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Osteometric Analysis of Sexual Dimorphism in the Sternal End of the Rib in a West African Population*

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ABSTRACT: This study, and others, are being carried out in order to establish a Forensic Anthropology databank on age estimation and sex determination of skeletonized remains in Ghana. An osteometric study of sexual dimorphism in the sternal end of the right fourth rib on 346 consecutive coroner's autopsy cases (221 males, 125 females) of known age, sex, and race was conducted. The height and width of the sternal end of the rib were measured in each case. The sample was analyzed in three groups: young (<30 years), old (≥30 years), and total sample (total group). Stepwise discriminant function analysis showed that the accuracy of sex determination varied from 80% in the young and 74% in the old groups to 78% for the total group. Statistical analysis of the results obtained when the functions derived from the study were tested using another batch of ribs showed the functions to be effective and reliable in determining sex. When functions derived from a previous study of American Whites were used to determine sex in our study sample, the vast majority of males were misclassified as females. This is the first time, to our knowledge, that a Black African population has been studied osteometrically to evaluate sexual dimorphism in the sternal end of the fourth rib.

KEYWORDS: forensic science, forensic anthropology, sex determination, sternal rib, discriminant function, human identification, Ghana

The Department of Pathology of the University of Ghana Medical School and Korle Bu Teaching Hospital serves as a reference center for forensic pathology cases from the Homicide Unit, Criminal Investigation Department of the Ghana Police Service. The Department receives on average five skeletonized human remains annually for identification purposes and assessment of cause of death. About 15 exhumations are also done annually for medico-legal reasons. Sex and age determinations are always crucial and usually problematic all the skeletonized cases, especially when an incomplete skeleton is received, and in many of the exhumed bodies.

Determination of sex from the rib has not been carried out extensively except for radiological studies (1–4). To date there has been only one published study known to us of sexual differentiation by direct examination and measurements of bony ribs (5). This study was conducted on an American White population. There is no publication on determination of sex by rib measurements in Blacks in general, and in particular African Blacks, to our knowledge.

In order to establish a Forensic Anthropology databank in Ghana for age estimation and sex determination of unknown decomposed, mutilated, or skeletonized bodies, a series of studies involving measurement of different dimensions of various bones in the body have been initiated of which this work forms a part. The purpose of this study is to develop a set of formulas using discriminant function analysis, analogous to that of İşcan (5), with the expectation that they will be useful in determining the sex from the skeletal remains of unknown individuals.

Materials and Methods

The sternal end of the right fourth rib was obtained from 346 Black West Africans, predominantly Ghanaians (221 males, 125 females), of known age and sex. All were coroner's cases referred to the Korle Bu Teaching Hospital mortuary for autopsy. Age was recorded from the police request forms to the nearest year. A short segment of the sternal end of the right fourth rib was removed along with its costal cartilage. Any adherent soft tissue was removed. The specimens were left in polythene bags for several weeks to allow autolysis of any remaining soft tissue. The bones were boiled in water for about an hour and then dried at room temperature. Any fragments of cartilage present were detached from the ribs without any damage to the latter. The maximum superior-inferior height and the maximum antero-posterior thickness of the sternal end of each specimen were measured using a Vernier calliper to the nearest tenth of a millimeter. To control for the effect of age on sexual dimorphism, the sample was analyzed in three age groups: the young (i.e., adults less than 30 years), the old (30 years and older), and young and old combined (5).

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Statistics

The sex of each case was first predicted using İşcan's discriminant function formulas for the defined age groups (5). The Statistical Package for the Social Sciences (SPSS/PC+) (6) was then used to calculate descriptive statistics for each sex in the three groups to provide basic information about distribution of the variables (age, maximum superior-inferior height, and maximum antero-posterior thickness) within the groups. Univariate tests to determine significant differences between the means of the various measurements in each sex in the three age groups were also done. P-value less than 0.01 was chosen as level of significance. Separate stepwise and canonical discriminant functions for each age group and the total sample was calculated. The functions derived from the analysis were then used in the formula:

$$D = B_0 + B_1X_1 + B_2X_2 \ldots + B_PX_P$$

where X is the value of the independent variables, B is the coefficient estimated from the data, and D is the discriminant value for the rib. The probability that the a case with a discriminant value of D being male or female was estimated using Baye's Rule (6). The case was then assigned to the sex group with the higher probability. The number of cases correctly classified for each sex in each of the three groups was also determined and expressed as a percentage of the actual number of cases in that sex class for that group. The percentage of cases correctly classified was then used as an index of the effectiveness of the discriminant function. Misclassification rates were determined by subtracting the percentage of cases correctly classified from 100% and compared statistically with the rate of misclassification expected by chance alone (which is 50%).

The effectiveness of the formulas derived from the functions to correctly assign sex was determined by collecting and treating a "test sample" of ribs at consecutive autopsies from 74 Ghanaians in the manner described above. The various measurements were then taken and the formulas used to calculate the discriminant values. The predicted sex was noted for each case and the percentages of cases correctly classified were then calculated as before. The misclassification rates of the "test sample" were determined and statistically compared to those obtained in the study using the z-test for independent proportions. Level of significance was set at P-value less than 0.01.

Results

Table 1 shows the percentage of cases in this study correctly classified using İşcan's discriminant function formulas (5). Clearly, these formulas are not suitable for discriminating between the sexes in the Black West African population studied. Descriptive statistics and univariate tests of significance of the study population are summarized in Table 2. There were no significant age differences between the sexes within the three groups. Males were significantly larger in the two dimensions ($p < 0.001$) with the exception of the A-P thickness in the young group in which the difference was significant only at $p < 0.05$. Table 3 contains the results of the stepwise discriminant function analysis. The analyses show that both osteometric measurements are optimal variables for

TABLE 1—*Percentage of correct classification by discriminant function formulas of İşcan.*

Test Group and Function	Male		Female		Total N
	%	N	%	N	
Younger Group					
1. Function 1*	8.8	5/57	100.0	47/47	104
2. Function 3*	0.0	0/57	100.0	47/47	
3. Function 4*	1.75	1/57	100.0	47/47	
Older Group					
1. Function 1	42.68	70/164	91.0	71/78	242
2. Function 3	18.90	31/164	100.0	78/78	
3. Function 4	22.56	35/164	100.0	78/78	
Total Group					
1. Function 1	33.94	75/221	94.4	118/125	346
2. Function 3	14.03	31/221	100.0	125/125	
3. Function 4	17.19	38/221	100.0	125/125	

* Functions derived by İşcan (5).

TABLE 2—*Descriptive statistics and univariate F ratios.*

Variables	Male		Female		F Ratio
	Mean	S.D.	Mean	S.D.	
Younger Group*					
N	57 (46)		47 (21)		
Age	22.82 (24.48)	4.27 (4.43)	23.51 (23.38)	4.18 (5.78)	
A-P thickness (mm)	6.64 (7.64)	0.78 (0.92)	6.19 (6.63)	1.00 (0.63)	6.56 [P = 0.0119]
S-I height (mm)	14.06 (16.75)	1.25 (1.50)	11.69 (13.95)	1.49 (1.24)	77.42 [P = 0.0000]
Older Group†					
N	164 (64)		78 (61)		
Age	50.77 (46.27)	13.49 (14.14)	51.50 (47.75)	14.60 (17.48)	
A-P thickness (mm)	7.64 (8.74)	1.14 (1.09)	6.78 (7.07)	1.06 (1.03)	41.27 [P = 0.0000]
S-I height (mm)	15.12 (18.20)	1.61 (1.80)	13.07 (14.99)	1.38 (1.58)	92.78 [P = 0.0000]
Total Group‡					
N	221 (94)		125 (72)		
Age	43.56 (39.93)	17.02 (16.11)	40.97 (43.43)	19.15 (19.11)	
A-P thickness (mm)	7.42 (8.24)	1.06 (1.17)	6.56 (6.91)	1.07 (1.03)	43.10 [P = 0.0000]
S-I height (mm)	14.84 (17.95)	1.59 (1.85)	12.55 (14.78)	1.57 (1.55)	166.7 [P = 0.0000]

*t-test for age: Pooled variance estimate $t = -0.82$; $P=0.413$
†t-test for age: Pooled variance estimate $t = -0.36$; $P=0.719$
‡t-test for age: Pooled variance estimate $t = 1.30$; $P = 0.195$.
Işcan's results are in parenthesis for comparison.

discriminating between the sexes in the older and combined groups. For the younger group, A-P thickness was not an important variable in separating the sexes.

The results of the canonical discriminant functions analysis are shown in Table 4. The raw coefficient was used in the mathematical formula to calculate a discriminant score which classified a rib as male if the score was positive and as female if the score was negative. The relative contribution of each variable (standardized coefficients) to the functions show that the S-I height contributed at least 84% to the discriminant function. The structure coefficient, which considers inter-variable correlation, also showed a dominant role for the S-I height in determining sex.

The percentages of cases correctly classified by the discriminant functions derived in this study for the various age groups appear in Table 5. The average accuracy ranges from 74% in the older group to 80% in the younger group. Females were more accurately classified in the older group while males were more accurately classified in the younger and combined groups. These differences, however, are small and not significant. The misclassification rates range from an average 26% in the older group (z = 4.78, $p < 0.001$) through 22% in the combined group (z = 5.88, $p < 0.001$) to 20% in the younger group (z = 7.68, $p < 0.001$). The discriminant function formula developed for each age group was tested on the other two age groups to determine whether the sexes can be separated with the same degree of accuracy as that of the original age group formula. The results of this test are shown in Table 6. The young age group formula classified most of the older females as males (53.8%) while the converse was true for the older group formula which classified most young males as females (56.15%). The total group formula gave better sex predictions than the original group formula in the young females and older males.

TABLE 3—*Summary of stepwise discriminant function analyses.*

Variable Entered	Wilk's Lambda	F Ratio	Degrees of Freedom	Sig.
Younger Group				
1. S-I height	0.5685	77.42	1102	.0000
2. A-P thickness				
Older Group				
1. S-I height	0.7212	92.78	1240	.0000
2. A-P thickness	0.7091	50.0185	2239	.0000
Total Group				
1. S-I height	0.6736	166.7030	1344	.0000
2. A-P thickness	0.6700	84.4547	2343	.0000

Sig. = Significance.

TABLE 4—*Canonical discriminant function coefficients.*

Functions and Variables	Standardized Coefficients	Unstandardized Coefficients	Structure Coefficients	Group Centroids*
Younger Group				
1 S-I height	1.0000	0.731 5185 (A)	1.000 00	+0.783 47
A-P thickness	–	–	0.213 42	−0.950 17
Constant		−9.502707 (C)		
Older Group				
2 S-I height	0.8809	0.571 680 7 (A)	0.97062	+0.439 94
A-P thickness	0.2568	0.230 019 6 (B)	0.56446	−0.925 00
Constant		−9.958 770 (C)		
Total Group				
3 S-I height	0.9383	0.592 201 7 (A)	0.992 00	+0.526 24
A-P thickness	0.1372	0.122 497 0 (B)	0.504 39	−0.930 38
Constant		−9.168 604 (C)		
Mathematical Formula: [(A) × S-I height + (B) × A-P thickness]+ (C)				

*Positive centroid for males, negative for females.
Sectioning point = 0.0.

TABLE 5—*Percentage of correct classification by the discriminant functions.*

Functions and Variables	Total N	Male		Female		Average %	Misclassification Rate %
		%	N*	%	N*		
Younger Group							
1 S-I height	104	80.7	46/57	78.7	37/47	79.81	20†
Older Group							
2 S-I height	242	73.8	121/164	74.4	58/78	74.00	26‡
A-P thickness							
Total Group							
3 S-I height	346	78.3	173/221	77.6	97/125	78.04	22§
A-P thickness							

*Represents the number of cases correctly classified in a given sex sample.
†Critical ratio, z = 4.78; $p < 0.001$.
‡Critical ratio, z = 5.88; $p < 0.001$.
§ Critical ratio, z = 7.68; $p < 0.001$.

The characteristics of the "test sample" and the results obtained after application of the formulas derived from the functions are shown in Table 7. The average correct classification rates ranged from 74 to 90% giving error rates of 26 to 10%. The formulas gave better predictions of the female gender in all groups. Statistical comparison of the misclassification rates obtained in the "test sample" and in the study sample did not yield any statistical difference between the two samples.

Discussion

A number of bones have been studied in attempts to establish methods of sex determination based on examination of bones. The pelvis and skull have been the most reliable giving accuracies of determination of 95 and 90% for adult material (7). Other bones result in varying degrees of reliability. İşcan and Miller-Shaivitz (8) in a study of the femur in White and Black Americans found that femoral head diameter and distal breadth provided an accuracy of 90 and 89% respectively in discriminant functions analysis. When the two measurements were combined into a single function the accuracy rose to 94%. The same authors (9) developed various discriminant function formulas for determination of sex from the tibia and found that for a single measurement proximal epiphyseal breadth was the most discriminating parameter with 87% accuracy followed by the distal epiphyseal breadth with an accuracy of 85%. Combining the two measurements the accuracy was a high as 90%. Kimura (10) using discriminant functions analysis on the transverse width of the sacral base and the transverse width of the wing (the lateral margin of the base to the most lateral margin of the wing) in Japanese and American Whites and Blacks obtained accuracies of 75, 80, and 83% respectively. In a study on the head of femur of Nigerians from Calabar, Singh et al. were able to obtain up to 45% correct prediction of sex in males and 27.5% in females. They used the largest vertical and transverse diameters of the female femoral head as identification points for males (diameters greater than the identification points) and the smallest diameters of the male femoral head as identification points for identifying females (diameters less than the identification points). However, using demarking points (mean ± 3 S.D to determine largest and smallest diameters) they were able to assign sex with 100% accuracy in up to 14% in males and 12% in females (11).

There have been very few studies on the determination of sex from the rib. Most of these studies were based on radiological examination of the entire anterior thorax focusing on the pattern of calcification of the costal cartilages (1–4). In the process of developing standards for age determination from the rib, İşcan et al. observed that age-related changes were sexually dimorphic (12–14) and this led to the development of separate standards for males and females. These observations led to the only osteometric study of sexual dimorphism in the rib using discriminant functions analysis (5). In this study İşcan showed that accuracy of sex determination from the right 4th sternal rib ranged from 80% for young males less than 30 years to as high as 89% for males 30 years and above with accuracy for females of both age groups in between the two values. The percentage of cases classified correctly is often taken as an index of the effectiveness of the discriminant function. The present study has shown correct classification rate as high as 80% which compares favorably with the rates of the long bones and the sacrum and also with İşcan's results. However, when evaluating the percentage of cases correctly classified it is important to compare the observed misclassification rate to what would have been expected if the classification was due to chance alone (6). In this study there was a statistically significant difference between the misclassification rates obtained in the various groups and that due to chance. It is concluded, therefore, that the discriminant functions obtained in this study are effective in discriminating between the sexes.

TABLE 6—*Cross validation of sex determination formulas.*

Test Group and Function	Male %	Male N	Female %	Female N	Total N
Younger Group					
1. Function 2*	43.85	25/57	95.74	45/47	104
2. Function 3*	59.65	34/57	89.36	42/47	104
Older Group					
1. Function 1*	93.90	154/164	46.15	36/78	242
2. Function 3*	83.54	137/164	70.51	55/78	242
Total Group					
1. Function 1	90.50	200/221	58.40	73/125	346
2. Function 2	66.06	146/221	82.40	103/125	346

* Functions derived in this study.

TABLE 7—*Test of efficiency of discriminant functions.*

Test Group and Function	Total N	Male %	Male N*	Female %	Female N*	Average %	Error Rate %
Younger Group							
Function 1	35	78.95	15/19	93.75	15/16	85.71	14.29[a]
Average Age (years)			22.16		21.56	21.50	
STD			3.28		4.83	4.67	
Older Group							
Function 2	39	84.21	16/19	95.00	19/20	89.74	10.25[b]
Average Age (years)			44.37		46.30	45.36	
STD			10.80		12.32	11.65	
Total Group							
Function 3	74	60.53	23/38	88.89	32/36	74.32	25.68[c]
Average Age (years)			33.26		35.31	34.26	
STD			13.68		15.68	14.72	

*Represents the number of cases correctly classified by formulas.
Comparison of misclassification rates: a. $z_c = 0.895$; $P = 0.368$.
b. $z_c = 2.292$; $P = 0.022$.
c. $z_c = -0.604$; $P = 0.522$.

İşcan (5,14) has discussed the possible factors involved in the age and sex differences in morphology of the rib. Differences in hormonal production between the sexes can account for unequal rates of change in the rib. Biomechanical differences may also be involved. Males generally have larger chest expansion and associated vital capacity than females and İşcan, quoting King (15) and Semine and Damon (16), suggested that a difference in respiratory chest expansion could cause a proportionally larger increase in bone size in males (5). Human variability, occupation, general health and the effects of disease are all factors that are expected to influence rib size and thickness. A comparison of the means of the various measurements show that rib sizes were much larger for both sexes in İşcan's study population (5) than the population we studied. The differences may be racial as American Whites are generally of larger build than Black West Africans. It would be interesting to compare our population to American Blacks with whom racial differences would not be expected to play a great role. On the other hand since environmental factors such as nutrition play a role in general body build the better nourished American population would be expected to have larger rib sizes.

Using the discriminant functions formulas of İşcan (5) on our study population the vast majority of males were classified as females. This agrees with Krogman and İşcan's (7) general rule that standards should be used with reference to the group from which they were drawn and that standards are not ordinarily interchangeable.

The results of this study agree with İşcan's (5) finding that where the age is estimated (or known) the accuracy of sex determination is reliable. Although the current study used the 4th sternal rib, intercostal variation is not expected to create significant differences with other ribs as shown by Loth et al. (17). It may therefore be concluded that the discriminant function formulas obtained in the present study can be applied equally to the 3rd and 5th ribs without any significant loss of accuracy.

Any model usually fits the sample from which it is derived better than it will fit another sample from the same population. The main problem, as discussed by İşcan (5) is whether the results obtained in our study can provide equally successful results if applied to a different sample from the same population. To investigate the reliability of the discriminant functions obtained in this study, the functions were applied to a different set of ribs from 74 Ghanaians. It is expected that the observed misclassification rates in the "test sample" would better reflect the functions' effectiveness (6). Statistical analysis of the misclassification rates obtained from the study and those obtained from the use of the formulas showed that the differences were due to chance or variation in sample selection and not to a real difference between the study and test populations. It can thus be concluded that the functions are effective and reliable.

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