Sexing the Human Sternum: Archeological Applications

CECILE M. SANDS
Department of Anthropology, University of Arkansas,
Fayetteville, Arkansas 72701

The adult human sternum shows size differences related to both an individual's sex and age. Ashley (1956) using measurements of sternal length, width, and two ratios was able to discriminate between the sexes in a European and an East African population. He found that the absolute measurements varied with sex, irrespective of body height, and that continuing growth throughout adulthood slightly modified the value of any discrimination rule based on such measurements.

Jit, Jhingan, and Kulkarni (1980) applied Ashley's techniques to a North Indian population, but did not consider age except to use specimens over age 18. They also used multivariate analysis for discrimination in their sample. Their study claimed accurate in sex determination for 72.12% of the males and 62.50% of the females using Ashley's techniques, and 85% accuracy using mutivariate analysis of their sample (1980: 217). Ashley's study claimed 80% overall correct application of his discrimination rules (1956: 42).

These findings, then, form the basis of this paper. Utilizing both absolute measurements and ratios after Ashley (1956) and multivariate analysis after Jit, *et al* (1980), the following questions were addressed. Can these techniques be applied to archeological remains, including incomplete sterna, and how much of the resulting inaccuracy can be accounted for by age effects or abnormalities in individual sterna, for example fractures?

Materials

The present study utilized archeological materials recovered from two central Illinois mortuary sites: the Schild site, Greene County, and the Pete Klunk site, Calhoun County. Both sites were multi-component sites; Schild having Late Woodland and Mississippian mounds, and Klunk with Middle, Late Woodland, and one Archaic mound. Seventy-five Schild Mississippian and 61 Klunk Middle Woodland sterna, 136 total, were chosen for analysis because these components were better preserved than either Later Woodland component. Radiocarbon dates for these occupations are A.D. 175 ± 75 for Klunk Middle Woodland (Perino 1968:115) and A.D. 943-1194 ± 114 for Schild Mississippian (Droessler 1979:57).

Biological continuity has been demonstrated in this region (Buikstra 1977; Droessler 1979). Thus the Schild and Klunk materials used in this study can be considered to be genetically related.

Methods

The 136 sterna selected were divided into two groups: those sterna that were complete (manubrium and mesosternum) and those that were broken or had either the manubrium or mesosternum missing.

Measurements were taken in millimeters on the manubrium and mesosternum, excluding the xiphoid process, as shown in figure 1. The measurements are as follows:

M = manubrial length in midline (variable X1)
B = mesosternal length in midline (variable X2)
S_1 = width of first sternebra (variable X4)
S_3 = width of third sternebra (variable X5)

From these the following values were computed:

M + B = total manubrial-mesosternal length (variable X3)
$M \times 100/B$ = manubrium-corpus index (variable X6).
$S_1 \times 100/S_3$ = sternal width index (variable X7)

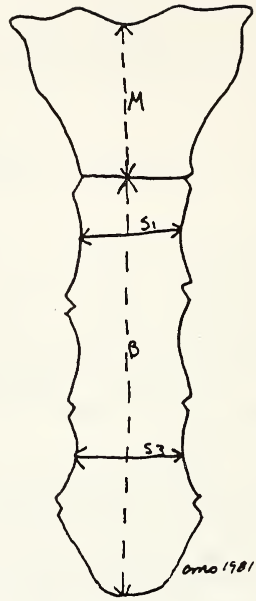

FIGURE 1

After the values were obtained, those from sample one (complete sterna, 75 in all) were subjected to statistical tests, computing mean and standard deviation for each variable category by sex. An F-test was run for each variable to determine if the differences between the means were significant, and 21 linear discriminant functions were generated.

Individual measurements were graphed using bar diagrams (see Figure 2), in which the measurements are given along the abscissa and the number of cases along the ordinate. From the graphs, cut off points were determined for assigning specimens to either the male or female group.

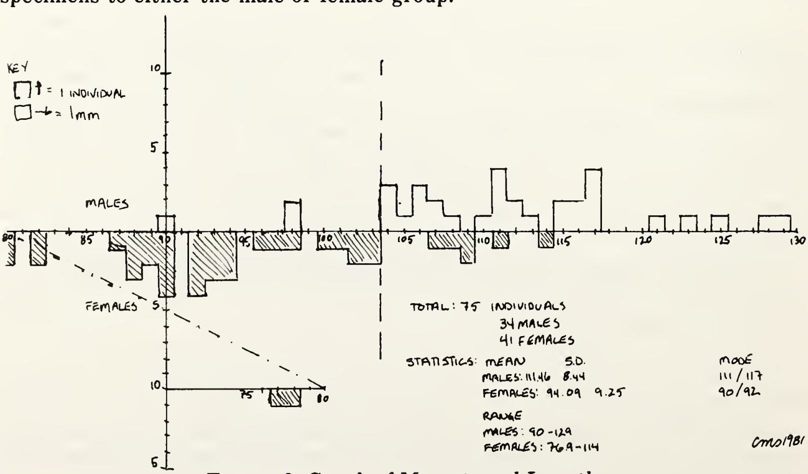

FIGURE 2: *Graph of Mesosternal Length*

After the statistical and graphic analyses were performed on sample 1, those sterna with incomplete measurements were analyzed using the graphic cut-offs and 12 of the 21 discriminant functions, chosen for their applicability and high accuracy. Applicability is here defined as including variables present in incomplete specimens. Those functions with over 70% accuracy were used, an arbitrary level of accuracy, in order to utilize as many possible combinations of variables in the sample of incomplete sterna.

Results: *Univariate Differences.*

A significance test (F-ratio) was run on the means of each measurement for the two groups. The means of the first six variables were found to differ significantly between the sexes. Variable X7: sternal width index was not found to have a significant difference in the group means.

Graphic Analysis

The following is a summary table of the results of graphic analysis:

Variable	Means	Standard Deviation	Cut-off	Accuracy Sample 1	Range Sample 1	Accuracy Sample 2
X1	M 49.84 F 45.00	5.00 4.56	46.5	ALL 72 % M 76 % F 68 %	36.8 - 67.5	59%
X2	111.46 94.09	8.44 9.25	103.5	88 % 99.9% 85 %	76.9 - 129.0	78%
X3	161.29 139.04	9.45 11.08	151.0	85 % 85 % 85 %	115.3- 178.9	67%
X4	27.89 23.92	3.38 2.61	26.5	73 % 59 % 85 %	19.7- 35.0	61%
X5	34.76 29.83	6.17 4.45	30.0	70.5% 85 % 56 %	22- 49	63%
X6	45 % 48.19%	6.00 6.08	47.5%	63 % 74 % 56 %	35.49%- 62 %	89%
X7	81.66% 81.46%	11.91 12.76	None	— —	59.92%- 131.82%	—

Overall, the results of graphic analysis in the determination of sex reflects the significance of the mean differences for each variable. The length measures (X1-3) are better discriminators than width measures; the ratios are the least useful. While the mesosternal length is the best of the variables to use, it is often broken post-mortem; this reduces its practicality. In the second sample, only 27 of 61 cases had a measureable mesosternum (44%). Variable X3, total sternal length, is also a good indicator, but since it is dependent on the presence of *both* the manubrium and mesosternum, its usefulness is limited despite its accuracy. The manubrial length, although not as accurate as these, is also useful, as it is often the only part of the sternum recovered. In sample two, 26% of the cases were single manubria.

Viewing the results, we see that the size of the mesosternum has a greater relationship to an individual's sex than does the size of manubrium.

The width measures, X4 and X5, show an extreme overlap in their distributions. The width of the first sternebra showed a high F-ratio; however, this significance was not borne out by the actual distribution. Both these can be useful when the mesosternum is broken.

Variable X6, the manubrium-corpus index, was used by Ashley to test the accuracy of Hyrtl's law, which asserts that if the relationship of manubrial length to mesosternal length is greater than 1:2 the sternum is female; if less, it is male. In this population the relationship was found to be somewhat less (47.7% instead of 50%). The index, like the total sternal length, is dependent upon the both the manubrium and mesosternum, and is not as accurate in classifying sterna as to sex as are the other measures.

Variable X7, the sternal width index, represents a measure of Paterson's female type sternum, that is, relatively broad at its lower portion (following Ashley 1956). If the sternum is relatively wide at its lower end, then the ratio wil be relatively small, and therefore female (1956: 34). Both in this and in Ashley's study, however, it was found that the ranges were nearly identical and that the means differed by small percentages. Consequently no cut-off was determined and the usefulness of this variable is slight.

Linear Discriminant Function Analysis

Twenty-one linear discriminant functions were generated using the preceeding seven variables and run on the cases with complete sterna (sample 1). Included in these were seven using only the single variables, to compare with graphic analysis. The range of accuracy obtained by all twenty-one functions was 56-90.7%. Twelve of these could be applied to the sample of incomplete sterna, with accuracies of 90.7-72%. The following is a summary table of the results of this analysis:

Function	Variables Used	Accuracy	Use With Sample 2 (accuracy)	Compare With Graphic Analysis
1	X2, X3, X4, X7	90.7%	–	–
2	X1, X2, X3, X6	85.5%	50 %	–
3	X2, X4, X7	88 %	82 %	–
4	X4, X5, X7	72 %	56 %	–
5	X1, X2, X4, X5	90.7%	–	–
6	X3, X6, X7	85.3%	–	–
7	X2, X4	86 %	83 %	–
8	X3, X5, X6	89.3%	100 %	–
9	X1, X4, X5	76 %	62.5%	–
10	X1, X5, X6	89.3%	100 %	–
11	X1	69.3%	–	72 %
12	X2	86.7%	70.4%	88 %
13	X3	85.3%	–	85 %
14	X4	72 %	–	73 %
15	X5	61.3%	–	70.5%
16	X6	62.7%	–	63 %
17	X7	56 %	–	–
18	X1, X4	77.3%	70 %	–
19	X1, X5	73.3%	60 %	–
20	X2, X4, X5	88 %	83 %	–
21	X1, X2	85.3%	66 %	–

Summary

Discriminant function analysis is extemely helpful in the determination of sex using combinations of sternal measures.

Sample 1, with all measures present and age and sex known was used to establish the classificatory scheme using discriminant scores. The incomplete specimens (Sample 2) were used to independently test the accuracy of classification.

The functions (2, 3, 4, 7, 8, 9, 10, 12, 18, 19, 20, 21) were applied to the second sample using a program that computed the discriminant scores for only those cases fitting the conditions. Conditions were specified such that if a particular variable did not equal zero, certain equations were used to calculate discriminant scores. Coefficients of the equations were derived in the discriminant analysis of Sample 1.

Functions 11-17 were generated using each variable singly in order to compare the accuracy of this technique to that of graphic analysis, where only one measurement is available. It was found that in this circumstance, graphic analysis is more accurate (or as accurate), and is recommended.

The resultant scores were compared to the distribution of scores in the first sample and sex determinations were made accordingly. Only sixteen of the sixty-one cases in sample two were misclassified according to the twelve functions, (26%). Percent accurate values for this limited set of specimens generally reflect the accuracy seen in the original sample, although some categories are too small to provide meaningful estimates of accuracy of classification.

Misclassifications

The secondary question of this study was to account for any misclassifications. First, the factor of age was considered. Ashley's study found that there was a 2-3% increase in four of the five measurements with increasing age (Ashley 1956:33). With this in mind, the following question was asked: Were the misclassified females older (over 40) and the misclassified males younger (aged 20-30)? A tally of the misclassified sterna shows that 47 out of 136 (total sample: 34.6%) were misclassified, with 23 of these being most likely due to to age (48.9%). Twelve (52%) of these were females aged 40 or more, and eleven (48%) were males in this 20-30 year age bracket, six of them under twenty-five.

Other factors considered were: presence of extra sternebrae in the mesosternum, a shallow or the absence of the jugular notch, and assymetry of either the manubrium or the mesosternum, which would affect the measuring process as well as the measurements, and fractures or other pathologies.

Table of Misclassifications

Factor:	Percentage (of 47):	
Age	48.9%	
# of sternebrae		
extra	2.1%	(one female aged 45-50)
less		(one, male aged 20-24)
jugular notch, absent or shallow	12.7%	(two females aged 50 +)
assymetry	25 %	(3 males aged 20-30, 3 females 45 +)
fracture	2.1%	(one female 50 +)
		(one, male 20-24, Cleft mesosternum)

Summary and Conclusions

To summarize, then, this study applied a set of graphic and statistical techniques for sex determination to a sample of sterna collected from two genetically related aboriginal populations from the Lower Illinois River Valley. The hypothesis of a sex-related difference in sternal size was confirmed. Discriminant function analysis and univarate analysis were used to assign individual sterna to either sex on the basis of various measurements and ratios. Overall, 47 of 136 sterna were misclassified (65.4% correct), but the accuracy of individual methods ranged from 90.7 to 56%. If only a single measurement is present, then graphic analysis is preferred as it yields a higher accuracy of classification than does discriminant function analysis. Age was found to have a significant effect as well, and accounts for the bulk of the misassigned sterna; females over ages 40 tend to be classed as males and males under age 30 tend to be classed as females.

Application to Archeological Data

The techniques presented in Ashley (1956) and Jit *et al* (1980) are applicable to archeological data, as demonstrated here. The cut off values of graphic analysis and discriminant scores will vary with populations, but the basic techniques are valid. Following the methodology of this study, the classification scheme should be set up with a sample of complete sterna of know sex and age. Then measurements from incomplete or isolated sterna can be plugged in and analysed.

The results of this classification can be useful in many ways, specifically in confirming sex of individuals whose classification is unclear using other techniques, possible association of isolated sterna with other skeletal remains, analysis of cremated materials, and obtaining more accurate assessments of demography.

Acknowledgements

Special thanks go to Dr. Della Collins Cook, Amy Brenna, Paul DeClark, David Johnson, and the Honors Committee at Indiana University's Department of Anthropology.

Literature Cited

1. ASHLEY, G.T., 1956. The Human Sternum. The Influence of Sex and Age on its Measurements. Journal of Forensic Medicine, 3:27-43.
2. BUIKSTRA, J.E., 1977. Biocultural dimensions of archeological study: A Regional Perspective. Southern Anthropological Society Proceedings 11: 67-84.
3. DROESSLER, J.B., 1979. Change and Continuity: Biocultural Interaction at the Late Woodland-Mississippian Interface. Doctoral Dissertation, Indiana University. (unpub)
4. GILES, E. and O. ELLIOT, 1963. Sex Determination by Discriminant Function Analysis of Crania. AJPA 21:53-68.
5. JIT, I., JHINGAN, V. and M. KULKARNI, 1980. Sexing the Human Sternum. AJPA 53:217-224.
6. NIE, NORMAN H., *et al.*, 1977. Statistical Package for the Social Sciences, McGraw-Hill, New York.
7. PERINO, G., 1968. The Pete Klunk Mound Group, Calhoun County, Illinois: The Archaic and Hopewellian Occupations. Illinois Archeological Survey Bulletin 6:1-12.
8. PERINO, G., 1971. The Mississippian Component at the Schild Site, Greene County, Illinois. Illinois Archeological Survey Bulletin 8: 1-141.