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Estimation of Sex from the Talus in Prehistoric Native Americans

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A B S T R A C T

We present both a multivariate discriminant analysis and a univariate procedure to estimate sex from measures of the talus (length, width and height). Both methods are comparable in accuracy (about 85%), but the univariate procedure is preferred due to its simplicity.

Introduction

Accurate estimation of sex for adults in skeletal populations is essential for accurate biocultural reconstruction of the living populations. The amount and diachronic patterns of sexual dimorphism in characters such as stature, disease patterns, and activity-related osteological and dental features provide primary information concerning the biocultural adjustments of populations related to health and nutrition, technological change, and diet and subsistence. A population's response to changes in these features has a fundamental impact on most social and biological systems in the population including demographic parameters. Because change in these systems, especially in demographic parameters in females, can have a profound effect on the evolution of the population, it is necessary to be able to identify correctly the sex of adults in a population as one of the initial steps in the evaluation of the pattern of the population's evolutionary status.

A large number of skeletal features have in the past been shown to express sufficient sexual dimorphism to allow accurate identification of sex in skeletonized individuals. Of these features, the most accurate is the morphology of the pubic bone, which can yield correct sex identification in about 95% of tested cases[1]. Other features of the pelvic bones along with metric features of the postcranium and even morphological features of the face and cranium have been shown to be sexually dimorphic in various populations and thus effective characteristics in sex identification[2]. In optimum situations when the entire skeleton is present and well preserved and is from a known population, the totality of sexually dimor-

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phic features ensures the correct identification of sex. However, the optimum situation is all too rare. More frequently samples consist of at least some fragmentary or poorly preserved adults in which features of known utility in sex identification are not preserved. It is our purpose here to address the problem of sex identification in these kinds of remains by using the metric attributes of a tarsal bone – the talus. Our rationale for choosing this bone for analysis rests on the fact that during locomotion the talus is a weight-bearing bone and all human populations show *at least* some sexual dimorphism in size and weight[3].

Material and Methods

In order to test the utility of the talus for estimating sex in prehistoric Ohio Valley Native Americans we used a total sample of 142 individuals (68 females and 72 males) from three Late Archaic hunting-gathering populations, (Duff, Kirian Treglia, and Boose sites), two Late Prehistoric populations, (Pearson Village and Sun Watch sites) and Buffalo, a Proto-Historic site (Table 1). Each individual was sexed using pubic bone morphology and within site seriation of metric and morphological features. The samples from the Late Archaic populations, which date to 3000   150 years BP have been shown to be metrically indistinguishable[4] and have thus been pooled for this analysis. Likewise the two Late Prehistoric samples, dating to 850–950 BP, are pooled as they have been shown to be virtually identical in size[5]. The Buffalo site dates to approximately 400 AD.

We collected three measures of the talus from the right and left side of each individual (where possible) using an osteometric board: talus length, talus width and talus height (Figure 1). Talus length is the maximum anterior-posterior diameter from the most anterior portion of the navicular articular surface to the most posterior portion of the medial tubercle of

TABLE 1
DESCRIPTION OF STATISTICS OF TALUS MEASURES BY GROUP AND SEX

Group	N	Length		Width		Height		Volume[a]	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Late Archaic									
Male	15	56.9	3.6	43.7	1.9	34.9	2.8	86.7	9.3
Female	15	50.7	2.6	3834	2.1	29.9	2.3	58.5	8.8
% Dimorphism[b]		89%		88%		86%		68%	
Late Prehistoric									
Male	39	58.5	3.5	46.0	2.4	36.0	3.6	97.8	17.8
Female	35	52.8	2.1	41.6	1.9	31.8	2.3	70.1	8.9
% Dimorphism		90%		90%		88%		72%	
Proto-Historic									
Male	20	56.9	3.4	43.5	2.4	33.6	2.2	83.8	13.9
Female	18	51.3	2.6	39.1	3.0	30.3	1.8	61.3	10.9
% Dimorphism		89%		89%		89%		73%	

[a] Units for volume are cm^3. All other measures are in mm;
[b] (male-female)/male .

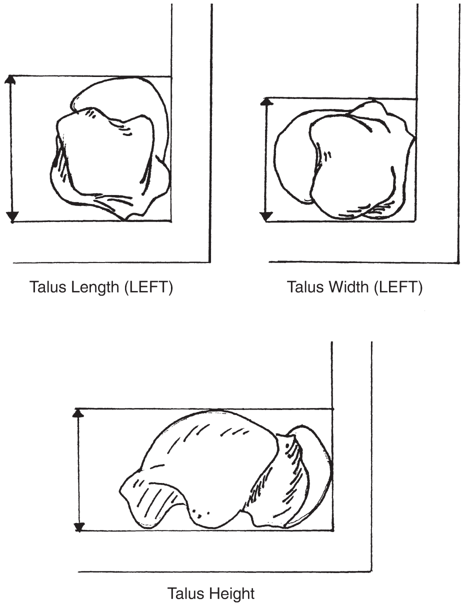

Fig. 1. Measures of the talus.

the posterior process. Talus width is the maximum medio-lateral diameter from the most medial portion of the body to the most lateral portion of the lateral process. Talus height is the maximum inferior-superior diameter with the base of the talus on the vertical portion of the osteometric board and the sliding arm placed on the most superior portion of the trochlea. The osteometric board is used as its larger surfaces allow a more stable orientation of the irregular posterior and inferior surfaces. Because some individuals had only the right or left talus preserved, we used the t-test to evaluate the differences between the sides for each measure in both sexes. For both sexes in each of the time periods we found that the sides could not be shown to be significantly different. Thus, for individuals with both tali we averaged the measures and for individuals with only one we used that side to represent the individual. In addition to talus length, width, and height, we also combined all three measures into a single »volume« estimate simply by finding the product of the three linear measures.

To evaluate the amount of sexual dimorphism we used the t-test (males vs. females) for each measure. Because some showed some deviations from normality, we log transformed the data prior to performing the t-tests. We then performed a linear discriminant function analysis for each sample and for the total sample. Again we used the log-transformed data in this analysis.

Results and Discussion

Table 1 contains the non-transformed descriptive statistics for the talus measures as well as the percent sexual dimorphism. Although the Late Archaic sample shows a somewhat greater amount of sexual dimorphism, the magnitude as well as the pattern of dimorphism is very similar in the Late Prehistoric and Protohistoric samples. Interestingly, although the percentage of sexual dimorphism appears to decrease slightly subsequent to the Late Archaic period, the actual size of the talus increases in both males and especially females. In fact, Late Prehistoric females are significantly larger for all measures than their Late Archaic counterparts, while Late Prehistoric males are significantly larger for only talus width and talus volume. The decrease in sexual dimorphism over this period appears to be the result of the greater increase in the size of females as compared to males.

Within each sample, males exhibit statistically significantly larger tali in all dimensions. However as Table 2 shows, the covariance matrices of the males and females are homogeneous and thus can be pooled for the discriminant analyses.

TABLE 2
RESULTS OF DISCRIMINANT ANALYSES

Group	Male	Female	Total	% Correct	Homogeneity of Covariance Matrices		
					^{2}	d.f.	p
Late Archaic							
Male	14	1	15	93.3	9.28	6	0.16
Female	1	14	15	93.3			
Total	15	15	30	93.3			
Late Prehistoric							
Male	33	6	39	84.6	10.50	6	0.10
Female	5	30	35	85.7			
Total	38	36	74	85.1			
Proto-Historic							
Male	17	3	20	85.0	8.69	6	0.19
Female	6	12	18	66.7			
Total	23	15	38	76.3			
Combined Results[a]							
Male	64	10	74	86.5			
Female	12	56	68	82.4			
Total	76	66	142	84.5			

[a] Sum of results of individual samples.

The discriminant analyses shown in Table 2 reflect these differences in magnitude between the sexes. The allocation summaries shows that the three talus measures (length, width and height) are relatively accurate at correctly identifying the sex of an individual –93.3% correctly allocated in the Late Archaic sample and 86.6% in the Late Prehistoric sample. The somewhat greater success in the Late Archaic sample reflects the somewhat greater amount of sexual dimorphism in that sample.

Linear measures of the talus thus appear to be relatively good discriminators, of sex- on par with other postcranial measures such as femur and humerus head diameter, femur midshaft circumference, and long bone length[2]. However, these analyses and allocation procedures are fairly complex and can be time consuming. In order to investigate a simpler method we considered talus volume, which exhibited the greatest amount of sexual dimorphism in all samples.

Figure 2 shows the distribution of male and female talus volume in the total sample. As can be seen, the distribution is bimodal with overlap between males, to the right and females, to the left, in the 65–89 cm^3 range. The descriptive statistics in Table 1 show the relatively greater amount of sexual dimorphism for talus volume in each sample as compared to the other linear measures. Considering just talus volume in the Late Archaic sample, the »cut-point«, that is, the value at which discrimination between the sexes is a maximum, is the midpoint between the means of the sexes. In this

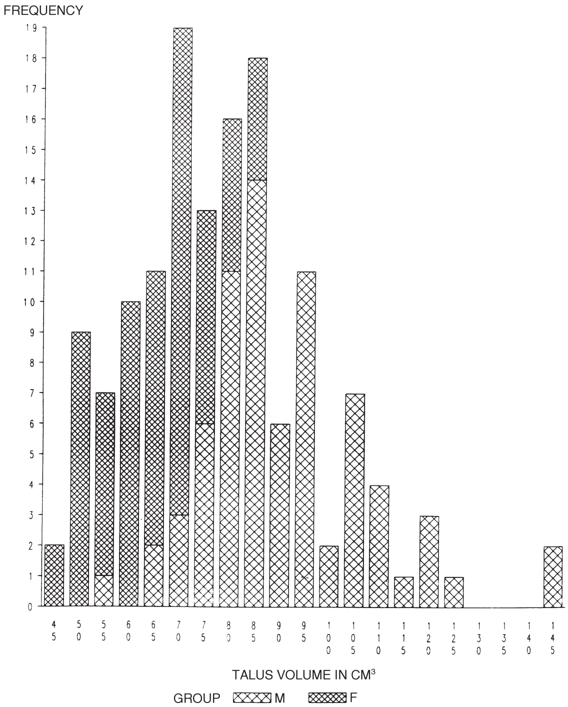

Fig. 2. Distribution of male and female talus volume in the total samples.

case, the cut point is 72.6 or 73 cm^3. If talus volume is less than 73 cm^3 the individual is allocated to females and if talus volume is greater than 73 cm^3 allocation is to males. The allocation summary for the Late Archaic sample in Table 3 shows that talus volume is just about as good as the discriminant function analysis in identifying the correct sex of individuals. For the Late Prehistoric sample talus volume is less accurate, overall, for correctly identifying sex, but more accurate for correctly sexing males than discriminant analysis. The accuracy of determining sex by talus volume for the Protohistoric sample is better for females than discriminant function. The overall percentage of correctly sexed individuals for the Protohistoric is actually greater using talus volume than discriminant function analysis.

Conclusion

Comparison of the combined results in Tables 2 and 3 show that both the discriminant functions and talus volume yield comparable results. Since allocation based on talus volume is a much simpler method, allocation based on talus volume is preferable. In addition, this technique, because of its simplicity, can easily be applied to other populations with results that are readily comparable.

The pattern of talus size evolution in Late Archaic to Late Prehistoric is analogous to changes in stature observed during this interval. In females average stature remains fairly constant at about 154–155 cm (5'1") while male stature declines about 3% from 170 cm (5'7") to about 165 cm (5'5")[6]. This phenomenon of

TABLE 3
ALLOCATION SUMMARIES FOR TALUS VOLUME

Group	Male	Female	Total	% Correct
Late Archaic[a]				
Male	15	0	15	100.0
Female	1	14	15	93.3
Total	16	14	30	96.7
Late Prehistoric[b]				
Male	37	2	39	94.9
Female	11	24	35	68.6
Total	48	26	74	82.4
Proto-Historic[c]				
Male	16	4	20	80.0
Female	4	14	18	77.8
Total	20	18	38	78.9
Combined Results[d]				
Male	68	6	74	91.9
Female	16	52	68	76.4
Total	84	58	142	84.5

[a] Allocation rule: if volume > 73 sex = male;
[b] Allocation rule: if volume > 84 sex = male;
[c] Allocation rule: if volume > 73 sex = male;
[d] Sum of results of individual samples.

reduced sexual dimorphism stemming primarily from a reduction of size in males has been found in a number of diachronic studies of post Pleistocene skeletal populations and has been attributed to technological and subsistence base changes over time[7]. While talus size increases in both females and males subsequent to the Late Archaic the reduction of sexual dimorphism is due to the greater increase in talus size of the females. We propose that this phenomenon is the result of subsistence base changes. The Late Prehistoric horticulturalists' diet consisted of greater amounts of carbohydrates compared to the Late Archaic hunter and gatherers, resulting in a greater weight at a given stature for Late Prehistoric individuals. Because males decreased in stature over this period their weight increase per unit height would have been less than that of females, who remained relatively constant in average stature. We hypothesize that this phenomenon explains the changes seen in the dimensions of the weight-bearing talus. This hypothesis is supported by the decrease in the volume of both male and female tali during the Protohistoric period when Native American populations were stressed both from introduced disease and nutritionally.

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PROCJENA SPOLA IZ TALUSA U PREHISTORIJSKIH SJEVERNOAMERIČKIH INDIJANACA

SAŽETAK

Prikazane su dvije procedure – univarijatna i multivarijatna diskriminantna analiza – za određivanje spola iz dimenzija talusa (duljina, širina i visina). Obje metode usporedive su točnosti (oko 85%), no zbog svoje jednostavnosti, preporučuje se korištenje univarijatne procedure.