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Sex Determination from the Ribs of Contemporary Turks

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ABSTRACT: There have been several in-depth studies showing that the sternal extremity of the fourth rib can be used in estimating age as well as in determining sex, as illustrated in North American whites and blacks. Yet biological differences between populations may preclude the cross-application of standards. To test this hypothesis and develop a sex determination standard for the Turkish population, a sample of the sternal ends of the fourth rib was collected from 294 individuals autopsied in Istanbul, Turkey. Dimensions from the superior edge to the inferior one (SI) and the anterior edge to its posterior edge (AP) were measured with a caliper. The sample was divided into three age groups, "young," "old," and "total." Using discriminant function analysis, three formulae were developed, one for each group. The results indicated that SI height is the most dimorphic dimension and that both dimensions together can give an accuracy of 86% to 90%. To reach such an accuracy, the age of the unknown should be estimated, at least whether it is phase 4 or above or below, using the age standards for ribs developed by İşcan and associates. When cross-validation tests are carried out, incorrect formulae reduce accuracy by as much as 20%. Furthermore, it was observed that North American based white sex determination formulae assign many Turkish males into a female category. In conclusion, it is important to note that population and age specificity are essential in determining sex from the rib. Yet its accuracy is as good as, if not better than, many bones of the postcranial skeleton.

KEYWORDS: forensic science, sex determination, ribs, discriminant function, osteometry, Turks

With an increasing success in determining sex from a complete skeleton, anthropologists have turned their attention to obtain more information from fragmentary as well as smaller bones (1). With this in mind, many seemingly less sexually dimorphic fragmentary and small bones have been analyzed to determine sex. These bones include the clavicle (2), sternum (3,4), radius (5,6), metacarpals and phalanges (7–10), metatarsals (11), vertebrae (12), and pelvis (13–18).

Nearly 15 years ago, İşcan and associates (19–22) introduced the rib phase method to estimate age from the sternal ends of ribs. It was then noted that the aging process was different between sexes as well as between North American blacks and whites. During the process of developing rib phase standards it was realized that knowledge of the sex of the unknown remains was essential to make a more accurate estimation of age (19–25).

Based on the assumption that populations differ from each other due to environmental and genetic factors, the aging process and sexual dimorphism must be assessed separately. This is especially true for those populations which are geographically distant from the population used to set the standard. The Turkish population is suitable for such an analysis because of its distance from North American whites. Turkish researchers (25–27) initiated a project similar to that of İşcan and associates' (19–21), where age related changes at the costochondral end of the fourth ribs collected at autopsy were studied. Their research agreed with İşcan et al. (19–21) that ribs provide an accurate estimation of age in the adult. The present study is an attempt to develop a discriminant function technique to determine sex from the sternal rib extremity of the fourth rib, using a demographically known sample from Turkey.

Materials and Methods

The sternal end of the right fourth rib was collected at autopsy from recent forensic pathology cases of known sex and age. The original sample (*n* 4 294) consisted of 150 males and 144 females. The specimens were left in a glass container filled with water for about three months. Bones were later boiled gently for about 30 minutes to remove the remaining soft tissue. Following the technique presented by İşcan (23), two measurements were taken at the costochondral junction of the rib: maximum superior-inferior height (SI) and maximum anterior-posterior breadth (AP). All dimensions were taken with a coordinate caliper calibrated to the nearest 0.1 mm. SI height was the maximum distance between the most superior and inferior points at the end of the bone and AP breadth the maximum dimension between the most anterior and posterior points.

Various subroutines including stepwise discriminant function of mainframe SPSSx were used for the statistical analysis (28). To control the effect of age on sexual dimorphism, separate functions were developed for specimens in three age groups, that is, "young" (phases 1–4, mean ages 17–29), "old" (phases 4–7, mean ages 30–63) and "total" (phases 1–7, mean ages 17 to 63). Ribs in phase 0 (N 4 10 males; N 4 2 females) were excluded from the statistical analysis because they had not reached skeletal maturity. Specimens in phase 4 were considered transitional and were included in the analysis of both young and old groups in order to minimize errors of assignment. Specimens in phase 8 representing individuals over a mean age of 77 (N 4 6 males; N 4 2 females) were excluded from the analysis because bone quality was highly deteriorated especially in males and measurements were less reliable.

Discriminant function formulae were cross-validated with each other to determine if age based formulae can be used interchangeably. The formula developed for young group was tested with data

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TABLE 1—*Means, standard deviations, and univariate F ratios.*

	Male		Female		
Variables*	Mean	S.D.	Mean	S.D.	F Ratio
Young group (Phases 1–4)					
N	63		89		
Age	24.32	4.87	22.34	5.15	5.17†*
SI height	16.28	1.58	13.76	1.34	113.00**
AP breadth	7.49	.94	6.31	.72	77.32**
Old group (Phases 4–7)					
N	91		81		
Age	42.55	10.84	40.48	13.46	1.24‡
SI height	17.38	1.73	14.07	1.44	183.80**
AP breadth	7.97	1.04	6.51	.81	103.00**
Total group (Phases 1–7)					
N	135		139		
Age	35.78	13.34	31.57	14.83	6.11§*
SI height	16.87	1.77	13.87	1.36	248.90**
AP breadth	7.77	1.02	6.36	.74	173.00**

*All dimensions except age are in millimeters.
†df (degrees of freedom) 1, 150.
‡df 1, 170.
§df 1, 272.
*significant at $p < 0.05$, and ** significant at $p < 0.0001$ levels.

TABLE 3—*Canonical discriminant function coefficients.*

Functions and Variables	Standardized Coefficients	Unstandardized Coefficients*	Structure Coefficients	Centroids and Sectioning Points
Young group				
SI height	0.72	0.5003966	0.72	1.11882†
AP breadth	0.44	0.5433948	0.44	1 0.79197†
		1 11.1049600		0.163425‡
Old group				
SI height	0.77	0.4828588	0.89	1.10097
AP breadth	0.48	0.5080096	0.48	1 1.23690
		1 11.3386000		1 0.067965
Total group				
SI height	0.72	0.4561907	0.88	1.10432
AP breadth	0.51	0.5713021	0.73	1 1.07254
		1 11.0298300		0.015890

*These coefficients are used to calculate discriminant scores.
†Positive centroids defines male and negative females.
‡Discriminant scores less than the sectioning point would classify as female.

from old group and formula developed for the old group was tested with the data from the young group. Finally, the sample was also cross-tested using the discriminant function formulae developed for North American whites (23) to assess if the metric standards developed for this population can be applied to the Turkish sample.

Results

Table 1 shows the descriptive statistics and statistical significance between sexes (univariate F ratio) for all three groups. Males were larger in all dimensions with a significance level less than $p < 0.0001$, and slightly older than females in each group. Table 2 illustrates the results of the stepwise discriminant function analysis. Both dimensions took part in all functions to separate the sexes. Coefficients associated with the discriminant function analysis appear in Table 3. The unstandardized coefficient is similar to B weight in a multiple regression analysis and is applied to the raw unstandardized predictor variables. The constants must be added to the sum of the appropriate cross products of weights to calculate a discriminant score. For example, to calculate the discriminant function score for an individual in the younger age group (phases 1–4) the formula to use is [SI (mm) 2 0.5003966] ` [AP (mm) 2 0.5433948] 1 11.10496. This coefficient is based on the assumption that groups form a continuum from one sex to the other with a sectioning point at the mean of two centroids. If the discriminant score is less than the sectioning point a rib is classified as female, and otherwise male. The standardized coefficient indicates the relative contribution of each dimension to a function and assumes no intercorrelation between variables (Table 3). Also like "b weights" in a multiple regression analysis, this coefficient is applied to predictor variables to discriminate one sex from the other. In all functions, SI height contributed 72% or more to the discriminant function. One must however interpret this cautiously because of intercorrelation between the predictor variables. The structure coefficient shows the pooled within group correlations between the predictor variables and the discriminant function. This coefficient controls the possibility of intercorrelation. This analysis indicates that SI height was more discriminating than AP breadth. The average classification accuracy given in Table 4 varied from 86% in the young group to 90% in the old group. In all groups females were more accurately predicted than males.

The results of the cross-validation tests, that is, whether the formula for the young group can accurately determine the sex of an individual in the old group or the formula for the old group can accurately determine the sex of an individual in the young group, are shown in Table 5. As predicted the old group formula presented in Table 3 misclassified most of the young males as

TABLE 2—*Stepwise discriminant function analysis for young, old, and total sample.*

Variable/Step Entered	Wilks' Lambda	Equivalent F Ratio	Degrees of Freedom
Younger group			
1 SI height	0.570	113.0	1, 150
2 AP breadth	0.527	66.9	2, 149
Old group			
1 SI height	0.480	183.8	1, 170
2 AP breadth	0.421	116.4	2, 169
Total group			
1 SI height	0.522	248.9	1, 272
2 AP breadth	0.455	161.7	2, 271

TABLE 4—*The percentage of correct prediction of three age based functions.*

Functions and Variables	Total N	Male %	Male N	Female %	Female N	Average %
Young group 1 SI height AP breadth	152	81.0	51/63	88.8	79/89	85.5
Old group 2 SI height AP breadth	172	87.5	79/91	92.6	75/81	89.5
Total group 3 SI height AP breadth	274	84.4	114/135	91.4	127/139	88.0

TABLE 5—*Cross-validation of sex determination formulae.**

Test groups and Functions	Total N	Male %	Male N	Female %	Female N	X^2†
Application of formula for the Old group						
Young group	152	61.9	39/63	96.6	86/89	63.2
Application of formula for the Younger group						
Old group	172	91.2	83/91	77.8	63/81	84.1

*See Table 3 for the formulae and Table 4 for comparison.
†Both with df 1, and significant at $p < 0.0001$.

females. The opposite was true when the young group formula was applied to old individuals. Table 6 shows the results of a cross-application of the present data to North American white formulae. It is clear that American formulae sexed almost all Turkish females correctly, yet nearly half of the males were misclassified as females.

Discussion

İşcan and associates introduced the rib phase techniques nearly 15 years ago (19–22), where they discovered morphological differences in aging pattern between males and females at the sternal extremity of the rib. İşcan's work (23) indicated that sexual differences in the adult rib can be assessed with great reliability using discriminant function statistics.

It has been demonstrated that ribs show sexual dimorphism not only in the Turkish sample but also in North American whites and blacks, as well as in others (23,24,29,30). In comparison, the present work provided equally good results (86%–90% accuracy) if not better than those based on contemporary North American whites (86%–88%) (23), an early 20th century North American Terry skeletal collection blacks (80%–89%) (24), and a historical sample from the Spitalfields of England of mid-18th to mid-19th century (79%) (29). It should also be noted that these accuracies are on a par with those obtained from other bones like the femur (80%–95%) (31–32) and tibia (80%–87%) (33–34).

This study as well as others show that the sternal extremity of rib size becomes larger with age (Table 1) (23,24). In order to take this factor into account in determining sex and reducing the error of age estimation, the sample was analyzed in three age groups,

TABLE 6—*Percentage of correct prediction of sex from the Turkish sample using the coefficients (formulae) based on the North American White sample.**

Test group and Functions	Total N	Male %	Male N	Female %	Female N
Young group	152 (67)	58.7 (80.4)	37/63 (37/46)	96.6 (85.7)	86/89 (18/21)
Old group	172 (126)	63.7 (87.7)	58/91 (57/65)	98.8 (88.5)	80/81 (52/61)
Total group	274 (167)	54.1 (81.1)	73/135 (79/95)	98.6 (86.1)	137/139 (62/72)

*The following discriminant function formulae were used in this cross-testing (23): Young group F 4 0.6020059*AP ` 0.5233218*SI-12.66007 Old Group F 4 0.3689679*AP ` 0.4640968*SI-10.75248 Total group F 4 0.1825911*AP ` 0.5101099*SI-9.856245. Values in parenthesis are the number of cases and percentages obtained from the North American White sample.

young and old, as well as the total group. The exclusion of specimens in phase 0 and 8 should be relatively simple because of their unique morphological characteristics. To obtain a more accurate determination of sex, one must know at least whether the age of the individual being assessed is above or below rib phase 4. Cross-validation of sex determination, that is, the applicability of one age group's formula to the other, was performed (Table 5). It was found that if an approximate age (below or above phase 4) is not known, error in determination can be as much as 20% (compare Table 4 with Table 5). Males of the young group are determined as females using the old group function. The opposite is true when the young group function is applied. Therefore, to avoid misapplication of the age specific formulae, the authors recommend using the formula for the total group because the outcome is not significantly different (88%) from those obtained by the age related functions (Table 4).

It is clear that the rib size is not only age specific but also population specific at least in the case of North American whites and Turks. Any formula developed for one population must be carefully assessed before applying it to another. This important consideration must be taken seriously especially when sex determination is based on a single bone like the rib. Furthermore the present research underscores the importance of developing paleodemographic and forensic standards for populations distant from those with known standards. The term "distant" implies genetic and environmental differences between the Turkish and the comparative populations. Discriminant function standards developed for North American whites misclassify Turkish males as females because of the differences in body size between them. The accuracy was nearly 25% less for males when North American formulae were used (Table 6).

The posterior probability which measures which of the sexes a specimen really belongs to is best assessed by the absolute value of the discriminant score and how far it is from the sectioning point. Conversely, as the score approaches the sectioning point, the probability of misclassification increases.

As in many osteological studies there are some concerns. It should be noted that in all these studies the fourth rib is used for this assessment. One must also consider whether other ribs can be equally used for this purpose. In a recent study (35), an analysis of intercostal age variation at the sternal end of rib indicated that differences among 3rd, 4th, and 5th ribs were within one phase for 98% of the sample, thus making rib sequence identification as a less serious handicap. In ongoing research (30) a complete osteological analysis of variation in ribs 2–7 of the rib cage was carried out and preliminary results indicated that SI and AP dimensions of ribs 3 through 7 are not statistically significant from the adjacent one. Therefore, the present findings using the fourth rib may be applicable with caution to the adjacent ribs. Although it is ideal that the technique should be applied to the fourth rib only, it is not always easy to determine which rib is the fourth one. There are however attempts to determine anatomic sequence of ribs (24).

Another concern is the preservation of the sternal end of the rib. As many osteologists know, soil condition is critical in this matter, and the less acidic the soil, the better the preservation. This problem is also seen in many cancellous bones like the pubic symphysis and the auricular surfaces of the pelvis. To reduce any potential damage, one must be careful when ribs are collected from the ground or a burial site. Ideally, in a forensic setting, a qualified anthropologist should be consulted before excavating this seemingly fragile bone.

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