubic Contour	25.6%	23.8%	87.8%	86.5%	**Right**	**Right**
Medial Aspect	23.4%	33.3%	97.8%	90.0%	**Right**	Left
Mastoid Process	41.0%	36.0%	86.0%	92.8%	**Right**	**Right**
Supra-Orbital Margin	32.2%	27.7%	85.9%	76.4%	**Right**	**Right**

Figure 3. Asymmetry in the ventral arc and subpubic contour. Right side scored higher.

Figure 4. Asymmetry of the mastoid process. Right side scored higher.

- Most asymmetric individuals were within +/- 1 score (Table 3)
- Most traits were right dominant (higher score) (Table 3)
- Significant differences in classification accuracies between groups were observed (Table 4)
- Intraobserver error
  - Pelvic traits: substantial agreement
  - Skull traits: fair to moderate agreement
- Multi-dimensional scaling of traits (Fig. 5)

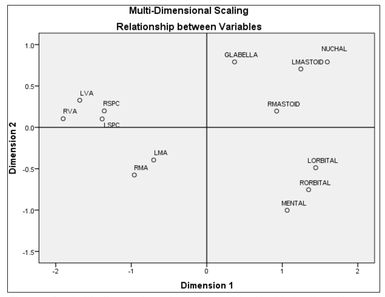

Figure 5. Multi-dimensional scaling of traits. Note that the pelvic and skull traits are not associated. Also note that the facial and vault traits are not associated, but traits related to neck muscle insertions are closely related.

Results Continued

Table 4. Classification accuracies (%) between the symmetric group and asymmetric group by method. For the Klales et al. (2012) method, the symmetric group refers to individuals symmetric for all three traits. Bolded text indicates statistical significance at p < 0.05. Males are in shown in blue and females are shown in red.

	Asymm	Symm	P-Value	Asymm	Symm	P-Value
Klales L VA	93.3	95.5	0.10	**96.2**	**98.4**	**0.01**
Klales R VA	92.2			**90.6**		
Klales L SPC	95.2	95.5	0.89	95.8	98.4	0.10
Klales R SPC	96.4			95.8		
Klales L MA	91.1	95.5	0.08	97.8	98.4	0.65
Klales R MA	93.1			97.8		
Klales L VA, SPC	**77.8**	**95.5**	**<0.001**	**92.5**	**98.4**	**<0.001**
Klales R VA, SPC	**81.9**			**85.0**		
Klales L VA, MA	91.8	95.5	0.14	100.0	98.4	0.92
Klales R VA, MA	91.8			98.4		
Klales L SPC, MA	93.0	95.5	0.60	97.4	98.4	0.59
Klales R SPC, MA	95.3			97.4		
Klales L VA, SPC, MA	**80.6**	**95.5**	**0.03**	**95.8**	**98.4**	**0.01**
Klales R VA, SPC, MA	**96.8**			**87.5**		
Walker L Equation 1	89.1	93.0	0.19	62.4	63.5	0.36
Walker R Equation 1	96.0			58.4		
Walker L Equation 2	89.7	92.8	0.36	59.4	56.6	0.80
Walker R Equation 2	93.2			52.2		
Walker L Equation 4	89.4	94.1	0.12	36.8	37.2	0.38
Walker R Equation 4	94.5			32.0		
Walker L Equation 5	93.8	96.4	0.14	26.3	28.1	0.14
Walker R Equation 5	95.7			21.1		
Walker L Equation 6	**77.3**	**91.3**	**<0.001**	57.4	55.0	0.19
Walker R Equation 6	**88.6**			44.5		

Discussion & Conclusions

- Kappa results indicate the presence of asymmetry is not due to scoring inconsistency alone
- Asymmetry significantly decreases classification accuracy for the Klales et al. (2012) and Walker (2008) methods depending on which traits are affected and which equation is utilized
- Preferentially analyzing the left side creates a systematic bias in favor of correctly classifying females at the expense of misclassifying males
  - Because individuals are largely right dominant for nearly all traits, males classify better using the right side and females classify better using the left side
- **Recommended:** report classification accuracies from both sides when asymmetry is present

Acknowledgements

This research was funded by National Institute of Justice grant 2015-DN-BX-K014 (P.I. Klales). Thanks go to Lyman Jellema, David Hunt, Marius Loots, Dawnie Steadman, Daniel Wescott, and Kate Spradley for providing access to the skeletal collections used in this research.

For a copy of the poster, full list of references, or questions/comments, contact **scole86@lakers.mercyhurst.edu**