Sex estimation using coronal measurements of permanent canines in a contemporary mestizo population from Manizales, Colombia

Estimación del sexo a partir de medidas coronales de caninos permanentes en una población mestiza contemporánea de Manizales, Colombia

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Keywords: sexual dimorphism, physical anthropology, forensic anthropology, dentition

ABSTRACT

Introduction: sex estimation is one of the most important aspects of bioanthropological analysis. Teeth are a key tool to obtain this information, especially in cases where the action of taphonomic agents or funeral characteristics are unfavorable for preservation. The aim of this study was to examine the degree of sexual dimorphism in permanent canines of a contemporary mestizo population from the city of Manizales, Colombia. ***Method:*** descriptive study, measuring the mesiodistal (MD) and bucolingual (BL) diameters of permanent canines in 109 mestizo individuals (63 male and 46 female) aged 15 to 18, born in the city of Manizales, Colombia. The used statistical methods helped obtain the cut-off points, the percentages of cases correctly allocated, the likelihood estimation for new individuals and the sexual dimorphism values. ***Results:*** the cut-off points were 7.88 mm and 7.33 mm for MD and BL of the upper canine, respectively, and 6.81 mm and 6.76 mm for the same variables in lower canines. Correct allocations range from 71.42% to 78.26%, except for bucolingual diameter in the upper canine, which yielded low values. The correct likelihood estimation of external individuals ranges from 0.71 to 0.83. Finally, sexual dimorphism is relatively low (between 2.79% and 6.80%), although it falls within the expected range. The most dimorphic tooth is the lower canine, in line with reports in other populations around the world. ***Conclusions***: the size of permanent canines is a good predictor of sex in the studied population and can be used when other osteological indicators are not available, or as a complement to them.

Palabras clave: dimorfismo sexual, antropolog a f sica, antropolog a forense, dentici n

RESUMEN

Introducci n: la estimaci n del sexo es uno de los aspectos m s importantes de los an lisis bioantropol gicos. Los dientes son una herramienta fundamental para obtener esa informaci n, sobre todo en casos donde la acci n de agentes tafon micos o las caracter sticas del tratamiento funerario son poco favorables a la preservaci n. El objetivo del presente estudio consisti en examinar el grado de dimorfismo sexual en caninos permanentes de una poblaci n mestiza contempor nea procedente de la ciudad de Manizales, Colombia. ***M todo:*** *estudio descriptivo, en el cual se midieron los di metros mesiodistales (MD) y bucolinguales (BL) de caninos permanentes de 109 individuos mestizos (63 masculinos y 46 femeninos) con edades entre 15 y 18 a os, nacidos en la ciudad de Manizales, Colombia. Los m todos estad sticos aplicados permitieron obtener los puntos de corte, los porcentajes de casos correctamente asignados, las probabilidades de estimaci n para nuevos individuos y los valores del dimorfismo sexual.* ***Resultados:*** los puntos de corte son 7,88 mm y 7,33 mm para MD y BL del canino superior, respectivamente, y 6,81 mm y 6,76 mm para las variables del canino inferior. Las asignaciones correctas var an entre el 71,42% y el 78,26%, con excepci n del di metro bucolingual del canino superior, que arroj valores bajos. Las probabilidades de estimaci n correcta de individuos externos oscilan entre 0,71 y 0,83. Por ltimo, el dimorfismo sexual es relativamente bajo (entre 2,79% y 6,80%), aunque se ubica dentro del rango esperado. El diente m s dim rfico es el canino inferior, en concordancia con lo identificado para otras poblaciones del mundo. ***Conclusiones***: el tama o de los caninos permanentes es un buen predictor del sexo en la poblaci n estudiada y puede ser empleado cuando no se cuenta con otros indicadores osteol gicos, o como complemento de ellos.

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INTRODUCTION

Sex estimation is a key stage in the analysis of biological profile when studying skeletonized human corpses in both forensic and archaeological investigations. This process involves a number of methods to record the most dimorphic morphological characteristics expressed in the skeleton, i.e. differences in phenotypical expression between male and female individuals.[1] Although sexual dimorphism of the skeleton and dentition in human species is relatively small compared to other animals and varies among populations,[2,3] different morphological observation techniques and metric analysis have been developed to establish sex with a level of confidence of up to 90%.[4,5]

The bone structures that offer the best results are mainly located in the pelvis, followed by cranial morphology and metric analysis of humeral and femoral heads.[6-8] In practice, few complete skeletons are available and in good preservation conditions; on the contrary, intrinsic (e.g., age of death, health status, certain pathologies, and cause of death) and extrinsic conditions (e.g., funeral treatment, taphonomic conditions, excavation and conservation techniques) significantly affect the representativeness of bone structures needed to obtain reliable information about an individual's sex and age.[9] It is therefore critical to have alternative sex estimation methods that provide reliable analysis and consider interpopulation phenotypic variation. Dental analysis is a useful method in samples lacking traditional osteological indicators due to poor bone preservation, or in the analysis of sub-adult individuals with full dental crowns.

Among the aspects that indicate that teeth are especially relevant units of analysis in osteobiographic and population reconstructions as well as in the identification of people, it is worth noting that most tissues teeth are made of, mainly enamel, have much more structural hardness than bone remains, allowing them to be preserved for longer periods and in better conditions in archaeological contexts; in addition, they can resist physical, chemical, thermal, and biological postmortem damage. Also, due to their small size, recovered teeth are generally more unbroken than most bones.[10] Additionally, human permanent dentition has morphological characteristics and dimensions that do not vary after the end of the growth and development period, so they can be used to estimate sex from early ages.[11,12]

In human populations, sexual dimorphism in dentition is mainly expressed in size differences. Women tend to have smaller teeth than men, and this is the main feature for teeth to be used to estimate sex.[10,13-16] These differences are generally explained by the variations between the sexes in the process of dental morphogenesis, as suggested by Moss and Moss-Salentijn,[17] who point out that variations in the dimensions of permanent canines are due to two main factors: a thicker enamel due to a longer period of amelogenesis among men and a slow male maturation as a result of the action of the Y chromosome.[14,18]

The most commonly used dental measurements for sex estimation are the mesiodistal (MD) and bucolingual (BL) diameters of the crowns.[13,19-21] Several authors have tried to identify the dental dimensions that are the most accurate for sex estimation,[22] concluding that the MD diameter is a better predictor than the BL dimension. However, since wear produced by interproximal contacts can yield measurements with varying error levels, it is recommended to use

both dimensions, which is a more reliable approach for sex estimation.[20,23]

Research on this field has shown that the degree of sexual dimorphism in teeth depends on genetic and environmental factors[18,24] and therefore varies among populations.[25,26] This makes it necessary to implement population-specific data analysis protocols for the development of local standards to achieve reliable sex estimation.

In Colombia, studies on sexual dimorphism in permanent dentition are scarce but significant. In all of them, the upper canine appears as the most dimorphic tooth.[27] In this context, the present study analyzed sexual dimorphism in permanent canines of a population from the city of Manizales, Colombia. The city is located at 2.150 m.a.s.l., on the country's Cordillera Central of the Andean mountain range and is the capital of the Department of Caldas. It was founded in 1849 by Antioquia settlers and now is a city of great economic, industrial, cultural and tourist activity. Like the rest of the country, Manizales is considered a multi-ethnic and multicultural community, as a result of a varied miscegenation due to a biocultural process resulting from the mixture of different groups and lineages: Amerindian peoples (indigenous) Europeans, and Africans.[28-30] According to the Information and Statistics Center (Centro de Informaci n y Estad stica, CIE) of the Municipality of Manizales, the city has 398,830 inhabitants,[31] and according to the National Administrative Department of Statistics (Departamento Administrativo Nacional de Estad stica, DANE), the population in Manizales is made up mostly of mestizo and white people (98.9%), with low percentages of Afro-Colombians (0.9%) and indigenous (0.2%).[32]

Since it has been documented that the canine is the tooth with the highest values of sexual dimorphism in different populations worldwide,[14,22,33] the general objective of this study was to establish the most useful measurements in differentiating female and male individuals, and assessing the degree of sexual dimorphism in the study sample. These data are relevant for assessing the reliability of such measurements for estimating sex in forensic cases in the region or in individuals phenotypically similar to those in the sample.

METHODS

A descriptive study was conducted using a sample made up of the permanent canines of 109 individuals (63 were males and 46 females) aged 15 to 18 years. This age range was chosen because in this period the canines have minimal occlusal and interproximal wear, which allowed to maximize the number of measurements obtained.[34] The following inclusion criteria were also considered: 1. Full permanent dentition, 2. Residents in the city of Manizales with three generations born in the same city, and 3. Good oral health (no periodontal disease, coronary fractures or shape and size abnormalities). All participants were students from the city's public schools, and they all signed an informed consent. The project was endorsed by the Ethics Committee of the Universidad de Caldas School of Legal and Social Sciences (Resolution No. 21-2016). In addition, the sample complied with the two requirements suggested by Albanese, Cardoso and Saunders[35] to ensure unbiased results: a sample size greater than 40 individuals and a sexual ratio (or the proportion of male and female individuals) lower than 1.5:1 (in this case that value is 1.36:1).

An alginate impression (Tropicalgin-Zhermack) was taken from each participant to obtain a study model in Silky-Rock (Whip Mix) type 4 plaster. This procedure was led by a dental professional. Each impression was measured for the MD and BL diameters of the left upper and lower permanent canines, following the recommendations of specialized literature for dental measurements in samples of contemporary populations.[36] The MD diameter is defined as the largest distance between the most protruding points of the mesial and distal sides of the crown, and the BL diameter as the distance between the most protruding points of the buccal and lingual sides (Figure 1). The measurements were taken by one of the authors (VAY) with a digital calibrator (RM813, Ubermann), which has an accuracy of 0.01 mm.

Figure 1. Mesiodistal and bucolingual diameters of the crown of permanent canines.

To assess intra-observer error, measurements were repeated in 20 replicates at least 15 days apart between both measurements, calculating the Intraclass Correlation Coefficient (ICC) with the R software, version 2.12.2. Basic descriptive statistic was run for each variable, considering the sample as a set and separating by sex. The following values were then obtained: cut-off points (or the average of the closest values of both sexes), the percentages of cases correctly allocated for individuals in the sample [P (A|B)], the correct likelihood estimation in new individuals [P (A|B)], and the values of sexual dimorphism. The latter was calculated using the formula SD=(M-F)/F*100,[37] widely used in the field of dental anthropology, where M and F correspond to the averages for each sex.

RESULTS

The ICC results for the variables considered in this study range from 0.91 to 0.99, suggesting excellent reliability in the data survey.[38] The observer error yields 1% to 9% of the total variability of the results, ensuring that their incorporation into the obtained data is predictable and does not affect the interpretations made. The descriptive statistics showed that the minimum, maximum and averaged values of the four variables in male individuals are higher than those in females, which is a descriptive indicator of the existence of sexual dimorphism. The average and median in all variables have very similar values, suggesting that the data for each sex are distributed almost symmetrically and close to normality (Table 1). Also, while the lower canines are smaller than the upper ones, they are more dimorphic, as shown in Table 2.

The overall percentages range from 2.79% to 6.80%, ranking within the most expected range of values for human populations (Table 2). Also, the mesiodistal diameters have a greater dimorphism than the bucolingual ones in both the lower and upper canines. The correct allocation rates are greater than 71%, in some cases reaching 78% (the mesiodistal diameter of the upper canine in females), with only one exception regarding the values obtained for the bucolingual diameter of the upper canine in females, with a 45.65% success. On the other hand, regarding the likelihood of correct allocation of new individuals entering for analysis, the results help improve the estimates, with values ranging from 0.71 to 0.83. Most of these values are higher for males (Table 2).

Table 1. Descriptive statistics by sex and for the entire sample

	Female				Male				Both sexes			
	MD		BL		MD		BL		MD		BL	
Tooth	23 ULC	33 LLC	23 ULC	33 LLC	23 ULC	33 LLC	23 ULC	33 LLC	23 ULC	33 LLC	23 ULC	33 LLC
N	46	46	46	45	62	63	61	60	108	109	107	105
Min.	6.84	5.81	5.93	5.03	6.99	6.32	6.05	5.83	6.84	5.81	5.93	5.03
Max.	8.78	7.31	8.73	7.69	9.02	7.98	9.27	8.19	9.02	7.98	9.27	8.19
Average	7.64	6.65	7.54	6.62	8.01	7.09	7.74	6.96	7.85	6.91	7.65	6.82
Median	7.63	6.70	7.56	6.58	7.94	7.13	7.74	7.00	7.86	6.95	7.67	6.84
SD	0.43	0.39	0.60	0.59	0.45	0.45	0.66	0.65	0.48	0.47	0.64	0.64

Note: Min.: Minimum value (mm); Max: Maximum value (mm); SD: Standard Deviation; MD: Mesiodistal Diameter; BL: Bucolingual Diameter; 23 ULC: Upper Left Canine; 33 LLC: Lower Left Canine.

Table 2. Cut-off points, sexual dimorphism, percentages of cases correctly allocated for individuals in the sample [P (A|B)] and correct likelihood estimation for new individuals [P (B|A)]

Variable	CP	SD	Sex	P (A|B)		P (B|A)	
				N	%	*pF*	*pM*
23 ULC MD	7.88	4.75	F	36	78.26	0.77	0.22
			M	45	71.42	0.23	0.78
			F+M	81	74.31	-	-
33 IIC MD	6.81	6.80	F	33	71.74	0.81	0.17
			M	47	74.60	0.19	0.83
			F+M	80	73.39	-	-
23 ULC BL	7.33	2.79	F	21	45.65	0.71	0.24
			M	47	74.60	0.29	0.76
			F+M	68	62.38	-	-
33 IIC BL	6.76	5.37	F	33	71.74	0.72	0.21
			M	45	71.42	0.28	0.79
			F+M	78	71.56	-	-

Note: 23 ULC: Upper Left Canine; MD: Mesiodistal Diameter; 33 LLC: Lower Left Canine; BL: Bucolingual Diameter;
CP: Cut-off point (mm); SD: Sexual Dimorphism (%).
pF= Percentage of correct estimate for females and pM= Percentage of correct estimate for males.

DISCUSSION

Sex estimation is one of the most important steps in forensic identification and in the development of bioarchaeological interpretations. Dental parameters are a good indicator for sex estimation, as they can be obtained through a simple, reliable, economical method. Considering the dental differences among populations, it is necessary to build local standards to obtain adequate information, since phenotypes are variable within species, especially when dealing with metric studies. In this sense, the present study contributes to the creation of reliable and systematic analyses that can later be used to obtain biological information in other samples from similar origin and biological characteristics.

In Colombia, dental sexual dimorphism studies have mainly used dental dimensions like the maximum mesiodistal and bucolingual diameters of the crown, the height and area of the crown, and the MD and BL diameters of the neck.[27,39,40] In the present study, the analysis of the mesiodistal and bucolingual diameters of permanent canines suggests moderate sexual dimorphism, although it is sufficient to make adequate estimates of the sex of individuals. The values fall within the expected range for human populations, which usually range from 1 to 7%,[19] although values between 10 and 15% have been recorded in some prehistoric samples.[10,12,22,41] Therefore, this study shows that the coronal measurements of the canines in the study sample are systematically higher among male individuals, allowing to infer the actual sex in a high percentage of cases.

The univariate analysis showed that the MD and BL dimensions of the male canine are systematically larger than the female counterparts, in line with previous studies.[15,33,42] On the other hand, it became clear that the mesiodistal diameter is more dimorphic than the bucolingual, and the lower canine is more dimorphic than the upper one, in line with the trend generally observed in human populations.[19] As for the bucolingual diameter of the upper canine crown, female individuals were correctly allocated in a low percentage, and therefore this variable should be preemptively discarded as a sex estimator in this case, when following this procedure. However, the yielded information improves the estimates when analyzing data by considering them from a probabilistic perspective, that is, when calculating the chances of an individual of unknown sex being classified as male or female depending on the size of their canines. Bearing in mind that this study is the first step in a long-term research project, this alternative data processing strategy opens a promising field of work, as certainty levels can be easily improved when new individuals of known sex are entered in the sample.

As previously stated, this study is an initial step, and therefore the obtained data are mainly descriptive and univariate. The next steps will include multivariate analyses of coronal measurements of the canine, variables related to the entire dentition, and the application of formulas already published, generated both with Colombian samples and remains from other geographical origins, in order to assess their discriminatory potential. Similarly, the creation of standard mathematical formulas in the analyzed sample will be of paramount importance to improve the predictive power of the overall proposal, as will the approach from the perspective of conditional probability theory.

CONCLUSION

The proposal of this research project can be incorporated into anthropological work protocols aimed at identifying persons in the forensic field, provided that the individuals come from a geographical context similar to that of the analyzed sample. Also, any application in individuals from other regions or chronological periods should be considered with caution and tested prior to the interpretation of data.

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CONFLICTS OF INTEREST

The authors state that they have no conflict of interest.

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