TRABAJO ORIGINAL

Sex estimation using humeral and femoral head diameters in contemporary and prehispanic mexican populations

Estimación del sexo a partir del diámetro de la cabeza humeral y femoral en poblaciones mexicanas de época prehispánica y contemporánea

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Abstract

In bioarchaeology and forensic anthropology the most reliable skeletal element for sex estimation is the pelvis; nevertheless, when it is missing, other postcranial elements must be used. The main goal of this research is to provide sectioning points for sex assessment from humeral and femoral head diameters for three prehispanic and two contemporary Mexican populations. Using a sliding caliper, a total of 386 (45.3% female and 54.6% male) humeral and femoral head diameters were recorded. The sectioning point was calculated as the mean between sexes, and univariate independent sample t-tests were performed to test significant differences between sexes. The results demonstrate significant sexual differences in all populations and high percentages of correct sex classification (90%-94%). We conclude that the proposed cut-off points can be used as an alternative for sex estimation in Mexican populations, in contexts with incomplete skeletons and/or fragmented bones. Arg Antrop Biol 24(1), 2022. https://doi.org/10.24215/18536387e044

Keywords: bioarchaeology; forensic anthropology; osteoarchaeology; skeletal remains; Mesoamérica

Resumen

Tanto en bioarqueología como en antropología forense, la pelvis es el elemento óseo con mayor confiabilidad para la estimación sexual; no obstante, cuando no está pre-

sente, otros elementos deben ser utilizados. Es por ello que el objetivo principal de este trabajo es proveer puntos de corte para estimar el sexo a partir del diámetro de la cabeza del húmero y del fémur, en poblaciones mexicanas (tres prehispánicas y dos contemporáneas). Utilizando el compás de corredera, se midió un total de 386 (45,3 % femeninos y 54.6.% masculinos) diámetros de la cabeza humeral y femoral. Los resultados demuestran diferencias estadísticamente significativas entre sexos en todas las poblaciones y altos porcentajes de clasificación sexual correcta (90 %-94 %). Por lo tanto, concluimos que los puntos de corte propuestos pueden ser utilizados como una alternativa para la estimación sexual, para la población mexicana, en contextos con esqueletos incompletos y/o huesos fragmentados. Arg Antrop Biol 24(1), 2022. https://doi.org/10.24215/18536387e044

In bioarchaeological and forensic anthropology sex estimation from skeletal remains is crucial to develop a biological profile. Based on the patterns of sexual dimorphism, the primary skeletal structure used to determine the sex is the pelvis; however, it is important to propose alternatives due to the incomplete or/and fragmented condition of the recovered bones in bioarchaeological and forensic contexts (Albanese, 2013; Marlow & Pastor, 2011; Ostrofsky & Churchill, 2015; Torres *et al.,* 2020). In Mexico, there are several studies involving these conditions, such as non-funerary bioarchaeological contexts that exhibit several posthumous body treatments and ritual assemblage (Chávez, 2012; Gómez *et al.,* 2007; Ruiz Albarrán, 2019; Ruíz, 2020; Ruíz *et al.,* 2016; Tiesler, 2007; Tiesler *et al.,* 2013); ossuaries and secondary bone deposits related to epidemics *(*Barquera *et al.,* 2020; Márquez-Morfín & Meza, 2015; Meza & Báez, 1994) and forensic cases of enforced disappearance (Adams & Byrd, 2008).

Numerous metric studies using univariate and multivariate metric analysis of postcranial elements have reported high classification rates in sex estimation (Albanese *et al*., 2005; Asala *et al.,* 2004; Dittrick & Suchey, 1986; Spradley *et al.,* 2015; Spradley & Jantz, 2011). It is important to highlight that these approaches have some advantages in forensic and archaeological analyses, since they are based on objective morphometric measurements, with smaller intra and inter-observer errors and they are less time consuming (Milner & Boldsen, 2012).

It has been observed that long bones are reliable in sex determination, especially considering the epiphyseal measurements. Principally, the humerus and femur present high percentages of correct sex classification (Albanese, 2013; Spradley & Jantz, 2011). However, considerable overlap in the size and degree of robusticity in male and female skeletons complicates the estimation of sex. The accuracy of sex assessment depends on the degree of dimorphism expressed in the individuals (Green & Curnoe, 2009; Walrath *et al.,* 2004). Additionally, sexual identification of human skeletal material is most accurate after the individual reaches maturity (White & Folkens, 2005), because the secondary dimorphism anatomical differences tend to be more pronounced after the maturation period (Paciulli, 2017; Plavcan, 2001, 2012; Tague & Lovejoy, 1998).

The aim of the present study is to obtain the sectioning points of the humeral and femoral head diameters from contemporary (UNAM-Collection and Xigui) and prehispanic skeletal series (Monte Albán, Oaxaca; La Mesa, Hidalgo, and San Gregorio, Xochimilco) and provide values for sex estimation when the pelvic bones are not preserved. This ancient and contemporary population analysis permits us to set parameters for sex estimation in forensic and bioarchaeological contexts and assess the secular trends that affect the patterns of sex variation.

MATERIALS AND METHODS

A total of 386 adult individuals (45.3% female and 54.6% male) from prehispanic (n= 176) and contemporary (n= 210) human groups were analyzed. The UNAM-Collection and the Santa María Xigui correspond to a reference series of Mexican contemporary population subjects; as well as both mestizos from Mexico City and indigenous of a rural community of Hidalgo, Mexico. The prehispanic populations are from three different Mesoamerican sites: La Mesa (in Mixquiahuala, Hidalgo), El Japón (in San Gregorio Atlapulco, Xochimilco) and Monte Albán (in Oaxaca). For the prehispanic samples sex was determined by a morphoscopic analysis of the iliac bone, according to Phenice (1969) and Bruzek (2002).

Prehispanic population samples

Monte Albán

The city of Monte Albán was the Zapotec sociopolitical and economic center from the Preclassic to the Epiclassic periods (500 b.C.- 750 a.C.) located in the southwest state of Oaxaca. Monte Albán society was stratified, with social status dependent on the individual's participation in the economy, politics and religion. Blanton (1978) identified fifteen habitational units scattered on Monte Albán's hinterland terraces, and was able to determine that the neighborhoods adjacent to the Plaza Central and the important buildings were elite residences. Most of the population resided in domestic units in Monte Albán's neighborhoods, where manufacturing activities of products such as textiles, ceramics and lithic, among others, were performed (González-Licón, 2011). The skeletons that integrate the analyzed series belonged to the former inhabitants of Monte Albán, Oaxaca. They were part of the permanent resident population of the site between the Early Classic (Monte Albán II) 200 a.C., and the Late Classic (Monte Albán III) 900 a.C. periods (González-Licón, 2011). For the analysis, 56 individuals (28.6% female and 71.4% male) were measured (Table 1).

La Mesa

The archaeological site of La Mesa, located in the occidental area of La Mina Hill, was occupied in the Epiclassic period between 600-900 a.C. From the topographic view it has a military strategic position (Bonfil, 2005). This period was characterized by migrations, anarchy and intergroup conflicts for resources and territory at a regional level. Furthermore, because of migration (induced by the collapse of Teotihuacan), it is possible that the population of La Mesa was composed of different cultural and geographical origin groups into the same settlement (González, 2017). According to the distribution, dimensions and architecture of the site, research suggests two main activities: housing and ceremonial-administrative (Bonfil, 2005). The sample was composed of 27 indivuduals (52% females and 48% males) (Table 1).

San Gregorio Atlapulco

The chronology of the osteological series of San Gregorio Atlapulco corresponds to the Late postclassic and the Contact period (Medrano, 1999). More specifically, it belongs to the archaeological site of El Japón, located in the native town of San Gregorio Atlapulco, at the northeast of Xochimilco's urban area. The site was named El Japón for the channel of the same name that runs through its western border. The Chalco channel marks its northern border and the San Sebastián channel its eastern one (Civera, 2018). In prehispanic times it was a seasonal activity area and has been classified as a tributary center during the contact period (Bullock *et al.,* 2013; Hernández, 2006). Atlapulco featured a high demogra-

phic concentration and monumental architecture (Parsons *et al.,* 1982) during prehispanic times, and it depended on Xochimilco (Civera, 2018). The main characteristic and subsistence mode of Atlapulco was agriculture based on the chinampas system. In this sample, 93 individuals were considered (57% females and 43% males) (Table 1).

Contemporary samples

UNAM-Collection

The UNAM-Collection sample consists of 150 Mexican Mestizo individuals (41.3% females and 58.7% males) from the Osteological Collection of the Physical Anthropology Laboratory, Department of Anatomy, School of Medicine of the Universidad Nacional Autónoma de México (UNAM) (Table 1). The UNAM-Collection is comprised of contemporary skeletons (1990-2010 chronological range of the years of death) belonging to unclaimed bodies from forensic institutes, public hospitals, psychiatric institutions, and shelters. The individuals have recorded antemortem data such as sex and age at death. In some cases, name, death cause and provenance are also known (Gómez-Valdés *et al.,* 2017, 2012; Menéndez Garmendia *et al.,* 2014). The study of the UNAM-Collection was conducted following the established norms in Items 4 and 5 from the Third Chapter of the Regulations for Safety and Coordination of Health Research of the Universidad Nacional Autónoma de México Legislation (Universidad Nacional Autónoma de México, 2021).

TABLE 1. *Summary age groups and sex for the analyzed samples, according to population chronological age*

Age		Population							Total
		Prehispanic				Contemporary			Total
		Monte Alban	La Mesa	San Gregorio	Total	Xigui	CDMX	Total	
Female									
Adult	n	4	4	0	8	14	11	25	33
	%	12%	12%	0%	24%	42%	33%	76%	100%
Young adult	n	4	7	26	37	1	9	10	47
	%	9%	15%	55%	79%	2%	19%	21%	100%
Middle adult	n	5	3	23	31	3	15	18	49
	%	10%	6%	47%	63%	6%	31%	37%	100%
Old adult	n	3	0	4	7	12	27	39	46
	%	7%	0%	9%	15%	26%	59%	85%	100%
Total	n	16	14	53	83	30	62	92	175
	%	9%	8%	30%	47%	17%	35%	53%	100%
Male									
Adult	n	11	1	1	13	11	16	27	40
	%	28%	3%	3%	33%	28%	40%	68%	100%
Young adult	n	11	5	18	34	2	17	19	53
	%	21%	9%	34%	64%	4%	32%	36%	100%
Middle adult	n	14	7	18	39	10	23	33	72
	%	19%	10%	25%	54%	14%	32%	46%	100%
Old adult	n	4	0	3	7	7	32	39	46
	%	9%	0%	7%	15%	15%	70%	85%	100%
Total	n	40	13	40	93	30	88	118	211
	%	19%	6%	19%	44%	14%	42%	56%	100%

Santa María Xigui

The Xigui sample consists of 60 individuals (50% females and 50% males) of Hña-Hñu -otomí- individuals from the Santa María Xigui of the Alfajayucan municipality, Hidalgo, México (Table 1). Xigui -a part of the Mezquital Valley- is a cultural and geographical region consisting of 27 Municipal localities characterized by semi-arid climate. This valley is subdivided into five sub-regions of which Alfajayucan is one of its main plains. The Mezquital Valley has been inhabited by different Native American groups that share a common genetic origin, with the Otomí population being the first to separate from the others in the late Early Preclassic period: 2500-1200 YBP (Gómez-Valdés *et al.,* 2017). In 2010, Santa Maria Xigui had a total population of 1,104 inhabitants (564 females and 540 males) of whom 37.93% were Otomí (hñä hñu) language speakers (Instituto Nacional de Estadística, Geografía e Informática, 2021). Skeletal data were obtained with informed consent from relatives during the relocation of the *Nuestro Señor San Isidro Labrador* cemetery in December of 2013. Sex and age at death data were obtained from cemetery records. The sample covers the period between 1960 and 2010 (Álvarez *et al.,* 2017; Gómez-Valdés *et al.,* 2017).

Data collection

The osteometric measurements of the maximum vertical diameter of the head of the humerus and maximum diameter of the femur head were taken using a digital sliding caliper, according to Langley *et al.* (2016) (Fig. 1) on the left side, or on the right side in its absence. As inclusion criteria, only adults in a well-preserved state, without fractures, pathological abnormalities or taphonomic alterations were analyzed. Although the age at death is not a variable of interest, we determine adulthood (entire maturation) using the ribs and the pubic symphysis (Digangi *et al.,* 2009; Gilbert & McKern, 1973; İşcan *et al.,* 1984, 1985; Mckern & Stewart, 1957;

FIGURA 1. Osteometric measurements of humeral and femoral head diameter. Humerus: the distance between the most superior and inferior points on the border of the articular surface. Femur: the maximum diameter of the femur head measured on the border of the articular surface (Langley *et al.,* 2016).

White & Folkens, 2005). A repeated measures design was carried on to evaluate the Technical Error of Measurement (TEM) (Knapp, 1992). TEM was tested in two steps. First, for UNAM-Collection, the intra (JAGV) and interobserver (external second observer) error was calculated. Subsequently, in the prehispanic samples, the maximum expected error value (1 mm) was considered at the time of acquiring the repeated measurements by one observer (AZ).

Statistical methods

The univariate statistical analysis was carried out in three stages: the first based on Shapiro-Wilk's Goodness-Fit test, which allowed us to determine whether or not it was possible to establish a normal distribution. In the second stage, One-way ANOVA (Analysis of Variance) was conducted to evaluate any significant differences ($α = 0.05$) between populations in each sex. Based on Tukey's test, we re-grouped the populations in two samples: prehispanic and contemporary. Finally, the independent sample t-test was applied ($α = 0.05$), comparing measurements between males and females. The cut-off point has been calculated as the average of the female and male mean values.

RESULTS

The percentage of TEM deviation was between a minimum of 0.48 and a maximum of 1.58. In all cases, TEM units for the intra and interobserver errors showed values less than 1 mm. The errors in humeral and femoral head measurements are similar; nevertheless, lower repeatability errors were detected on the femur head diameter. The intraobserver error is clearly inferior after taking into account a TEM criterion. In this work the margin of error was considered acceptable (Table 2).

All variables showed a normal distribution in each side and sex, tested with the Shapiro-Wilks test. The one-way ANOVA shows at least two population means that are significantly different ($p≤0.05$) between groups. Grouping of pairwise comparison obtained after the Tukey test allowed us to group Monte Albán, La Mesa and San Gregorio Atlapulco as a prehispanic sample, and UNAM and Xigui as a single group belonging to the contemporary Mexican population (Supplementary Table 1).

In Table 3, the descriptive results of female and male differences among the maximum vertical diameter of humeral and femoral head, is presented. In the prehispanic populations, the mean diameter of the humerus head for the female sample was 37.74mm, while for the males, 44.41mm. In the case of contemporary populations, the mean of the humerus is 39.31mm for the females and 44.77mm for males. Regarding the dimensions of the femoral head diameter, the female mean was 38.93mm and the male was 44.25mm for the prehispanic sample. Finally, for contemporary samples, a value of 38.73mm was calculated for the female and 44.87 mm for the male subjects (descriptive statistics of ungrouped skeletal series presented in Supplementary Table 2).

Independent samples t-test shows that sexual differences ($p≤0.05$) are observable on the considered variables for the humerus and femur, confirming that humeral and femoral head diameters are reliable indicators of sexual dimorphism. The sectioning points and associated percentages of classification rates are presented in Table 4. Prehispanic and contemporary populations had the same sectioning points, except for the humeral head diameter. The humeral head diameter provides a classification rate of 94.0% for prehispanic and 90.1% for contemporary populations; and femoral head of 90.8% and 92.5% for prehispanic and contemporary populations, respectively (Table 4).

TABLE 2. *Technical Error of Measurement (TEM)*

	Head diameter	N	TEM	%TEM
UNAM-Collection				
Intraobserver	Humerus	48	0.64	1.58
	Femur	48	0.33	0.82
Interobserver	Humerus	89	0.45	1.04
	Femur	89	0.39	0.89
Prehispanic series				
Intraobserver	Humerus	154	0.24	0.58
	Femur	200	0.20	0.48

TABLE 3. *Means, standard deviation and Shapiro-Wilk normality test for humeral and femoral head diameter*

		Female							
		N	Min.	Max.	Mean	S.D.	Shapiro-Wilk	d.f.	Sig.
Prehispanic	Humerus	67	34	42	37.74	1.74	0.973	67	0.16
	Femur	76	35	42	38.93	1.63	0.987	76	0.66
Contemporary	Humerus	91	34	43	39.31	2.01	0.968	91	0.03
	Femur	92	34	44	38.73	2.01	0.974	92	0.07

		Male							
		N	Min.	Max.	Mean	S.D.	Shapiro-Wilk	d.f.	Sig.
Prehispanic	Humerus	66	40	48	44.41	2.12	0.968	66	0.08
	Femur	84	41	49	44.25	1.90	0.980	84	0.23
Contemporary	Humerus	117	38	52	44.77	2.42	0.985	117	0.21
	Femur	118	39	51	44.87	2.41	0.987	118	0.32

Min.=Minimum; Max=Maximum; S.D.=Standard deviation; d.f.=Degree of freedom; Sig.=Significance

TABLE 4. *Univariate independent sample t-tests and associated percentage of classification rates between sexes for humeral and femoral head diameter*

Humerus

	Female	Male	t-value	d.f.	Sig.	Sectioning-Point	% Female	% Male	Total
Prehispanic	37.74	44.41	-19.86	131	0.00	41	100.0	87.9	94.0
Contemporary	39.31	44.77	-17.35	206	0.00	42	87.9	92.3	90.1

Femur

	Female	Male	t-value	d.f.	Sig.	Sectioning-Point	% Female	% Male	Total
Prehispanic	38.93	44.25	-18.91	158	0.00	42	94.7	86.9	90.8
Contemporary	38.73	44.87	-19.64	208	0.00	42	93.5	91.5	92.5

d.f.= Degree of freedom; Sig.=Significance

DISCUSSION AND CONCLUSION

In forensic anthropology and bioarchaeology, sex estimation is one of the steps to characterize and/or achieve a successful identification of unknown individuals. This research aimed to calculate sectioning points from the humeral and femoral head diameters for sex assessment in prehispanic and contemporary Mexican populations. Spradley and Jantz (2011) and Spradley *et al.* (2015) explored sexual dimorphism in postcranial metric elements through the application of uni and multivariate statistical analysis. Their results demonstrate that postcranial metric elements are more reliable sex estimators than metric traits of the skull. In fact, the authors mention that a single measurement (diaphyseal and epiphyseal diameters) provides the same classification rate as a multivariate analysis of the cranium. In the same way, various authors have provided valuable information to differentiate between sexes based on humeral and femoral head diameters (López Alonso, 1967; Milner & Boldsen, 2012; Moore *et al.,* 2016; Tise *et al.,* 2013; Vargas *et al.,* 1973).

In our work, the strong sexual dimorphism among the humerus and femur head diameters in ancient and recent Mexican populations, allowed us to propose new sectioning point values to estimate sex. Nevertheless, and contrary to other works as Guyomarc'h *et al.* (2016), we did not observe significant differences between prehispanic and contemporary populations. Accordingly, our sectioning points correspond to those reported by Spradley *et al.* (2015) from Hidalgo and Yucatan Native Americans and Mexican migrants from Tucson, Arizona. This suggests a low variation in size levels between ancient and modern Mexican populations. Nevertheless, it is important to mention that we found differences in the mean values compared with other populations (İşcan, *et al.,* 1998; Jiménez-Arenas, 2010; Kranioti & Michalodimitrakis, 2009; Milner & Boldsen, 2012; Spradley & Jantz, 2011), even in Latin American populations (Garrido-Varas *et al.,* 2014; Machado & Urgellés, 2011; Mazza, 2016; Rosique *et al.,* 2004).

However, we also observed different tendencies in the morphometric variation, in accordance with the physical activity patterns among populations. Monte Albán, La Mesa and Xigui exhibit more musculoskeletal markers on the lower limb -in contrast to San Gregorio and CDMX- due to a specific physical activity given by the highland environment. Our results support the use of the humeral and femoral sectioning points for sex assessment of prehispanic and contemporary Mexican populations. However, these values should be tested against samples from other periods and geographic populations.

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