Forensic Science International 271 (2017) 129.e1–129.e7

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Forensic Anthropology Population Data

Sexual dimorphism of the tibia in contemporary Greek-Cypriots and Cretans: Forensic applications

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ARTICLE INFO

Article history:
Received 3 June 2016
Received in revised form 5 November 2016
Accepted 10 November 2016
Available online 16 November 2016

Keywords:
Greek-Cypriots
Cretans
Tibia
Sex estimation
Discriminant function analysis
Forensic anthropology population data

ABSTRACT

Sex estimation is an essential step in the identification process of unknown heavily decomposed human remains as it eliminates all possible matches of the opposite sex from the missing person's database. Osteometric methods constitute a reliable approach for sex estimation and considering the variation of sexual dimorphism between and within populations; standards for specific populations are required to ensure accurate results. The current study aspires to contribute osteometric data on the tibia from contemporary Greek-Cypriots to assist the identification process. A secondary goal involves osteometric comparison with data from Crete, a Greek island with similar cultural and dietary customs and environmental conditions. Left tibiae from one hundred and thirty-two skeletons (70 males and 62 females) of Greek-Cypriots and one hundred and fifty-seven skeletons (85 males, 72 females) of Cretans were measured. Seven standard metric variables including Maximum length (ML), Upper epiphyseal breadth (UB), Nutrient foramen anteroposterior diameter (NFap), Nutrient Foramen transverse diameter (NFtrsv), Nutrient foramen circumference (NFCirc), Minimum circumference (MinCirc) and Lower epiphyseal breadth (LB) were compared between sexes and populations. Univariate and multivariate discriminant functions were developed and posterior probabilities were calculated for each sample. Results confirmed the existence of sexual dimorphism of the tibia in both samples as well as the pooled sample. Classification accuracy for univariate functions ranged from 78% to 85% for Greek-Cypriots and from 69% to 83% for Cretans. The best multivariate equations after cross-validation resulted in 87% for Greek-Cypriots and 90% accuracy for Cretans. When the samples were pooled accuracy reached 87% with over 95% confidence for about one third of the population. Estimates with over 95% of posterior probability can be considered reliable while any less than 80% should be treated with caution. This work constitutes the initial step towards the creation of an osteometric database for Greek-Cypriots and we hope it can contribute to the biological profiling and identification of the missing and to potential forensic cases of unknown skeletal remains both in Cyprus and Crete.

1. Introduction

Since the summer of 1974 when Turkey invaded Cyprus and placed a large part of the territory of the Republic of Cyprus under its control the fate of hundreds of people remains unknown. A total of 1508 Greek-Cypriots and 493 Turkish-Cypriots were declared missing during that period [1], and despite the efforts of the Committee of Missing Persons [2] in Cyprus only 629 were identified and returned to their families. Identification mostly relied on DNA analysis or comparison of antemortem dental records. Yet, for these methods to be applied, one must have an indication as to the biological profile of the individual in order to narrow down the possible matches from the missing person's database. Thus, osteometric standards from contemporary skeletons of both Turkish-Cypriots and Greek-Cypriots are essential.

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http://dx.doi.org/10.1016/j.forsciint.2016.11.018
0379-0738/

Macroscopic observation of the pelvis and/or the skull for sex estimation have been carried out by many researchers both in physical and virtual bones producing accuracy rates over 85% for both skeletal elements [e.g. Refs. 3–6]. The pelvic bone is the most reliable single sex indicator in the human skeleton exhibiting in certain occasions over 95% correct sexual diagnosis [4]. This can be attributed to the fact that sexual dimorphism of this skeletal element is related to functional adaptation of the female pelvis to support childbirth and thus it is population-independent. As an alternative to the traditional macroscopic examination, metric techniques allow accurate sexing through statistical analysis and therefore they provide a more rigorous assessment than the morphological approach [7]. Moreover, osteometric methods are long acknowledged to be valid for sex estimation of unknown skeletal remains when population-specific standards are employed [e.g. Refs. 4,8,9]. Long bones were disregarded in the past due to the belief that skull is the second most dimorphic bone of the skeleton after the pelvis. Recent data support that long bones actually perform well for sex estimation reporting high classification accuracies [e.g. Refs. 10,11]. Amongst them, tibia was extensively studied in populations of different chronology and geography [12–21] being robust, likely to survive harsh taphonomic conditions and scavenging in decomposed bodies found outdoors. Thus, many studies have tested different measurements on the tibia in different populations with sex allocation accuracy reaching 98% in some cases [e.g. Ref. 16]. Sexual dimorphism of the tibia during ontogeny was also reported in a European sample [22]. These results imply that tibia is extremely dimorphic and thus an element with great discriminatory power.

In addition to the traditional osteometric studies which routinely use discriminant function analysis to create sex estimation formulae, new methodologies on data acquisition and analysis have been emerging recently [23,24]. Three-dimensional reconstructions of bones from CT scans or surface scans allowed for virtual measurements in every bone of the skeleton and the development of sex estimation methods [25,26]. Furthermore, methods on quantifying size and shape such as geometric morphometrics [27,28] and machine learning approaches [29,30] also emerged. The possibility of creating osteological digital databases with access for researchers all over the world seems to have given an extra push in virtual methods. This led to creating population specific standards even in countries and regions lacking documented skeletal collections.

To date there are no data available on modern Greek-Cypriots while a large number of studies have been emerging recently for neighbouring Cretans [9,21,31–35] and mainland Greeks [36,37]. The same situation holds true for Turkish-Cypriots with an increasing number of studies from mainland Turkey appearing recently [25,38–41]. The main objective of this work is to develop population specific osteometric standards of the tibia for the Greek-Cypriots in an effort to contribute to the existing sex estimation methods employed for the identification of the missing in Cyprus. A secondary objective is to compare the dimensions of the tibia of two synchronous cemetery populations from Cyprus and Crete that share similar language, culture, dietary habits and climate.

2. Material and methods

One hundred and thirty-two skeletons (70 males and 62 females) were selected at random from a cemetery population housed in the ossuary of the main cemetery in the city of Limassol in Cyprus. The sample consisted of individuals who died between 1976 and 2003. The mean age for males was 69.3 ± 12 years and 70 ± 17.8 years for females. A contemporary collection from Crete (Greece) was used for comparison [9]. One hundred and fifty-seven skeletons (85 males, 72 females) with mean age 68.8 ± 14 years for males and 70.9 ± 17.8 years for females were used in this study. Seven measurements [4,12] were taken on the left tibia: Maximum length (ML), Upper epiphyseal breadth (UB), Nutrient foramen anteroposterior diameter (NFap), Nutrient Foramen transverse diameter (NFtrsv), Nutrient foramen circumference (NFCirc), Minimum circumference (MinCirc) and Lower epiphyseal breadth (LB).

Table 1
Intra- and inter-observer error is quantified by calculating TEM, rTEM and R for each variable.

	Intra-observer error (N = 30)			Inter-observer error (N = 15)		
	TEM	rTEM	R	TEM	rTEM	R
ML	0.56	0.16	0.99	1.88	0.51	0.96
UB	0.45	0.66	0.99	1.3	1.89	0.70
NFap	0.59	1.79	0.95	0.35	1.02	0.87
NFtrsv	0.43	1.90	0.94	0.6	2.3	0.69
NFCirc	0.73	0.87	0.99	2.4	2.75	0.79
NFmin	0.70	0.98	0.98	1	1.36	0.85
LB	0.74	1.50	0.94	0.95	1.93	0.86

Technical measurement error (TEM) was used to assess intra-observer error in a sample of 30 randomly selected bones. The relative TEM (rTEM), which expresses the error as a percentage of TEM divided by the average value for each measurement was also taken in order to scale the error. The coefficient of reliability (R) of the measurement is also calculated as suggested by Ulijaszek and Kerr [42].

The mean differences of the measurements between the population samples were tested using an independent T-test. Sex differences on the measurements were explored using a one-way ANOVA. Additionally, univariate and multivariate discriminant functions were developed for the Greek-Cypriot (Cy), the Cretan (Cr) and the pooled (P) sample. Multivariate equations were created using different combinations of variables for each sample. The functions FCy1, FCr1 and FP1 used all available variables with a direct procedure while FCy2, FCr2 and FP2 are the result of stepwise discriminant function analysis. In addition, three more equations were created for each sample in an effort to simulate different fragmented scenarios. FCy3, FCr3 and FP3 employ the four variables of the upper epiphysis (UB, NFap, NFtrsv and NFCirc) allowing for the rest of the bone to not be available. For cases where the upper epiphysis is missing while the lower part is preserved FCy4, FCr4 and FP4 were created using LB and MinCirc. Lastly, in the case both epiphyses are missing FCy5, FCr5 and FP5 provide a method of sex classification by using only the three measurements at the nutrient foramen (NFap, NFtrsv, NFCirc). In this last scenario MinCirc was omitted as it would be very difficult to define the measurement in a bone missing the lower epiphysis.

Posterior probabilities were calculated for the best equations as described in Kranioti and Apostol [21]. Statistical analysis was carried out with SPSS 22.0.

3. Results

3.1. Intra-observer error

Thirty randomly selected tibiae were measured by the same observer within 4 weeks of the first measurement. TEM, rTEM and R for each variable are presented in Table 1. rTEM is below 5% in all cases while R is consistently over 0.95 with the exception of TLB which is slightly lower. This is in accordance with the acceptable human error (rTEM < 5%, R > 0.95) as suggested by Ulijaszek and Kerr [42].

3.2. Inter-observer error

Fifteen randomly selected tibiae were measured by two independent observers. TEM, rTEM and R for each variable are