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Sex Determination of Prehistoric New Zealand Polynesian Clavicles

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ABSTRACT

Discriminant function analysis was used for sex determination of prehistoric adult New Zealand Polynesian clavicles (40 male and 36 female). Seven clavicular measurements were taken, using conventional osteometric techniques. Twenty discriminant functions were derived using the direct method in the SPSS subprogram DISCRIMINANT. The accuracy of sex determination ranged from 63.3% to 100%, with 14 of the 20 functions achieving a level of accuracy greater than 85%. Reduction in error over random assignment by sex ranged from 27% to 100%. These discriminant functions provide a useful tool for the assessment of human remains in the forensic and archaeological context because they incorporate measurements which can be taken on incomplete bones.

Keywords: FORENSIC ANTHROPOLOGY, DISCRIMINANT ANALYSIS, SEX DETERMINATION, NEW ZEALAND, POLYNESIANS, CLAVICLES.

Sexing of skeletal remains forms an integral part of the process of identification in the forensic and archaeological sciences. Multivariate discriminant function analysis is amongst the many techniques available. Little research has been undertaken using this method of sex determination of New Zealand Polynesian skeletal remains. The only previous study was that of Houghton and de Souza (1975) which used long bone lengths. To compensate for this paucity of information, sexing by discriminant function analysis has been undertaken in the present study using adult New Zealand Polynesian clavicles.

MATERIALS AND METHODS

Adult clavicles (40 male and 36 female) from the collection in the Department of Anatomy and Structural Biology, Otago Medical School, Dunedin, New Zealand were examined. This material, believed to be prehistoric, had been recovered from isolated burials and archaeological sites throughout New Zealand.

The criterion chosen to establish adult status was complete fusion of all epiphyses. No adult bone or major fragment capable of providing a measurement was excluded, unless affected by gross pathological or post-mortem distortion.

Since the skeletal remains were archaeological in origin, none of the material was of known sex. Thus, in order to evaluate this new method of sex determination, it was necessary to establish the sex of the individuals initially by some other means. In expert hands, the conventional pelvic morphological criteria which were used can achieve 95%

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accuracy in assignment of sex. Discriminant function number one, derived by Houghton and de Souza (1975), was also utilised in the initial sexing with a reported accuracy of 97.6%.

The measurements were chosen for their potential utility in assessment of poorly preserved or fragmentary remains, commonly encountered in forensic cases and archaeological excavations. Seven clavicular measurements were taken in this study, using an osteometric board, sliding calipers and a metal measuring tape.

Absolute length (ABSL) (Martin 1928). The clavicle was placed on the osteometric board with its superior surface uppermost. The sternal end was placed against the fixed upright and the movable upright was brought into contact with the most distant point on the acromial end, found by gently moving the acromial end from side to side.

Antero-posterior diameter of the acromial end (APACR). With the acromial end of the clavicle placed 15 mm within the jaws of the sliding caliper, one arm of the caliper was brought into contact with the anterior border of the acromial end and tangential to it. The other arm was applied to the posterior border of the acromial end.

Maximum diameter of the sternal end (STMAX). The arms of the sliding caliper were applied to the sternal end, avoiding the margins of the articular surface. The caliper was rotated from side to side until the maximum diameter was obtained.

Least circumference of the shaft (LCIRC) (van Dongen 1963). The measuring tape was applied to the shaft of the clavicle and moved along its surface until the least circumference was obtained.

Maximum depth of the shaft curvature (SHFCV) (adapted from Martin 1928). The clavicle was placed on the osteometric board with its superior surface uppermost, and with the posterior surface of the sternal end and the posterior curve of the acromial end contacting the fixed upright. The movable upright was applied to the anterior surface of the medial two-thirds of the clavicle, and the bone was gently rotated until the maximum depth of the shaft curvature was determined.

Maximum projected width of the acromial end (ACRWD) (adapted from Martin 1928). The clavicle was placed on the osteometric board in the same position as for the previous measurement. The movable upright was brought into contact with the most anterior point on the acromial end, found by gently rotating the bone.

Maximum depth of the acromial curvature (ACRCV). The clavicle was placed on the osteometric board with its inferior surface uppermost, and with the anterior surfaces of the anterior curvature and acromial end contacting the fixed upright. The movable upright was applied to the posterior surface of the posterior curve of the acromial end, and the bone was gently rotated until the maximum depth of the acromial curvature was determined.

Twenty discriminant functions were derived utilising the DISCRIMINANT procedure of SPSS, METHOD=DIRECT (Nie *et al.* 1975; Hull and Nie 1981). Ten of these functions used measurements from left side bones, and the remainder used those from the right side. Each function was generated using a specified combination of variables likely to be available from incomplete skeletal material. Thus, a single discriminant function was derived

during each of 20 separate analyses. Such an approach is identical to that of Houghton and de Souza (1975). The sectioning point for assignment of sex was designated as the midpoint between the male and female mean discriminant scores (Giles and Elliot 1963; Kajanoja 1966; Steele 1976).

To express the improvement achieved by the discriminant functions over random assignment by sex, a proportional reduction in error statistic termed *tau* (Klecka 1980) was calculated. The maximum value for *tau* is one and occurs when there are no errors in assignment. A value of zero indicates no improvement over random assignment.

RESULTS

Univariate statistics for the seven clavicular variables are shown in Tables 1 and 2. All dimensions were significantly greater in males than females.

TABLE 1[1]

NEW ZEALAND POLYNESIAN LEFT CLAVICLES

Variable	Male			Female			Significance[2]
	N	Mean	SD	N	Mean	SD	
ABSL	11	151.18	6.59	17	130.18	6.78	***
APACR	14	23.21	2.91	16	20.19	2.81	**
STMAX	15	27.47	2.77	17	23.12	2.34	***
LCIRC	18	37.83	3.75	18	32.50	3.94	***
ACRWD	12	33.00	4.95	15	27.47	2.70	**
SHFCV	17	30.59	3.54	18	26.11	3.10	***
ACRCV	14	32.57	4.01	16	26.31	2.57	***

[1] All dimensions in millimetres

[2] Significance levels (t-test) of the difference between male and female means: * 5%, ** 1%, *** 0.1%

TABLE 2[1]

NEW ZEALAND POLYNESIAN RIGHT CLAVICLES

Variable	Male			Female			Significance[2]
	N	Mean	SD	N	Mean	SD	
ABSL	12	148.33	8.03	15	130.27	7.81	***
APACR	17	24.29	3.46	13	21.69	2.72	*
STMAX	16	27.88	2.55	14	23.29	1.94	***
LCIRC	20	37.45	2.84	15	31.73	3.10	***
ACRWD	16	33.06	3.82	14	28.71	3.50	**
SHFCV	16	32.38	2.96	16	26.50	3.10	***
ACRCV	17	32.94	3.09	15	27.93	3.13	***

[1] All dimensions in millimetres

[2] Significance levels (t-test) of the difference between male and female means: * 5%, ** 1%, *** 0.1%

For each function, Tables 3 to 6 indicate the variables utilised in its derivation, the unstandardised discriminant coefficients, the sectioning point, the value for *tau* and the expected accuracy of sex determination. The accuracy of sex determination ranged from 63.3% to 100%, and values for *tau* ranged from 0.27 to 1.0.

TABLE 3

DISCRIMINANT FUNCTIONS DERIVED FROM LEFT CLAVICLES

Variable	**Discriminant Function No.**				
	1	**2**	**3**	**4**	**5**
ABSL	0.193960	0.190092	0.178094	0.200237	0.177835
APACR	0.022671	0.085240	0.044048	0.059044	-
STMAX	0.332110	0.275577	0.274476	0.324980	0.307549
LCIRC	-0.108859	-0.151060	-0.154918	-0.121920	-
ACRWD	-0.037024	-	-0.002864	-	-
SHFCV	-0.154567	-	-	-0.120617	-0.176165
ACRCV	0.097219	-0.062708	-	-	0.045311
Constant	-29.57898	-28.31453	-27.50884	-29.83292	-28.91090
Accuracy	100%	100%	100%	100%	96.3%
Tau	1.0	1.0	1.0	1.0	0.93
Sectioning Point	0.35964	0.34549	0.34335	0.35877	0.34264

TABLE 4

DISCRIMINANT FUNCTIONS DERIVED FROM LEFT CLAVICLES (continued)

Variable	**Discriminant Function No.**				
	6	**7**	**8**	**9**	**10**
ABSL	-	-	0.155093	-	-
APACR	-	0.168680	-	0.328429	-
STMAX	0.277608	-	-	-	0.386521
LCIRC	0.140395	0.169780	-	-	-
ACRWD	-	-	-	-	-
SHFCV	-	-	-	-	-
ACRCV	-	-	-	-	-
Constant	-11.82955	-9.462574	-21.60317	-7.129652	-9.791867
Accuracy	83.9%	73.3%	96.4%	63.3%	78.1%
Tau	0.68	0.47	0.93	0.27	0.56
Sectioning Point	0.14472	0.11670	0.26163	0.09813	0.12516

TABLE 5

DISCRIMINANT FUNCTIONS DERIVED FROM RIGHT CLAVICLES

Variable	**Discriminant Function No.**				
	1	**2**	**3**	**4**	**5**
ABSL	0.114820	0.108081	0.123565	0.077919	0.079804
APACR	-0.337556	-0.324468	-0.277544	-0.021875	-
STMAX	0.329583	0.324357	0.363110	0.191729	0.128882
LCIRC	-0.137487	-0.135767	-0.152833	0.000111	-
ACRWD	-0.077734	-	0.373409	-	-
SHFCV	-0.059023	-	-	0.139025	0.063281
ACRCV	0.657208	0.529651	-	-	0.195246
Constant	-27.97390	-27.50180	-26.33472	-19.47787	-22.44356
Accuracy	95.5%	100%	95.5%	95.5%	95.7%
Tau	0.91	1.0	0.91	0.91	0.91
Sectioning Point	0	0	0	0	0

TABLE 6

DISCRIMINANT FUNCTIONS DERIVED FROM RIGHT CLAVICLES

Variable	**Discriminant Function No.**				
	6	**7**	**8**	**9**	**10**
ABSL	-	-	0.134001	-	-
APACR	-	0.003396	-	0.303525	-
STMAX	0.240320	-	-	-	0.385290
LCIRC	0.171107	0.297389	-	-	-
ACRWD	-	-	-	-	-
SHFCV	-	-	-	-	-
ACRCV	-	-	-	-	-
Constant	-12.17153	-10.48904	-18.69313	-7.188019	-9.912450
Accuracy	88.9%	82.1%	96.3%	66.7%	86.7%
Tau	0.78	0.64	0.93	0.33	0.73
Sectioning Point	0	0	0	0	0

It is of interest to note that absolute length alone achieved an accuracy of 96.4% and 96.3% for left and right clavicles respectively. In terms of circumferential and articular surface dimensions, the least circumference of the shaft and the antero-posterior diameter of the acromial end demonstrated an accuracy of 73.3% and 82.1% for left and right clavicles respectively. The maximum diameter of the sternal end and the least circumference of the shaft achieved an accuracy of 83.9% and 88.9% respectively for left and right clavicles.

As an example of utilising a function: if the maximum diameter of the sternal end of a right clavicle is measured as 30 mm, and no other measurements can be taken, discriminant function 10 (Table 6) can be applied as follows:

Discriminant score = (30 x 0.385290) - 9.912450 = 1.646250

Since this score is above the sectioning point of zero, the clavicle is assumed to be from a male individual. This classification has an expected accuracy of 86.7%.

DISCUSSION

The accuracy of sex prediction demonstrated by many of the discriminant functions derived in this study indicates that they will be of considerable value to archaeologists and forensic investigators throughout New Zealand. The range of accuracy for these functions, with 14 of the 20 functions achieving a level above 85%, is an improvement on the results reported by previous researchers for various racial groups.

Two discriminant functions derived by Steel (1966) using Parsons' (1917) English Caucasian data were calculated using three clavicular measurements: maximum length, circumference at the middle of the bone and the 'index of the inner end'. An accuracy of 94% was obtained when the functions were applied to the St. Bride's Collection, London, and 87% when applied to Parsons' original (1917) data.

Using weight of the clavicle and mid-clavicular circumference, the discriminant function derived by Jit and Sahni (1983) from their North Indian data gave an accuracy of 79% for males and 82% for females. If length of the clavicle was also included in the analysis, the accuracy decreased to 56% for males and 55% for females. This puzzling result can be explained by the considerable degree of overlap in values for clavicular length in males and females.

Size of articular surfaces of bones has long been regarded as a useful indicator of sex (Dwight 1905). This has been confirmed by the present study in which the diameters of the ends of the clavicle are amongst the useful sexual discriminators.

Black (1978) commented that many of the techniques available for sex determination of human skeletal remains could be utilised only on well preserved bones from relatively complete skeletons. He noted that few reliable methods were available to the investigator confronted with incomplete bones.

Many of the discriminant functions derived in the present study have the practical advantage of permitting sexual assessment of poorly preserved remains, commonly encountered in archaeological excavations and forensic casework. Inclusion in the discriminant functions of measurements that can be taken on preservationally favoured portions of the clavicle reduces the likelihood of investigators being unable to locate a function which incorporates the measurements possible on their specimens.

Because of the well-documented population specificity of the discriminant function method (Kajanoja 1966; Steele 1976; Calcagno 1981), the functions derived in this study are unsuitable for use on non-Polynesian skeletal populations in New Zealand. It is intended to examine the applicability of these discriminant functions to other Polynesian samples from the Pacific region in a subsequent study.

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