Mandibular Sexing Functions for the Prehistoric Lower Illinois Valley

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Sex determination in archaeological skeletons is necessary to many studies concerned with the reconstruction of prehistoric lifeways, including paleodemography, the analysis of the social dimensions of mortuary practice, and the diagnosis of past health and disease states. Methods for sex assessment of bones range from partly subjective visual observation of gross morphological indicators to more objective statistical analyses of measurements. For examples, see Stewart's (20, 21) and Krogman's (14) reviews of observational methods, Keen (13) for a univariate approach, and Ditch and Rose (4), Garn *et al.* (5, 7, 8, 9), Giles (10), Giles and Elliott (11), Potter (19), and Thieme and Schull (22) for multivariate techniques. The present study employs multivariate discriminant function analysis, a means of statistically maximizing the distance, or differences, between two or more groups, to determine sex on the basis of mandibular measurements.

Birkby (1) and Henke (12) have shown that expressions of sexual dimorphism are population specific. A prehistoric Lower Illinois Valley Indian sample, because of its general homogeneity, is chosen for the present study over a cadaver population. The mandible is selected for analysis because it is a thick and structurally strong bone, known to exhibit sexual dimorphism, and apparently capable of withstanding the vagaries of preservation and archaeological recovery.

The purpose of this paper is to present a series of discriminant functions for sexing the human adult mandible. The major concerns in formulating the functions are to maximize the percent correct classification, to eliminate the most frequently indeterminable measurements in the specific skeletal series used, and to facilitate practical application of the functions. Because the expression of sexual dimorphism is population specific (1, 12), however, this study pertains only to the prehistoric Lower Illinois Valley Indian population of approximately 100 B.C. to A.D. 1300. The results obtained here, therefore, cannot be directly extrapolated to spatially, temporally, and/or genetically distinct populations. The basic approach, on the other hand, may be applicable in many situations where sex determination is desirable.

Materials and Methods

A sample of 172 individuals, 88 males and 84 females, was selected from the Lower Illinois Valley prehistoric Indian skeletal series housed at Indiana University, Bloomington. The bases for selection were minimal damage and disease, and an age at death assessment of 18 years or older for each individual. Four Lower Illinois Valley mortuary sites were represented: Schild, Koster, Pete Klunk and Yokem. The cultural periods involved were Middle Woodland (100 B.C. to A.D. 350), Late Woodland (A.D. 350 to A.D. 950) and Mississippian (A.D. 950 to A.D. 1300). The site-cultural period associations, and the age and sex distribution of the sample are summarized in Table 1.

TABLE 1. *Summary of the Sample*

		age (Todd's phases)									
Site-Cultural Period	Sex	I	II	III	IV	V	VI	VII	VIII	IX	X
Schild Late Woodland	male	—	—	—	—	—	2	—	2	1	—
	female	—	—	1	—	1	—	2	—	—	2
Schild Mississippian	male	2	—	—	2	1	4	3	2	1	1
	female	3	—	—	—	1	—	1	1	—	1
Koster Late Woodland	male	1	2	—	1	4	5	2	4	—	—
	female	—	—	—	—	1	1	—	1	2	—
P. Klunk Middle Woodland	male	1	1	—	4	3	4	9	—	2	2
	female	6	2	4	—	1	5	2	2	4	3
P. Klunk Late Woodland	male	—	—	—	—	—	—	1	—	—	—
	female	—	1	1	—	1	—	1	—	1	—
Yokem Late Woodland	male	1	1	1	1	1	—	1	—	—	—
	female	1	—	—	—	1	—	1	3	1	2
Yokem Mississippian	male	1	1	1	—	—	—	—	—	—	—
	female	2	—	—	1	1	—	2	—	—	—

The original sex assessment was based upon gross morphological indicators of the pelvis (14, 21). The age assessment was made using Todd's phases of the public symphyseal face (14, 21). In the case of individuals scored as younger than 20 years by Todd's phases, the age was verified by reference to the iliac crest, which fuses between 17 and 20 years of age (14). All sex and age determinations were made by the author. Comparison of the author's determinations with those recorded on the Indiana University inventories showed 94% agreement for sex and 85% agreement for age. Comparison of the author's original determinations with the reassessment of a random sample of 25 individuals showed 100% agreement for sex and 84% exact agreement for age, with the remaining 16% of the age determinations falling within one Todd phase of the original assessment.

The mandibular measurements were developed with reference to Morant (15) and Giles (10), in an attempt to describe mandibular size and shape. The majority of measurements were taken with a vernier dial calipers; breadth at ascending rami (BAR) was measured with a spreading calipers, and corpus length (CL) required a mandibulometer. Measurements were recorded in centimeters, and were read to the nearest 0.01 cm for the dial calipers and to the nearest 0.1 cm for the spreading calipers and the mandibulometer. Descriptions of the measurements are listed in the appendix. Unilateral measurements were taken on the left side, except where damage made the measurement questionable or impossible. In this case, the right side was substituted for the left.

Pearson product-moment correlation coefficients were calculated between two different measurement episodes of a random sample ($N = 25$) drawn from the original sample of 172 mandibles to test for measurement error. All 12 correlation coefficients were significant at $p = 0.001$; in addition, the slopes for the 12 measurements all approach one. Measurement error, therefore, is not a complication in the analyses.

A series of Student's t-tests were conducted on the measurements between sites and between cultural periods, separately for males and females, to determine whether the sample could be treated as part of a single, continuous population. Of a total of 216 t-tests, 4% were significant; this was less than the 5% expected due to random chance. Treating the sample as derived from a temporally and spatially continuous population was, therefore, appropriate.

Student's t-tests were also conducted on the measurements between the sexes to determine which measurements differed significantly between the sexes at a univariate level. All measurements except mandibular body thickness (MBT) had t-values significant at $p = 0.001$. These results implied that sexual dimorphism was a size phenomenon in this sample of mandibles.

Stepwise discriminant functions were formulated using an SPSS DISCRIMINANT program with an F of 0.01 to enter and an F of 0.005 to delete (17). The functions were designed to maximize the Mahalanobis distance (D^2) between groups, in this case between males and females, by weighting and linearly combining collections of variables. The objective was to produce satisfactory discrimination between the sexes with a few functions (combinations of discriminating variables) as possible. One analysis began with the total set of 12 measurements; the remainder began with various combinations of one to six measurements. The various combinations were developed by first grouping the measurements into mandibular breadths (BB, BAR, BMF), lengths (CL, MPC) and heights (SH, HC, HP1, HP2, HM1, HM2), and then taking each of these groups as a variable set for analysis. One or two measurements from each of these groups was also combined to form a variable set, and, in the case of heights, one or two measurements from the other groups were added to as many as four heights. Only the analyses correctly classifying more than 80% of the sample used in function formulation, i.e., the base sample of 66 males and 66 females (N = 132), and more than 70% of a random sample not used in function formulation, i.e., the check cases of 22 males and 18 females (N = 40), will be presented.

Discussion of Results

All of the functions had significant Mahalanobis D^2s. The significance of D^2 was determined by the F value of the final step of each analysis. All final F values for the analyses were significant at $p = 0.05$. Of the total of 44 functions, 28 correctly classified more than 80% (range, 81-86%) of the base sample. Of these 28 functions, however, only seven correctly classified more than 70% of the check cases. The percent correct classification as either male or female of the base sample and check cases, the standardized and unstandardized discriminant function coefficients, and the group centroids for each of the seven functions are presented in Table 2. Figure 1 depicts the standardized discriminant score distribution and male/female sectioning point for each sexing function.

In discussing the results, we should keep in mind that there is greater variability in the expression of sexual characteristics in the skelton than in soft tissue (3). We assume that age and sex were phenotypically expressed in the archaeological skeletons. Several studies of sex determination of known sex and age skeletal material, however, evidence that such assumptions are far from unwarranted (2, 5, 7, 8, 9, 10, 11, 13, 18, 19, 22, 23).

The accuracy of sex determination in this study indicates that certain aspects of the mandible are sexually dimorphic. The male mean is greater than the female mean for each measurement, and these differences are significant at $p = 0.001$ for 11 of the 12 measurement t-values, suggesting that this dimorphism is largely, if not entirely, a size phenomenon; i.e., male mandibles are significantly larger than female mandibles in all respects, considered, except MBT. Certain variables, however, can be singled out as large contributors to the observed sexual dimor-

TABLE 2. *Mandibular Sexing Function Formulae*

		Discriminant Function Coefficients		Group Centroids		% Correct Classification	
Function	Measurements	Standardized	Unstandardized	Male	Female	Base Sample	Check Cases
1	BB	-0.790	-1.012	-1.129	0.855	86%	78%
	BAR	0.349	0.576				
	MBT	0.380	2.453				
	BMF	0.104	0.403				
	MPC	-0.898	-6.748				
	SH	-0.556	-1.644				
	CL	-0.367	-0.816				
	HC	0.692	2.463				
	HP1	-0.822	-2.951				
	HP2	0.513	1.948				
	HM1	0.828	2.810				
	HM2	-0.957	-3.400				
	Constant	—	25.928				
2	BB	-0.428	-0.549	-0.948	0.718	83%	72%
	MPC	-0.950	-7.144				
	SH	-0.276	-0.818				
	Constant	—	24.741				
3	BB	0.469	-0.601	-0.927	0.702	83%	72%
	MPC	-0.975	-7.327				
	HC	-0.155	-0.551				
	Constant	—	24.548				
4	BB	-0.418	-0.536	-0.950	0.720	84%	72%
	MPC	-0.950	-7.140				
	HP1	-0.286	-1.028				
	Constant	—	24.942				
5	BB	0.403	0.517	0.959	-0.726	81%	72%
	MPC	0.974	7.323				
	SH	0.470	1.392				
	HC	-0.328	-1.168				
	HP2	0.105	0.399				
	Constant	—	-24.450				
6	BB	-0.399	-0.512	-0.992	0.752	81%	72%
	MPA	-0.989	-7.430				
	SH	-0.524	-1.551				
	HC	0.603	2.145				
	HP1	-0.787	-2.825				
	HP2	0.446	1.693				
	Constant	—	24.464				
7	BB	-0.445	-0.570	-0.963	0.729	86%	78%
	MPC	-0.949	-7.134				
	SH	-0.250	-0.741				
	HP1	-0.475	-1.706				
	HP2	0.435	1.653				
	Constant	—	24.831				

phism. On the basis of the standardized discriminant function coefficients, whose absolute values represent the relative contribution of each variable to discrimination, it appears that MPC is an extremely important aspect of mandibular sexual dimorphism, at least relative to the other measurements considered. In addition, the values of HC and HP1 suggest that this area of the mandible is also sexually dimorphic. The fact that the canine tooth tends to be the most sexually dimorphic tooth in humans (16), and the fact that the first premolar appears to be associated

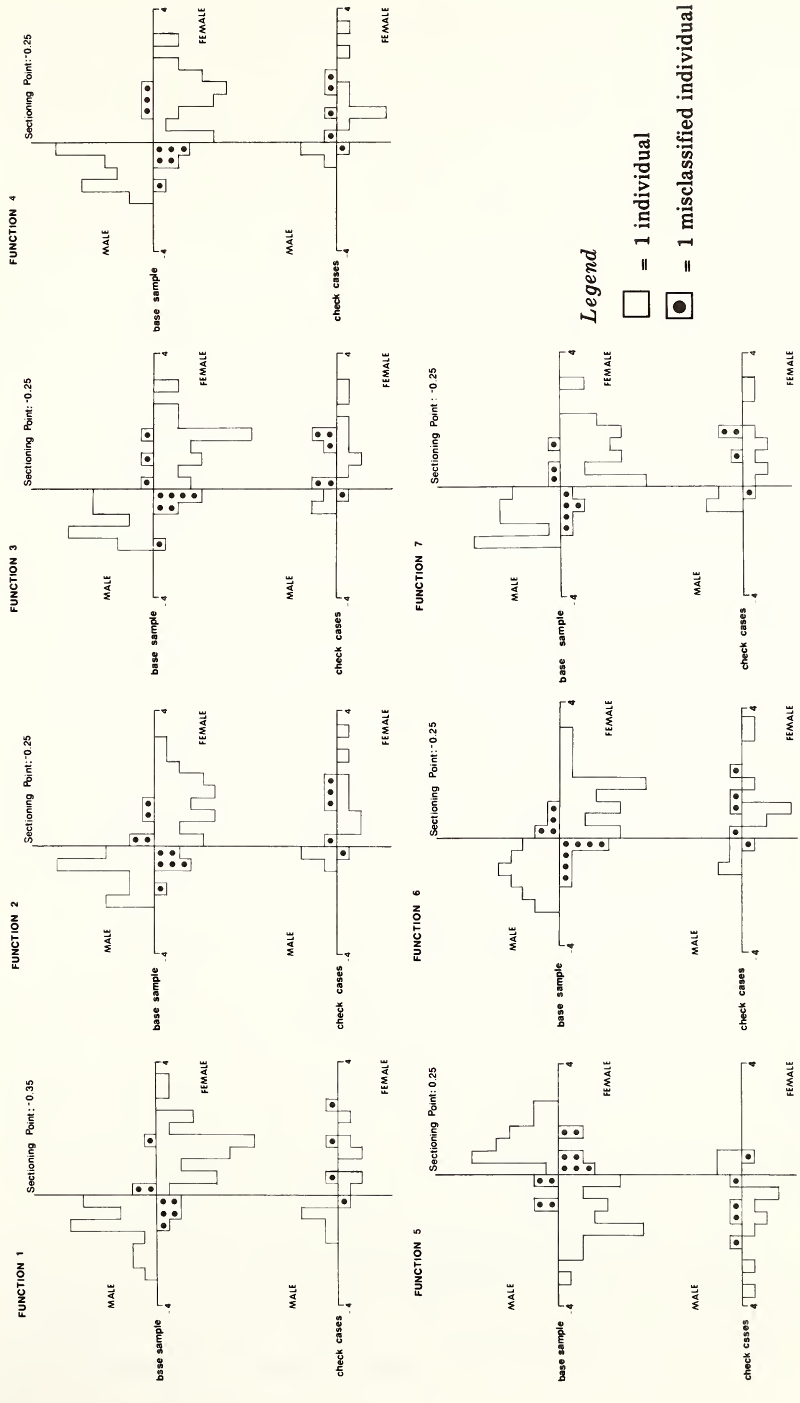

FIGURE 1. *Standardized Discriminant Score Distributions for the Base Sample and Check Cases of each of the Seven Functions.*

with the canine in a developmental tooth "field" (6) may have some bearing on future analysis of mandibular sexual dimorphism.

To apply the sexing functions, each measurement is multipled by the appropriate discriminant function coefficient from Table 2, and the products are added or subtracted according to their signs. The final score is then compared to the score distribution for the specific function (Figure 1), and the individual is assigned a sex according to the side of the sectioning point upon which the score falls. The distributions depicted in this paper are based upon the standardized coefficients. Sexing of individuals from outside the prehistoric Lower Illinois Valley will entail recalculation of at least the sectioning points, and probably recalculation of the sexing functions.

The functions presented here are not practical for sexing rather complete individuals, since other bones (e.g., the innominate) are more quickly and more accurately sexed by observation. The functions, however, are useful for sexing incomplete and/or damaged skeletons, and may be helpful in clarifying cases where other sexing methods have yielded ambiguous results. Unfortunately, individuals possessing only one half of a measureable mandible must be eliminated from the analysis because of the requirements of BB because all useful equations contain breadth measures. Since per cent correct classification as either male or female does not differ greatly between the functions, using the functions based upon three variables probably will not affect the results, and will make this method less time-consuming and more workable. There are, however, three possible sources of complications which must be realized. First, the sample used to formulate the functions excludes all individuals exhibiting obvious disease and/or ante-mortem tooth loss. Tooth loss and disease play a large role in craniofacial changes due to resorption and remodeling of bone. Thus, attempts to sex pathologic and edentulous individuals by these functions will probably yield spurious results. Secondly, the functions are formulated on a sample largely composed of middle-aged individuals (30-40 years old). There may be age effects or changes, possibly lined with continuing growth, disease and tooth loss, such that young and old adults will tend to be misclassified by the sexing functions. Finally, these functions are only directly applicable to prehistoric Lower Illinois Valley Indians. Other populations may exhibit aspects of mandibular sexual dimorphism, but they may differ in degree and/or kind.

APPENDIX. Description of Mandibular Measurements

1. Bicondylar Breadth (BB): The maximum breadth between the mandibular condyles proper, excluding excrescences commonly found in the region of the condylar neck, and taken from and to the lateral edges of the condyles. This measurement is the unmodified equivalent of Morant's W1 (15).

2. Breadth at Ascending Rami (BAR): The breadth between the ascending rami, taken from and to the lateral surfaces just external to the lingula mandibulae and perpendicular to the vertical axis of the mandible. The posterior margins of the mandibular foramina are appropriate substitutes in individuals who lack ligulae. This measurement was developed by the author.

3. Mandibular Body Thickness (MBT): The thickness of the mandible, taken at the midpoint of the cavity for the second molar, parallel to the vertical axis of the mandible. This measurement is modified from Giles (10), who takes it at the level of the second molar, but fails to specify where along that area the measurement is to be taken.

4. Breadth at Mental Foramina (BMF): The breadth of the mandible, taken

from the most anterior margins of the mental foramina, perpendicular to the vertical axis of the mandible. If the individual has more than one foramen per side, the largest is chosen for measurement. In the case where size differences are not discernable, the most anterior foramen of the group is used. BMF is equivalent to Morant's ZZ (15), but with the added specification of a plane for the measurement.

5. Molar-Premolar Chord (MPC): The length of the mandibular body, extending from the second molar anteriorly to the second premolar of the same side. The measurement is taken in line with the midpoints of the cavities for the respective teeth on the external surface of the mandible. MPC is similar to Morant's M2P1 (15), except that Morant measured anteriorly to the first, rather than to the second, premolar. The present author chose the second premolar because of the great variability in repeated readings caused by mandibular curvature when the measurement was extended to the first premolar.

6. Symphyseal Height (SH): The height of the mandibular symphysis, measured from the infradentale to the most inferior point on the anterior surface of the symphysis in the midline. This measurement is modified from both Morant (15) and Giles (10), the inferior reference point (defined as the lowest median point on the lower border of the mandible by these authors) being redefined as the lowest median point on the anterior surface of the bone. This modification was made because of the large number of protuberances observed on the lower border of the mandible, which created uncertainty in measurement.

7. Corpus Length (CL): The maximum length of the mandible resting in standard horizontal plane (15), from the most anterior point on menton to the posterior surface or both condyles. "Rockers" may be fixed in standard horizontal plane by a small piece of plasticine. CL is equivalent to Morant's CpL (15), except for the inclusion of both condyles as the posterior reference point.

The following measurements describe the height of the mandibular body, measured on the external surface in line with the midpoint of the cavity of each respective tooth. The superior limit of the measurement is the superior border of the alveolus; the inferior limit is the most inferior point on the external surface. The measurement is taken parallel to the vertical axis of the mandible. Height at second molar is equivalent to Morant's M2H (15); the other heights were developed by the author.

8. Height at Canine (HC).
9. Height at First Premolar (HP1).
10. Height at Second Premolar (HP2).
11. Height at First Molar (HM1).
12. Height at Second Molar (HM2).

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