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# SEX DETERMINATION USING THE TIBIA IN AN ANCIENT ANATOLIAN POPULATION

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## ABSTRACT

Sex determination is an important issue of anthropological and forensic sciences. Determination of sex is a priority issue for further analysis of unidentified ancient human remains, because all techniques of identification are markedly different for males and females. The present study provides sex determination using discriminant analysis from tibia measurements in an ancient Anatolian population. In this study, a total of 7 tibia measurements were taken from 123 adults of known sex (62 males and 61 females) in Medieval Dilkaya population (A.D. 10th century). Osteometric measurements included were the length, circumference of midshaft and minimum, transverse and sagittal diameters of midshaft and nutrient foramen levels. Data were analyzed by student t-test and discriminant analysis using Statistical Package for the Social Sciences (SPSS) version 13.0 program. Results showed that grouping due to sex differentiations was accurate by tibia metric values between 73.5% and 90.2% in Dilkaya population. The midshaft circumference was the best single discriminating variable and results of this study compare with other studies. It is suggested that discriminant formulas developed by tibia measurements in this study can be used for sex determination accurately on fragmentary skeletal remains in ancient Anatolian populations.

**KEYWORDS:** Human skeletons, discriminant function analysis, tibia, sex determination, ancient Anatolia.

## 1. INTRODUCTION

Determination of sex is a priority issue for further analysis of unidentified human skeletal remains, because all identification techniques based on the sexes and for males and females different formulas are needed. The determinants of sexual dimorphism from osteological material are related greatly in body size and muscularity, and the childbearing capability in females. In general, the pelvis and skull are the part of the skeleton that exhibits prominent sexually dimorphic characteristics to predict sex with high accuracy.

Some of the powerful methods of sex determination from skeleton are based upon the application of statistical analysis to osteological material. Discriminant function analysis is one of the most sophisticated mathematical approaches. Sex determination by discriminant function analysis provides information from each bone, which is very useful in disasters and forensic cases.

Methods of sex determination by discriminant analysis from skeletons have been described in several populations by many authors (Bainbridge and Genoves, 1956; Hanihara, 1959; Giles and Eliot, 1963; van Dongen, 1963; Giles, 1964; Kajanoja, 1966; Townsend *et al.*, 1982; Taylor and DiBennardo, 1982; İşcan and Miller-Shaivitz, 1984; Johnson *et al.*, 1989; Wu, 1989; Inoue *et al.*, 1992; Song *et al.*, 1992; Di Vella *et al.*, 1994; Murphy, 1994; İşcan *et al.*, 1994; İşcan *et al.*, 1995; Murphy, 1995; Hsiao *et al.*, 1996; Kalmey and Rathbun, 1996; Introna *et al.*, 1997; Robline and Ubelaker, 1997; Steyn and İşcan, 1997; İşcan *et al.*, 1998; Introna, 1998; Steyn and İşcan, 1998; İşcan and Steyn, 1999; Wiredu *et al.*, 1999; Gonzales-Reimers *et al.*, 2000; Safont *et al.*, 2000; Purkait, 2001; Murphy, 2002; Frutos, 2002; Koçak *et al.*, 2003; Bidmos and Dayal, 2003; Sakaue, 2004; Kanchan and Rajenda, 2005; Özer *et al.*, 2006; Özer and Katayama, 2006; Harma and Karakaş, 2007; Alunni-Perret *et al.*, 2008; Özer and Katayama, 2008; Robinson and Bidmos, 2009; Soni *et al.*, 2010; Robinson and Bidmos, 2011; Mastrangelo *et al.*, 2011; Janamala *et al.*, 2012; Seema, 2012; Slaus *et al.*, 2013, Özer, 2014).

Determination of sex from post-cranial skeleton is also studied in many researches and a limited number of studies based on tibia measurements (Kieser *et al.*, 1992; Singh *et al.*, 1975). Steyn and İşcan (1997) studied sex discrimination using tibia osteometric data of white South Africans. Having evaluated regression formulas from Hamann-Todd collection, Holland (1991) also reports that the proximal end of tibia is sexually dimorphic.

Population specific studies conducted so far for assessment of sex from tibia have reiterated the fact that metric standards must be developed for each population because of the differences in size between groups. The objective of the present study is to develop discriminant formulae for sex determination by using the tibia measurements and establish metric standards for ancient Anatolian human skeletal remains.

## 2. MATERIAL AND METHODS

In this study, we studied 123 adult tibias (62 males, 61 females) excavated from Dilkaya archaeological settlemant, Eastern Anatolia (Medieval Age). 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.

From each tibia, 7 variables were measured, using a sliding caliper, caliper rule, osteometric board and steel tape. Tibia measurements are; *maximum length*, *transverse diameter at nutritient foramen*, *sagittal diameter at nutritient foramen*, *midshaft circumference*, *transverse diameter at midshaft*, *sagittal diameter at midshaft* and *minimum circumference*.

Data were analyzed by using the Statistical Package for the Social Sciences (SPSS) program version 13.0. 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. 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 (Özer and Katayama, 2008).

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. Discriminant coefficients are the regression-like b coefficients in the discriminant function, in the form $y=b_1x_1 + b_2x_2 + ... + b_0x_0 + c$, 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 (Huberty, 1994).

## 3. RESULTS

Descriptive statistics; the means and standard deviations, student t-test and equality test of group means results of tibia measurements for males and females are given in Table 1. The t-test results showed that all measurements were significantly greater in males. This state repeats the fact that the average male tibia is more muscular than the average female. 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. Results indicated that minimum circumference was the first variable to be selected by the analysis in Dilkaya tibia measurements and followed sequentially by midshaft circumference.

Results of the discriminant function analysis are presented in Tables 2 and 3. For each function, the discriminant function coefficients, the sectioning point, the demarking point, the expected accuracy of sex determination are given. In Table 2 functions number from 1 to 7 based on single variables are given. The accuracy of sex determination ranged from 73.5% to 88.7%. The *midshaft circumference* measurement was the best single discriminating variable. For each function, when the Discriminant score is greater than the sectioning point, it indicates a male individual. In Table 3 functions numbered 1 to 5 indicates the contribution of a variable with the Discriminant score related to other variables. With all measurements (except *midshaft circumference*), 90.2% of cases could be classified correctly. Classification accuracy was generally higher for females than for males.

## 4. DISCUSSION AND CONCLUSIONS

Population specific studies and formulas have an important role in osteological data analysis. The present study has confirmed that for sex determination the measurements of the tibia display higher classification accuracy and a good sex indicator. Our prediction values showed that sex differentiation can be done by tibia measurements with accuracy between 73.5% and 88.7% in univariate and between 88% and 90.2% in multivariate analysis. So far numerous studies focus on the limitations of discriminant function formulae using more robust, skeletal elements including the femur, tibia and calcaneus and talus, and generally accuracies fall within the 80-90% range (Slaus *et al.*, 2013).

Gonzales-Reimers *et al.* (2000), investigated sex determination by discrimination by discriminant function analysis of the right tibia in the prehistoric population of the Canary Island and highlighted the high average accuracy (94.9 to 98.3%). Tibia breadth parameters showed better discriminant power than length measurements and authors explained on the basis of greater male muscular development.

Holland (1991) also points out the importance of the proximal of the proximal tibia due to heavy stress during on individuals life, and because the stress may have a sexual component and good indicator, in terms of sex determinations. Consequently, different bone remodeling between sexes may lead to greater cortical bone development in males during adolescence which continues throughout in adulthood (Slaus *et al.*, 2013).

Study conducted on contemporary Croatian tibias confirms various combinations of variables yield accuracies ranging from 84.4 to 91.1% (Slaus *et al.*, 2013). Although the discriminant power was lower than the prehistoric Canarian study, study results confirms that best discriminate values were archived by using maximum diameter of the tibia at the nutrient foramen, maximum epiphyseal breadth of the tibia and circumference of the tibia at the nutrient foramen.

İşcan and Miller-Shaivitz (1984) reported that the circumference taken at the nutrient foramen level of the tibia was predicted with 77.2% accuracy for whites and 80.0% for blacks in Terry Collection. Marked differences between groups is important, as well as the differences in nutrition, disease or physical activity within the group. Furthermore, they also reported that sexual dimorphism was better predicted by the tibia than the femur.

Safont et al. (2000) also confirm the high accuracy of the circumference at the nutrient foramen level of the tibia and the radial circumference which are the most useful individual functions to classify individuals. However controversially they suggest that the arm discriminate the sex better than the leg due to arm bone circumferences are being more greatly affected by mechanical stress. They reported that men showed a high muscular activity in Late Roman site of Mas Rimbau/Mas Mallol (Spain).

This study also agrees with the finding that diameter and circumference dimensions (between 80.2% and 88.7%) are more dimorphic than length (73.5%) measurements. This is also in accordance with the previous findings (İşcan and Miller-Shaivitz, 1984, İşcan *et al.*, 1994, Özer and Katayama, 2006, Özer and Katayama, 2008), and might be related on the basis of the greater muscularity of male anatomy. It was clear that certain parameters of tibia could help in determination of sex from fragments of the tibia (Seema, 2012). Consequently, it is worth to project that several muscles insert near the nutrition foramen and according to this transverse diameter parameters have high accuracy in terms of sex discrimination (İşcan *et al.*, 1994).

This study which involved some measurable characteristics of the tibia can help in identifying the sex of the tibia both in forensic and anthropological cases. In conclusion, the results show that discriminant formulas developed by tibia measurements can be used for sex determination accurately on fragmentary skeletal remains in ancient Anatolian populations, and this method can be used as an important tool for osteoarchaeological research for the area. Therefore it can be concluded that similar researches are needed in terms of evaluating various sexing methods for the specific areas.

Table 1: Means, standard deviations, univariate statistics and test of equality of group means of Dilkaya tibias

| | Male | | | Female | | | | |
|---|---|---|---|---|---|---|---|---|
| Variables (mm) | N | Mean | SD | N | Mean | SD | Wilks' Lambda | F |
| Maximum length | 48 | 367.61 | 23.80 | 50 | 338.16 | 18,81 | 0.670 | 44.398 |
| Tr. dia. at nut. foramen | 57 | 24.75 | 2.34 | 59 | 20.53 | 2.03 | 0.547 | 74.454 |
| Sag. dia. at nut. foramen | 57 | 34.49 | 2.56 | 59 | 29.53 | 2.52 | 0.498 | 90.808 |
| Midshaft circumference | 56 | 86.02 | 6.90 | 59 | 73.31 | 5.78 | 0.470 | 101.622 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Minimum circumference | 58 | 78.34 | 6.16 | 58 | 66.69 | 4.44 | 0.428 | 120.188 |
| Tr. dia. at midshaft | 57 | 23.22 | 3.12 | 59 | 19.29 | 2.05 | 0.591 | 62.191 |
| Sag. dia. at midshaft | 57 | 30.62 | 3.56 | 59 | 25.95 | 2.37 | 0.633 | 52.215 |

Table 2: Discriminant function analysis results of Dilkaya tibias (univariate)

| Function no | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Maximum length | 0.047 | | | | | | |
| Tr. dia. at nut. foramen | | 0.457 | | | | | |
| Sag. dia. at nut. foramen | | | 0.394 | | | | |
| *Midshaft circumference* | | | | 0.158 | | | |
| Minimum circumference | | | | | 0.186 | | |
| Tr. dia. at midshaft | | | | | | 0.380 | |
| Sag. dia. at midshaft | | | | | | | 0.332 |
| Constant | -16.473 | -10.326 | -12.581 | -12.523 | -13.512 | -8.068 | -9.368 |
| Sectioning point | 0.014 | 0.017 | 0.0165 | 0.026 | 0.00 | 0.013 | 0.0135 |
| Accuracy (%) | 73.5 | 85.3 | 80.2 | 88.7 | 84.5 | 80.2 | 81.9 |

Table 3: Discriminant function analysis results of Dilkaya tibias (multivariate)

| Function no | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Maximum length | 0.007 | 0.005 | 0.009 | 0.009 | 0.007 |
| Tr. dia. at nut. foramen | 0.062 | 0.032 | | 0.102 | 0.077 |
| Sag. dia. at nut. foramen | 0.156 | 0.131 | | 0.128 | 0.099 |
| Midshaft circumference | 0.065 | | 0.123 | 0.076 | |
| Minimum circumference | | 0.123 | | | 0.121 |
| Tr. dia. at midshaft | 0.103 | 0.099 | 0.116 | | |
| Sag. dia. at midshaft | -0.037 | -0.069 | -0.031 | | |
| Constant | -14,984 | -15,730 | -14,589 | -15,562 | -16,192 |
| Sectioning point | 0.076 | 0.0805 | 0.082 | 0.075 | 0.79 |
| Accuracy (%) | 89.1 | 90.2 | 88.2 | 88.0 | 90.2 |

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