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Sex Determination Using the Scapula in Medieval Skeletons from East Anatolia

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A B S T R A C T

Sex determination from skeletal human remains by discriminant function analysis is one of the methods utilized in the forensic and osteoarcheological sciences. The purpose of the present study is to establish metric standards for sex determination for medieval Anatolian populations using scapular measurements. The database for this research consisted of 93 adult skeletal remains (47 males and 46 females) from the Dilkaya medieval collection. Four measurements were taken: maximum scapular height, maximum scapular breadth, glenoid cavity height, glenoid cavity breadth, and subjected to discriminant function analysis. All measurements demonstrated some degree of sexual dimorphism, with the highest accuracy of sex determination (94.8%) obtained using maximum scapular breadth. Overall accuracies of the functions ranged from 82.9% to 95.0%, with a higher accuracy rate obtained for female skeletons than for males. Population specific discriminant formulas were developed using combinations of measurements, which can be used in ancient Anatolian populations.

***Key words**: scapula, sex determination, medieval, Anatolia*

Introduction

Identification of ancestry is important in both forensic contexts and bioarchaeological research on skeletal remains from archaeological sites. In all human populations, adult male and female skeletons reflect different shape and size characteristics. Therefore, sex determination can be based upon measurements of dimorphic dimensions and observations of morphological traits[1]. Accurate sex determination from skeletal remains is the first step toward making individual identification, and is crucial for further analysis of unidentified human remains because age at death and stature estimation are markedly different for males and females.

It is widely agreed that the skull and pelvis are the most useful skeletal regions for sex determination[1,2]. Although the pelvis and the skull provide the most numerous and accurate morphological indicators of sex, many other aspects of the human skeleton are sexually dimorphic to one degree or another[1–3]. In the case that the skull and pelvis are fragmentary or absent, sex must be determined using other skeletal elements. Krogman and Iscan[3] ranked skeletal regions in order of their accuracy for determining sex: the pelvis 95%, the skull 92%, the mandible 90% and long bones (humerus and femur) 80%.

A range of skeletal elements have been studied to determine their usefulness in determining sex, including the humerus[4–7], the ulna[5–8], the radius[5–7], the femur[5–7,9–21], the tibia[5–8,22–24], the patella[25,26], the clavicle[27], the ribs[28,29], the talus[30,31], the calcaneus[32–35], the metatarsals[36] and the scapula[37–43].

Because patterns of sexual dimorphism vary among populations, identification standards cannot be applied across populations, which call for the establishment of group-specific standards[1]. These standards must also take into account temporal changes that can occur within a single population[11].

The determination of sex using discriminant function analysis on human scapulae is crucial in disasters and forensic cases, and other circumstances in which other portions typically used to determine sex are either not presented or not adequately preserved.

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The purposes of the present study were to develop formulae for sex determination from scapular measurements taken on a medieval Anatolian population using discriminant function analysis.

Material and Methods

This study utilized 93 adult skeletons (47 males and 46 females) with intact and well-preserved scapulae. These represent the best-preserved skeletons of a larger pool of 156 adult skeletons excavated from Dilkaya Archaeological site, Van City in East Anatolia, which date from the 10^{th} –11^{th} century AD. Most of the skeletons had been recovered from burials in sand and are currently housed in Laboratory of Paleoanthropology, Ankara University. Only adult skeletons with closed epiphysis were included in the analysis. In order to develop metric standards for sex determination, the sex of the individuals from collection must be first determined independently. The sex of the individuals in the Dilkaya collection was assed using the conventional pelvic and skull morphological criteria[1,44].

Four measurements of the left scapula were taken utilizing a sliding caliper and were defined as follows[45,46];

Maximum scapular height (MSH): Maximum distance between the highest point of the superior angle and the lowest point of the inferior angle.

Maximum scapular breadth (MSB): Maximum distance between the point on the longitudinal axis of the glenoid cavity and the point on the prolongation of the inferior boundary of the dorsal margin of the spine.

Glenoid cavity height (GCH): Maximum distance from the inferior point of the glenoid margin to the most prominent point of the supraglenoid tubercle.

Glenoid cavity breadth (GCB): Maximum breadth of the articular margin, perpendicular to the glenoid cavity height.

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 10.0. Descriptive statistics were calculated, and a student t-test for equal variances was applied to assess the difference between the means of the male versus female groups and Bonferroni correction was used. Univariate analysis of variance was used to measure the variation within and between the groups. A stepwise discriminant function procedure was applied to all dimensions, using the Wilks' lambda minimization procedure, to determine which variable provided the best discrimination between the sexes. The Wilks' lambda performs in the multivariate setting, with a combination of dependent variables, the same role as the F-test performs in one-way analysis of variance. Lambda ranges between 0 and 1, with values close to 0 indicating the group means are different and values close to 1 indicating the group means are similar. Discriminant function analysis was applied in order to classify individuals as male or female. The procedure generates a discriminant function based on linear combinations of the predictor variables that provide the best discrimination between the groups[47]. Discriminant coefficients are the regression-like b coefficients in the discriminant function, in the form $y = b_1x_1 + b_2x_2 + ... + b_nx_n + c$, where y is the variable formed by the discriminant function, the b's are discriminant coefficients, the x's are discriminating variables, and c is a constant[48].

Results

The results of descriptive statistical analysis and t-test with Bonferroni correction are given in Table 1 showing the mean, standard deviation (SD) and t values for both sexes. The result of the t-test between males and females reveals that all measurements were statistically significant ($p<0.005$, $p<0.001$).

Results of stepwise discriminant function analysis for the variables can be seen in Table 2. The Wilks' lambda shows the percentage contribution of each variable. Lambda values emphasize different group means with values close to 0 and similar group means with the values close to 1. Therefore, glenoid cavity height was the first variable to be selected by the stepwise discriminant function analysis, followed sequentially by glenoid cavity breadth, maximum scapular breadth and maximum scapular height.

In Table 3 results of the discriminant analysis for each function, the unstandardized coefficient, the sectioning point, the demarking point and the expected accuracy of sex determination are given. Overall accuracies of the functions when applied to the Dilkaya population ranged from 82.9 to 95.0%, with a greater accuracy for the female than for the male group. The sectioning point for the assignment of sex was designated as the midpoint

TABLE 1
DESCRIPTIVE STATISTICAL ANALYSIS AND t-TEST RESULTS (AFTER BONFERRONI CORRECTION)

Variables (mm)	Males			Females			t value
	N	X	SD	N	X	SD	
Maximum scapular height	20	151.70	12.17	21	137.12	7.10	4.66*
Maximum scapular breadth	29	110.62	5.82	29	95.74	4.48	10.91**
Glenoid cavity height	45	38.71	2.71	45	33.79	3.08	8.04**
Glenoid cavity breadth	47	27.33	2.40	45	22.72	1.90	10.24**

*p<0.005, **p<0.001

TABLE 2
STEPWISE DISCRIMINANT FUNCTION ANALYSIS

Variables	Wilks' lambda	Equivalent F-ratio	Degrees of freedom	Significance
Glenoid cavity height	0.265	105.138	1.38	0.000
Glenoid cavity breadth	0.325	78.993	1.38	0.000
Maximum scapular breadth	0.362	66.943	1.38	0.000
Maximum scapular height	0.652	20.302	1.38	0.000

TABLE 3
UNIVARIATE AND MULTIVARIATE DISCRIMINANT FUNCTION ANALYSIS

	Discriminant function number						
Variables	1	2	3	4	5	6	7
Maximum scapular height	0.101				0.033		0.024
Maximum scapular breadth		0.193			0.168		0.043
Glenoid cavity height			0.345			0.143	0.316
Glenoid cavity breadth				0.464		0.367	0.145
Constant	–14.570	–19.863	–12.501	–11.637	–21.895	–14.340	–22.838
Sectioning point	0.0175	0	0	–0.0230	0.0340	0	0
Demarking point	Females <144.23< Males	Females <103.18< Males	Females <36.25< Males	Females <25.08< Males			
Percent accuracy (%)	82.9	94.8	90.0	88.0	90.2	88.9	95.0

between mean group centroids of the male and female. For each discriminant function, a discriminant score greater than the sectioning point indicates a male individual. The demarking point was indicated as the midpoint between male and female arithmetical averages. For each discriminant function, a discriminant score greater than the demarking point indicates a male individual. The combination of measurements that demonstrate the greatest sexual differentiation does not always provide the best multivariate functions. In our results, the combination of four variables derived from the direct discriminant functions generated the function with the highest accuracy. Discriminant function number 7, with the combination of all measurements, proved the most accurate, with a rating of 95.0%, shown in Table 3. Function number 1**,** obtained by using the maximum scapular height, shows the lowest percentage of correct sex determination**,** with a rating of 82.9%. The three functions numbered 2–4, show a moderate percentage of correct classification; 94.8% with the maximum scapular breadth, 90.0% with the glenoid cavity height and 88.6% with the glenoid cavity breadth. The functions derived from associating different parameters can be grouped correctly as follows; 90.2% with the combination of maximum scapular height and maximum scapular breadth, 88.9% with the combination of glenoid cavity height and glenoid cavity breadth.

The evaluated formulae can be usefully applied by calculating the discriminant score from the function. To do so, each dimension should be multiplied by its coefficient and added together along with the constant (e.g. discriminant function number 7).

$$y = (MSH \times 0.024) + (MSB \times 0.043) + (GCH \times 0.316) + (GCB \times 0.145) + (-22.838)$$

where y= discriminant function score, MSH: maximum scapular height, MSB: maximum scapular breadth, GCH: glenoid cavity height, GCB: glenoid cavity breadth, constant: –22.838.

MSH, MSB, GCH and GCB are the corresponding measured values of these parameters. This equation gives the value of *y*, which is compared with the value of the sectioning point (0). Because the mean values of these parameters are greater in males than in females, *y* greater than the sectioning point will indicate a male scapula (Table 3).

Discussion

The population specificity of the discriminant function method of sex determination using the scapula has been put forward by many authors[37–43]. Cross-validation tests have confirmed that formulae developed for one population are less discriminating when applied to another population[4,15]. It has been observed that sexual dimorphism varies according to region of the skeleton measured and its use[4]. In 1894, Dwight demonstrated that maximum scapular length and glenoid cavity were useful indicators of sex[2]. Stepwise discriminant function analysis calculates the optimal calculation of variables and weights them to reflect their contribution to sex determination[4]. The results of the present study indicate that glenoid cavity height was the first (the most powerful) variable to be selected by the stepwise discriminant function analysis.

In Italian (Apulian) skeletal remains, the most effective single dimension as determined by discriminant analyses was the maximum scapular breadth, with an accuracy of 91.25%[40]. In the present study, the accuracy of this measure was even higher, with a rate of 94.8%.

In previous studies of the scapula using different populations, discriminant functions incorporating several variables have demonstrated greater accuracy than those using a single variable only. This was also the case with the Dilkaya population, as the multivariate discriminant analysis accuracy (95.0%) is greater than the single score (94.8%). The function derived with the association of maximum scapular height, maximum scapular breadth, glenoid cavity height and glenoid cavity breadth measurements was the best discriminator. However, the fragile nature of the scapula in general must be taken into consideration carefully and when dealing with fragmented materials, it could be of help not to be reliant on complete elements with all measurements observable. The difference between the multivariate and direct discriminant analysis accuracy is a mere 0.2%, it can be suggested that a single score of MSB assessment is almost equal in accuracy for sex determination, a fact that may be of great importance, given that the scapula is an easily fragmented element. In addition, it is worth to mention that both maximum scapular height and breadth measurements showed lower reliable discriminant values than glenoid cavity measurements.

It is reported that in a Japanese population the scapula yielded on average a accuracy of between 94.1% – 96.8% using the combined five scapular measurements of scapular height, maximum scapular breadth, projective length of spine, glenoid cavity height and glenoid cavity breadth[38]. For the Italian (Apulian) historical population Di Wella et al.[40] reported that using only three measurements (maximum distance acromion-coracoid, maximum length of coracoid and length of glenoid cavity) provided a 95% correct sex determination. A prehistoric New Zealand Polynesian population, scapula dimensions examined by Murphy could be divided by sex with an accuracy of 86.5% and 93.6% for left and right bones, respectively, using the combination of maximum height and maximum breadth of the glenoid cavity[41–42]. Finally, Frutos[43] studied measurements of clavicle and scapula for the metric determination of sex from Guatemalan rural indigenous sample of forensic origin. Multivariate discriminant analysis using two measurements (height and breadth of the glenoid fossa) demonstrated accuracy ranging from 85.6 to 94.8%.

In conclusion, in forensic anthropological cases in which the skull and pelvic bones are fragmentary or missing, sex can be assessed with a high degree of accuracy using other regions of the skeleton. The present study has confirmed that the accuracy of sex determination using scapular measurements of the medieval East Anatolian population can be improved by deriving a discriminant function, which utilizes a combination of the four respective dimensions. Our findings showed that both maximum scapular breadth alone and the combination of all measurements used in the study are good discriminators. The high percentage of accuracy for scapular measurements achieved in our discriminant analysis is comparable to the findings of other researchers[38,40–43] who noted the utility of scapular measurements in this context. This study has affirmed that scapular measurements can be used with a high degree of accuracy to determine sex in ancient Anatolian populations.

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REFERENCES

1. BUIKSTRA, J. E., D. H. UBELAKER, Arkansas Archeological Survey. (Fayetteville, Arkansas, 1994). — 2. WIENKER, C. W., Sex determination from human skeletal remains. In: RATHBUN, T. A., J. E. BUIKSTRA (Eds.): Human Identification. (Charles C Thomas Publishers, Springfield, Illinois, 1984). — 3. KROGMAN, W. M., M. Y. ISCAN, The Human Skeleton in Forensic Medicine. (Charles C Thomas Publishers, Springfield, Illinois, 1986). — 4. ISCAN, M. Y., S. R. LOTH, C. A. KING, D. SHIBAI, M. YOSHINO, Forensic Sci. Int., 98 (1998) 17. — 5. SAFONT, S., A. MALGOSA, E. SUBIRA, Am. J. Phys. Anthropol., 113 (2000) 317. — 6. WROBEL, G. D., M. E. DANFORT, C. ARMSTRONG, Ancient Mesoamerica, 13 (2002) 255. — 7. SAKAUE, K., Anthropological Science, 112 (2004) 75. — 8. PURKAIT, R., J. Forensic Sci., 46 (2001) 924. — 9. TAYLOR, J. V., R. DIBENNARDO, J. Forensic Sci., 27 (1982) 417. — 10. LIU, W., J. Forensic Sci., 34 (1989) 1222. — 11. STEYN, M., M. Y. ISCAN, Forensic Sci. Int., 90 (1997) 111. — 12. PEARSON, K., J. BELL, The study of the long bones of the English skelton I- Femur. (Drapers' Co. Research Mem., University of London, 1917/1919). — 13. BLACK, T. K., Am. J. Phys. Anthropol., 48 (1978) 227. — 14. ISCAN, M. Y., D. SHIHAI, Forensic Sci. Int., 74 (1995) 79. — 15. KING, C. A., M. Y. ISCAN, S. R. LOTH, J. Forensic Sci., 43 (1998) 954. — 16. MALL, G., M. GRAW, K. D. GEHRING, M. HUBIG, Forensic Sci. Int., 113 (2000) 315. — 17. PURKAIT, R., Can. Soc. Forensic Sci. J., 25 (2002) 209. — 18. PURKAIT, R., H. CHANDRA, Forensic Sci. Commun., 4 (2002). — 19. ALBANESE, J., J. Forensic Sci. 48 (2003) 1. — 20. PURKAIT, R., H. CHANDRA, Forensic Sci. Int., 146 (2004) 25. — 21. MURPHY, A. M. C., Forensic Sci. Int., 154 (2005) 210. — 22. ISCAN, M. Y., P. MILLER-SHAIVITZ, Am. J. Phys. Anthropol., 64 (1984) 53. — 23. ISCAN, M. Y., M. YOSHINO, S. KATO, J. Forensic Sci., 39 (1994) 785. — 24. GONZALEZ-REIMERS, E., J. VELASCO-VAZQUEZ, M. ARNAY-DE-LA-ROSA, F. SANTOLARIA-FERNANDEZ, Forensic Sci. Int., 108 (2000) 165. — 25. INTRONA, JR. F., G. DI VELLA, C. P. CAMPOBASSO, Forensic Sci. Int., 95 (1998) 39. — 26. BIDMOS, M., M. STEINBERG, K. L. KUYKENDALL, Homo, 56 (2005) 69. — 27. MURPHY, A. M. C., New Zealand J. Archaeol., 16 (1994) 85. — 28. WIREDU, E. K., R. KUMOJI, R. SESHADRI, R. B. BIRITWUM, J. Foren-

sic Sci., 44 (1999) 921. — 29. KOCAK, A., E. O. AKTAS, S. ERTURK, S. AKTAS, A. YEMISCIGIL, Legal Medicine, 5 (2003) 100. — 30. MURPHY, A. M. C., Forensic Sci. Int., 128 (2002) 155. — 31. BIDMOS, M., M. R. DAYAL, Am. J. Forensic Med. Pathol., 24 (2003) 322. — 32. BIDMOS, M. A., S. A. ASALA, J. Forensic Sci., 48 (2003) 1213. — 33. INTRONA, JR. F., G. DI VELLA, C. P. CAMPOBASSO, M. DRAGONE, Forensic Sci. Int., 42 (1997) 725. — 34. MURPHY, A. M. C., Forensic Sci. Int., 129 (2002) 205. — 35. BIDMOS, M., S. ASALA, J. Forensic Sci. 49 (2004) 1. — 36. ROBLING, A. G., D. H. UBELAKER, J. Forensic Sci., 42 (1997) 1062. — 37. BAINBRIDGE, D., S. GENOVES, J. Roy. Anthropol. Inst., 24 (1956) 21. — 38. HANIHARA, K., J. Anthrop. Soc. Nippon, 67 (1959) 191. — 39. DONGEN, R. V., Am. J. Phys. Anthropol., 21 (1963) 469. — 40. DI VELLA, G, C. P. CAMPOBASSO, M. DRAGONE, F. JR. INTRONA, Boll. Soc. Ital. Biol. Sper., 70 (1994) 299. — 41. MURPHY, A. M. C., New Zealand J. Archaeol., 17 (1995) 29. — 42. MURPHY, A. M. C., Forensic Sci. Int., 125 (2002) 134. — 43. FRUTOS, L. R., Am. J. Forensic. Med. Pathol., 23 (2002) 284. — 44. Workshop of European Anthropologists, J. Hum. Evol., 9 (1980) 517. — 45. OLIVIER, G., Practical Anthropology. (Charles C Thomas Publishers, Springfield, 1969). — 46. WHITEHEAD, P. F., W. K. SACCO, S. B. HOCHGRAF, A photographic atlas for physical anthropology. (Mortan Publishing Company, 2005). — 47. MCLACHLAN, G. J.: Discriminant analysis and statistical pattern recognition. (John Wiley & Sons, New York, 1992). — 48. HUBERTY, C. J.: Applied discriminant analysis. (John Wiley & Sons, New York, 1994).

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ODREĐIVANJE SPOLA SREDNJOVJEKOVNIH SKELETA IZ ISTOČNE ANATOLIJE POMOĆU LOPATICE

SAŽETAK

Određivanje spola iz ljudskih koštanih ostataka pomoću diskriminacijske analize jedna je od metoda koje se koriste u forenzičkim i osteoarheološkim znanostima. Cilj ovog istraživanja bio je uvesti metričke standarde za determinaciju spola srednjovjekovnih populacija Anatolije na temelju mjera lopatice. Baza podataka za ovo istraživanje sastojala se od skeletnih ostataka 93 odrasle individue (47 muškog i 46 ženskoga spola) iz srednjovjekovne zbirke nalazišta Dilkaya. Uzete su četiri mjere: maksimalna visina lopatice, maksimalna širina lopatice, visina zglobne površine lopatice, širina zglobne površine lopatice, te su podvrgnute diskriminantnoj analizi. Sve mjere su pokazale određen stupanj spolnog dimorfizma, s najvećom preciznošću funkcije za determinaciju spola (94,8%) dobivene pomoću maksimalne širine lopatice. Preciznost funkcija u cjelini nalazi se u rasponu od 82,9% do 95,0%, s većom preciznošću dobivenom za ženske skelete nego za muške. Kombinacijom mjera razvijene su populacijski specifične diskriminacijske formule za korištenje u drevnim populacijama Anatolije.