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How Children Score on Discriminate Functions Designed for Adults

Abstract

Existing discriminant functions for sex, as used in forensic anthropology, are designed to be used with adults. The question of how well they work with children has not been adequately explored. I constructed a discriminant function for sex using 7,428 adults from the Boas Anthropometric Data Set and used the function to estimate sex for 6,102 children from this data set. I examined the accuracy of sexing for individuals of all ages. The accuracy was about 50 percent for people 12 and under, about 90 percent for people 19 and older, and increased in a nearly linear fashion between ages 12 and 19. The function scores small people as female.

Key words: discriminant functions, forensic anthropology, sexing.

Introduction

Forensic anthropology is the application of the methods and expertise of physical anthropology to the legal process. In one common situation, the anthropologist takes custody of skeletal material provided by a law enforcement agency and attempts to determine the age, sex, race, height, and medical history of any represented human beings. The anthropologist's findings may then be used to scan lists of missing persons in an attempt to determine the identity of the deceased (Haviland, 1994). One of the important identifying items in a missing person's description is their sex and many forensic anthropologists have discussed methods of estimating sex from the skeleton (Dutra 1944, Brues 1958, Ubelaker 1978, Stewart 1979, Snow 1982, Krogman and Iscan 1986, Rogers 1986, Bass 1987, Bennett 1987, Steele and Bramblett 1988, Iscan and Kennedy 1989, Rogers 1989, Killam 1990, White and Folkens 1991).

There are two useful approaches to estimating sex from skeletal material. In the first approach the anthropologist visually inspects the skeleton, looking for characters that are more commonly associated with one sex than the other (Derry 1909, Derry 1912, Pearson 1914, Parsons 1920, Derry 1923, Thoms and Greulich 1940, Washburn 1948, Thieme and Schull 1957, Phenice 1969, Kelley 1978, Weaver 1980, Lovell 1989, Anderson 1990, Budinoff and Tague 1990, Hunt 1990, Maclaughlin and Bruce 1990, Sutherland and Suchey 1991, Schutkowski 1993). These characters are primarily features of the pelvis and skull, although other elements of the skeleton can occasionally be useful. In the second approach, the anthropologist measures parts of the skeleton and plugs these measurements into a computer-generated formula, called a discriminant function. The discriminant function yields a score, which can be interpreted as indicating that the person is of one sex or the other (Hanihara 1958, Hanihara 1959, Giles and Elliot 1963, Giles 1964, Steel 1966, Ditch and Rose 1972, Day and Petcher-Wilmott 1975, Steele 1976, Henke 1977, Flander 1978, Dibennardo and Taylor 1983, Owlsey and Webb 1983, Dittrick and Suchey 1986, De Vito and Saunders 1990, Holman and Bennett 1991). Both of these approaches are useful, and

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good forensic analyses utilize both of them.

It is generally recognized that sex determination is unreliable for young children because secondary sexual characteristics are not manifested until puberty (Bass 1987). Visual methods are at least occasionally reliable for individuals who are postpubertal, but who have not achieved full skeletal maturity (Steele and Bramblett 1988, Schutkowski 1993). However, the question of whether discriminant functions can be used to estimate sex in adolescents remains unanswered. Existing discriminant functions are designed for use with adults. The question of how children and adolescents score on these functions has not been adequately explored.

The study reported herein is part of a continuing effort by various members of the forensic anthropology team at The University of Montana - Missoula to explore and identify the limitations of the discriminant functions approach to estimating sex and race (Stagg 1993, Skelton 1994, Olson 1995). In this study I will examine how children score on discriminant functions for sex that are designed for use with adults.

Materials and Methods

I worked with the Boas Anthropometric Data Set, which was kindly provided by R.L. Jantz and S. Ousley of the University of Tennessee, Knoxville (Jantz *et al.* 1992) This data set includes six cranial and six postcranial measurements on over 15,000 living Native Americans of various tribes. These data were collected about 100 years ago by colleagues of Franz Boas, a prominent historical figure in American anthropology (Hays 1964). Although the Boas data set consists of measurements of living people and, therefore, cannot be applied directly to investigations of the skeleton, these measurements should behave similarly to skeletal measurements.

The Boas data set includes data for individuals of all ages and both sexes. I chose to work with individuals who had no missing values for any of the 12 measurements. This gave me 13,530 cases with complete data. Table 1 provides a breakdown of the sample by age and sex. For presentation and plotting purposes, people age 30 through 59 are grouped by 10-year age category. Similarly, all people 60 and over are grouped into a single category.

A discriminant function for sex was constructed for the individuals age 20 and older, using the SPSS-X Discriminant procedure on the U.M. campus mainframe. This function was then used to classify all 13,530 individuals in the data set. Mean sexing accuracy by age was calculated and plotted. Overall sexing accuracy was obtained by averaging the accuracies for the males and the females.

Three methods of correcting for the effect of size were applied to the data. First a principal components analysis was performed using the SPSS-X Factor procedure (Andrews and Williams 1973, Morrison 1976, Karson 1982, Berenson *et al.* 1983, Darroch and Mosimann 1985). Second, a form of size scaling was attempted, wherein the values for each of the variables are summed to yield an overall size variable. Each value was then divided by the overall size variable (Albrecht *et al.* 1993). This method is widely acknowledged to be an ineffective way to adjust for the effect of size (Atchley *et al.* 1976, Corruccini 1985, Gelvin and Albrecht 1985, Reist 1985, Packard and Boardman 1987, Gelvin *et al.* 1991, Albrecht *et al.* 1993). Third, the data were divided into three age groups: 1 to 12, 13 to 19, and 20 or older. Each variable was regressed on age, using the SPSS-X Regression procedure, separately for each of the age groups. The residuals for each variable, after the effect of age was accounted for by this procedure, were retained and a discriminant analysis was performed

Table 1. *Sample sizes and classification results by age and sex.*

AGE	Number of Females	Females Correctly Classified (%)	Number of Males	Males Correctly Classified (%)	Total Number of Individuals	Total Correctly Classified (%)
1	6	6 (100 %)	10	0 (0 %)	16	6 (38 %)
2	4	4 (100 %)	19	0 (0 %)	23	4 (17 %)
3	26	26 (100 %)	31	0 (0 %)	57	26 (46 %)
4	49	49 (100 %)	42	1 (2 %)	91	50 (55 %)
5	61	61 (100 %)	79	0 (0 %)	140	61 (44 %)
6	114	114 (100 %)	120	0 (0 %)	234	114 (49 %)
7	143	143 (100 %)	143	0 (0 %)	286	143 (50 %)
8	193	193 (100 %)	213	0 (0 %)	406	193 (48 %)
9	185	185 (100 %)	234	0 (0 %)	419	185 (44 %)
10	199	199 (100 %)	241	2 (1 %)	440	201 (46 %)
11	213	213 (100 %)	242	0 (0 %)	455	213 (47 %)
12	230	230 (100 %)	319	1 (0 %)	549	231 (42 %)
13	206	206 (100 %)	262	7 (3 %)	468	213 (46 %)
14	204	204 (100 %)	274	14 (5 %)	478	217 (45 %)
15	193	190 (98 %)	269	59 (22 %)	462	249 (54 %)
16	198	189 (95 %)	232	88 (38 %)	430	277 (64 %)
17	161	156 (97 %)	208	140 (67 %)	369	296 (80 %)
18	202	189 (94 %)	223	162 (73 %)	425	351 (83 %)
19	130	119 (92 %)	224	190 (85 %)	354	309 (87 %)
20	150	138 (92 %)	266	233 (88 %)	416	371 (89 %)
21	64	57 (89 %)	207	185 (89 %)	271	242 (89 %)
22	108	101 (94 %)	220	194 (88 %)	328	295 (90 %)
23	76	68 (89 %)	153	142 (93 %)	229	210 (92 %)
24	47	44 (94 %)	142	131 (92 %)	189	175 (93 %)
25	100	94 (94 %)	244	211 (86 %)	344	305 (89 %)
26	43	39 (91 %)	139	122 (88 %)	182	161 (88 %)
27	57	52 (91 %)	138	130 (94 %)	195	182 (93 %)
28	84	78 (93 %)	176	158 (90 %)	260	236 (91 %)

using them (Albrecht *et al.* 1993). Finally, the sexing accuracies by age of the size-scaling and the residuals procedures were averaged and plotted as described above.

Results And Discussion

The results obtained from the original discriminant analysis procedure are shown in Figure 1. The accuracy of sexing females age 13 and younger was effectively 100 percent, the accuracy of sexing females age 19 and older was around 90 percent, and the accuracy of sexing females age 14 through 18 declined from about 100 percent to about 90 percent in a fairly linear fashion with increasing age. The accuracy of sexing males age 12 and younger was effectively 0 percent, the accuracy of sexing males age 19 and older was around 90 percent, and the accuracy of sexing males age 13 through 18 increased from about 0 percent to about 90 percent in a fairly linear fashion with increasing age. The combined accuracy of sexing people 12 and younger was around 50 percent, the combined accuracy of sexing people age 19 and older was around 90 percent, and

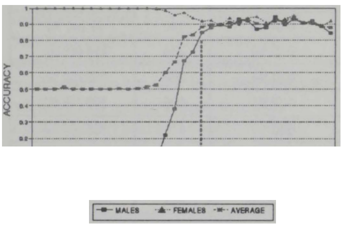

Figure 1. *Sexing accuracy: unmodified data*

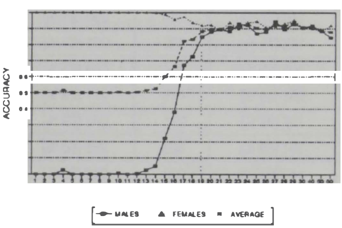

Figure 2. *Sexing accuracy: size-scaled data*

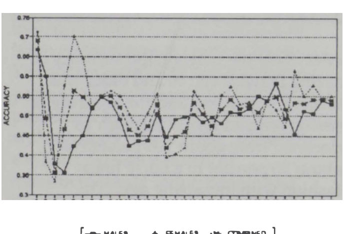

Figure 3. *Sexing accuracy: residuals*

the accuracy of sexing people age 13 through 18 increased from around 50 percent to around 90 percent in a fairly linear fashion with increasing age.

These results imply that size is the primary factor reflected in the discriminant function, and that small people are classified as female.

The above results also imply that discriminant functions for sex are highly accurate only for people age 19 and older. People age 15 to 18 can be sexed with moderate accuracy (around 60 percent to 80 percent), but the accuracy of sexing people younger than 15 by this method is not significantly different from random chance (or more accurately, no better than classifying all individuals as female).

None of the methods of adjusting for the effect of size was useful. The principal components analysis yielded only one principal component, upon which all variables loaded moderately high, and which can be interpreted as size.

The results obtained using data scaled by the overall size variable are shown in Figure 2, and are identical to those obtained using unmodified values.

The results obtained using the residuals left after the effect of age was removed are shown in Figure 3. The sexing accuracy is effectively 50 percent across all age groups. The variability in accuracy by age is quite variable for people younger than about 8, probably due to the relatively smaller sample sizes for these younger ages and to nonlinear growth early in life.

Conclusions

The primary conclusion is that sexing by discriminant functions is highly reliable only for individuals 19 or more years old. Therefore, they should be applied only to individuals showing evidence of skeletal maturity, such as erupted 3rd molars, closure of the basilar suture, or closure of all epiphyses of the long bones.

The secondary conclusion is that, at least in this study, discriminant functions detect only sexual dimorphism in size, with small people being classified as female. There does not seem at this time to be a way to correct for size differences in such a way that children can be sexed accurately using discriminant functions designed for adults.

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