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Osteometry of the Human Iliac Crest: Patterns of Normality and Its Utility in Sexing Human Remains

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ABSTRACT: We recorded nine measurements and one index of the iliac crest in 42 human hip bones from a Spanish skeletal collection. Common values of seven of these parameters and index are reported. We could detect statistically significant differences of means depending on side for two of these parameters (iliac crest rise, distance from the upper point of the iliac crest to the anterior superior spine) and for the iliac crest index, and relating to sex for three parameters (iliac crest arch, iliac crest rise, distance from the upper point of the iliac crest to the anterior superior spine) and for the index. These measurements and index are useful for sexing human remains.

KEYWORDS: physical anthropology, *os coxae*, sex determination, human identification

Because of its peculiar morphology and its evident sexual dimorphism, the human *os coxae* is useful from the anatomical, anthropological and forensic points of view.

Various visual criteria have been proposed to sex hip bones accurately. These are based on the observations of the morphology of the hip bone which take into account the differences between males and females, with reference to the whole *os coxae* [*1*] or only to a small fragment of the bone [*2*]. The use of these criteria, by their nature, is subjective, and many authors use osteometric approaches to reduce subjective judgment.

The diverse authors who studied human hip bones with osteometric methods focused on, either the parameters relating to the global dimensions of the *os coxae* or those of the bones making it up [*3–14*]; the greater sciatic notch [*10,14–23*]; the inferior border and the *facies symphysialis* [*23*]; the *acetabulum* [*11,14,24*]; the *foramen obturatum* [*6*]; the *linea arquata* [*14,23,25*], and distances between diverse morphologic points of the hip bone borders [*5–8,23*].

Similarly, discriminant function formulas from several variables of the hip bone [*13,14,26*] or this and other bones [*26–29*] have been used for sex determination.

On the other hand, the clinical interest of the iliac biopsy technique has led some authors to study the inner architecture of the iliac crest with histomorphometric techniques [*30*], as well as to examine the changes that take place in the iliac crest with age [*31*] and even relating to side [*32*].

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Despite our efforts, we could not find any studies intended to establish, with osteometric methods, the common morphologic pattern of the human iliac crest, nor to the possible repercussion of sexual dimorphism or side upon its outer morphology. With all this in mind, we decided to carry out this study into the frame of a larger one on the systematic construction of the human *os coxae* [*33*].

Materials and Methods

We studied a random sample of 42 human hip bones from a Mediterranean Caucasoid skeletal collection belonging to the Department of Morphological Sciences and Surgery of the University of Alcalá de Henares. All the bones were from the adult male and female dead bodies of the modern rural and urban population of Madrid (Spain). None of the bones were damaged or showed any pathological alterations that could lead to error in measurements. From the 42 dry hip bones, 26 were from the right side and 16 from the left; likewise 27 were male and 15 female hip bones.

For each one of the 42 hip bones, nine parameters of the iliac crest were measured (Fig. 1 to 3):

1. Iliac width or distance from the anterior superior spine to the posterior superior spine (distance ASS-PSS).
2. Curved length of the iliac crest, taken from the anterior superior spine to the posterior superior spine (iliac crest arch).
3. Maximum thickness of the iliac crest in its anterior third (anterior thickness).

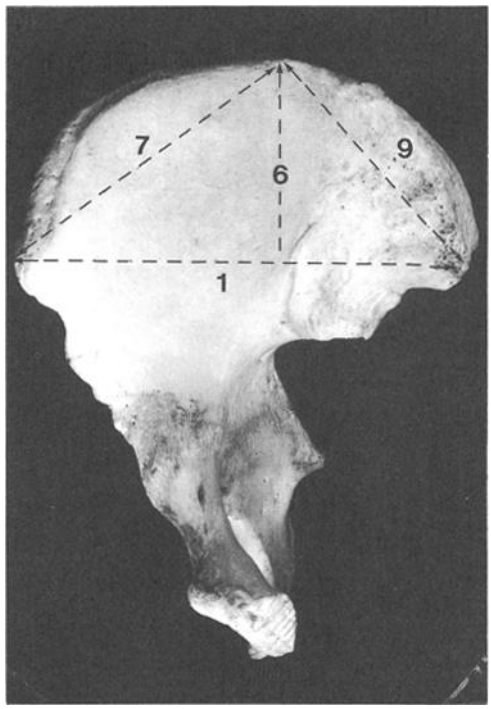

FIG. 1—*Parameters number 1 (distance ASS-PSS), 6 (iliac crest rise), 7 (distance Apex-ASS) and 9 (distance Apex-PSS).*

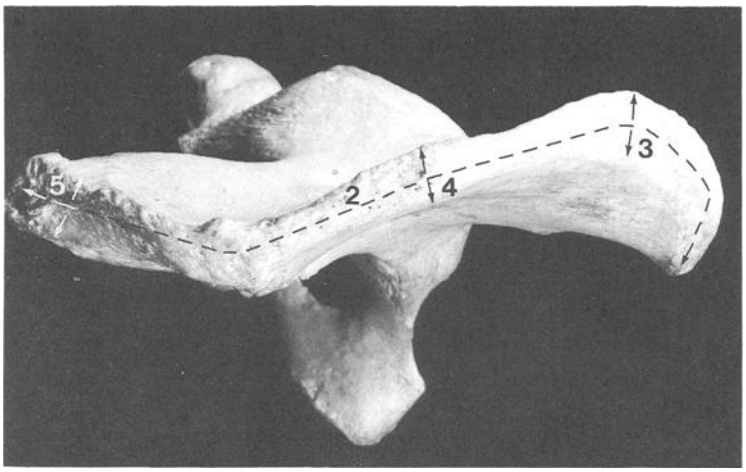

FIG. 2—*Parameters 2 (iliac crest arch), 3 (anterior thickness), 4 (middle thickness) and 5 (posterior thickness).*

FIG. 3—*Parameter 8 (distance tubercle-ASS).*

4. Maximum thickness of the iliac crest in its middle third (middle thickness).
5. Maximum thickness of the iliac crest in its posterior third (posterior thickness).
6. Maximum rise of the superior border or maximum line perpendicular to the plane of the iliac width from the iliac crest (iliac crest rise).
7. Distance from the upper point of the iliac crest to the anterior superior spine (distance apex-ASS). The upper point of the iliac crest is the point of the iliac crest to which a plane parallel to that of the iliac width is tangent.
8. Minimum distance from the tubercle of the iliac crest to the anterior superior spine (distance tubercle-ASS).

9. Distance from the upper point of the iliac crest to the posterior superior spine (distance apex-PSS).

To obtain the measurements, we used an osteometric board, two callipers with ± 0.05 mm accuracy, inextensible thread, two metallic squares able to be held on a plane and a metallic millimetre ruler. All the measurements were taken in millimetres with two decimals.

In order to avoid measuring errors, as those reported by Clabeaux Geise [*34*], the measurements were performed days in which the relative humidity was not over 55%. Likewise, three estimates of each measurement of each bone were made by the same operator, the mean value being used in the study.

In addition, one index was calculated:

$$\text{Iliac crest index} = (\text{iliac crest rise/distance ASS-PSS}) \times 100.$$

For the statistical analysis of data, the total sample was subdivided according to sex, which produced two subsamples of 15 female specimens and 27 male, in which we calculated, for each measurement and index, its histogram, mean, standard deviation, standard error of the mean, sample size, and maximum and minimum values. The existence (or nonexistence) of significant difference of means by sex could be determined to, at least, 95% accuracy. To obtain this, we analyzed first the equality of variances with Levene's F-test [*35*]. Then, we studied the equality of means with Student's T-test, either separate or pooled, depending on the verification or non verification of the statistically significant difference of variances.

Next, the total sample was subdivided according to side (26 right and 16 left) and we proceeded in a similar way as in the above mentioned study to analyze sex differences.

Results and Discussion

The mean ($\overline{X}$), standard error of the mean (SEM) and standard deviation (SD) for each parameter and index from the subsamples by sex, are shown on Table 1, and those relating to the subsamples by side are shown on Table 2. On Table 3, we can see the signification levels, that is, *P* for the statistics F (Levene's), T separate and T pooled, obtained from the subsamples according to sex and those relating to side. Table 4 shows the statistical data ($\overline{X}_m$, 95% CI, $\overline{X}_f$, 95% CI, D, SED, 95% CI, *P* VALUE) for the parameters with statistically significant differences of means relating to sex.

The distance from the anterior superior spine to the posterior superior spine (distance ASS-PSS) was studied by Martin and Saller, [*5,6*] in its relation to sex and race, showing

TABLE 1—*Values obtained for the subsamples relating to sex.*

Variables	Male (n = 27) $\overline{X}$	ST DEV	SEM	Female (n = 15) $\overline{X}$	ST DEV	SEM
Distance ASS-PSS	150.79	8.11	1.56	147.83	6.15	1.58
Iliac crest arch	238.74	17.30	3.33	221.64	15.78	4.07
Anterior thickness	17.75	1.98	0.38	16.71	1.62	0.42
Middle thickness	11.53	2.27	0.43	10.44	2.48	0.64
Posterior thickness	18.68	2.70	0.52	17.82	2.21	0.57
Iliac crest rise	67.04	5.57	1.07	56.00	6.95	1.79
Distance apex-ASS	96.59	10.67	2.05	88.85	10.43	2.69
Distance tubercle-ASS	59.06	7.96	1.53	54.43	8.87	2.29
Distance apex-PSS	107.97	11.49	2.21	101.54	10.50	2.71
Iliac crest index	44.50	3.36	0.64	37.86	4.33	1.11

TABLE 2—*Values obtained for the subsamples relating to side.*

Variables	Right (n = 26) $\bar{X}$	SD	SEM	Left (n = 16) $\bar{X}$	SD	SEM
Distance ASS-PSS	149.53	7.76	1.52	150.06	7.37	1.84
Iliac crest arch	229.75	21.42	4.20	237.32	11.68	2.92
Anterior thickness	17.20	1.80	0.35	17.66	2.11	0.52
Middle thickness	10.84	2.30	0.45	11.63	2.48	0.62
Posterior thickness	18.37	2.83	0.55	18.38	2.07	0.51
Iliac crest rise	61.26	9.23	1.81	66.07	4.46	1.11
Distance apex-ASS	90.54	11.60	2.27	99.17	8.01	2.00
Distance tubercle-ASS	57.26	8.63	1.69	57.65	8.52	2.13
Distance apex-PSS	107.20	13.49	2.64	103.19	6.68	1.67
Iliac crest index	40.91	5.37	1.05	44.09	3.25	0.81

TABLE 3—*Value of P for test of equality of variances (Levene's F) and means (T Separate (S) or T Pooled (P)), relating to sex and side.*

Variables	Sex		Side	
	Levene's F test	Student's T test (S or P)	Levene's F test	Student's T test (S or P)
Distance ASS-PSS	.4384	P .2273	.6509	P .8273
Iliac crest arch	.9847	P .0030[b]	.0181	S .1473
Anterior thickness	.1952	P .0912	.1635	P .4507
Middle thickness	.6822	P .1574	.3943	P .3050
Posterior thickness	.3477	P .2973	.1507	P .9977
Iliac crest rise	.1644	P .0000[c]	.0111	S .0296[a]
Distance apex-ASS	.7285	P .0286[a]	.1307	P .0127[a]
Distance tubercle-ASS	.3194	P .0908	.7506	P .8887
Distance apex-PSS	.9324	P .0811	.0196	S .2076
Iliac crest index	.2847	P .0000[c]	.0453	S .0217[a]

[a]Significant at $P \leq 0.05$.
[b]Significant at $P \leq 0.01$.
[c]Significant at $P \leq 0.001$.

differences but without using hypothesis test. Similarly Olivier [7] reported that in white women it was 8 mm smaller than in males. The mean and SD obtained by us for this parameter from male and female hip bones are similar to those reported by Day and Pitcher-Wilmott [13] and slightly higher than Rose's ones [36]; likewise, Iscan's values [29] are higher than ours. Laffont et al. [9] found similar mean values for both sides. Trouilloud et al. [37] reported mean values of 150 mm but without discriminating sex nor side. According to our sample data, the existence of significant differences of means between sexes or sides (Table 3) cannot be affirmed for this parameter.

According to our results the thickness of the iliac crest is not uniform, being higher at its posterior third and anterior third levels, what agrees with Gómez Oliveros qualitative observation [1]; we must point out that we could not find significant differences depending on sex for these parameters.

Regarding the minimum distance between the tubercle of the iliac crest and the anterior superior spine (distance tubercle-ASS), Testut and Latarjet [38], and Williams and Warwick [39] reported values similar to ours (5 to 6 cm), though they did not discriminate sex nor side.

TABLE 4—*Statistically significant differences of means relating to sex for the various parameters of the human iliac crest* (n = *42*).

Variables	Male (n = 27)	95% CI		Female (n = 15)	95% CI		Differences of means		95% CI		
	$\bar{X}_m$	Lower	Upper	$\bar{X}_f$	Lower	Upper	D	SED	Lower	Upper	P Value
Iliac crest arch	238.74	231.88	245.60	221.64	212.93	230.35	17.10	5.54	11.56	22.64	.0030[b]
Iliac crest rise	67.04	64.84	69.24	56.00	52.17	59.83	11.04	2.01	9.03	13.05	.0000[c]
Distance apex-ASS	96.59	92.37	100.81	88.85	83.10	94.61	7.74	3.49	4.25	11.23	.0286[a]
Iliac crest index	44.50	43.18	45.82	37.86	35.48	40.23	6.64	1.23	5.41	7.87	.0000[c]

[a]Significant at $P \leq 0.05$.
[b]Significant at $P \leq 0.01$.
[c]Significant at $P \leq 0.001$.
$\bar{X}_m$ means for male; $\bar{X}_f$ means for female; 95% CI: 95% confidence interval of the mean; D: differences of means; SED: standard error of the difference of the means; P VALUE: P value for Student's T test.

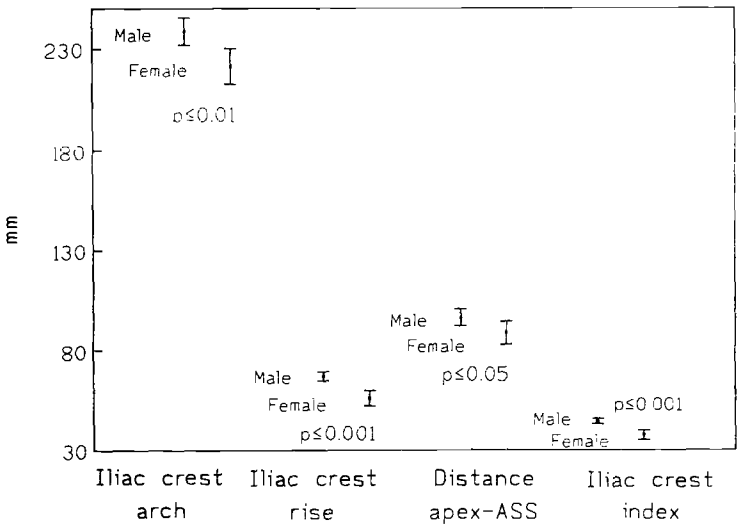

FIG. 4—*Means for the various parameters of the human iliac crest.*

Three parameters of ours, iliac crest arch, iliac crest rise and distance between the upper point of the iliac crest and the anterior superior spine (distance apex-ASS), as well as the iliac crest index (Table 4), show statistically significant differences of means depending on sex; therefore they can be used for sexing human remains when the iliac crest is undamaged. And here we must point out the maximum rise and the iliac crest index, whose probability of error in affirming these differences of means is .0000 (Table 3), thereby we think these two parameters are the most useful for sexing human skeletal remains.

The iliac crest arch has a P value ($P \leq 0.01$) higher than the above mentioned parameters.

Finally, the distance between the upper point of the iliac crest and the anterior superior spine (distance apex-ASS) has shown a probability of error even higher ($P \leq 0.05$), being the least accurate for sexing human skeletal remains.

Our results allow us to affirm that in its systematic construction the *os coxae* shows a marked sexual dimorphism evident at the iliac crest, with the male hip bone having a higher arch, and in which the iliac crest has, specially in its anterior third, a more marked superior convexity.

Figure 4 shows, for these four parameters, the mean and the limits of its 95% confidence interval in male and female hip bones.

We found statistically significant differences of means depending on side (at $P \leq 0.05$), for two parameters (iliac crest rise and distance apex-ASS), as well as for the iliac crest index, the values being higher for left hip bones (Table 3).

Summary

We recorded nine measurements and one index of the iliac crest in 42 human hip bones from a Mediterranean Caucasoid skeletal collection. Common values of seven of these parameters and index are reported for the first time. We could detect statistically significant differences of means depending on side for two of these parameters (iliac crest rise and distance from the upper point of the iliac crest to the anterior superior spine) and for the iliac crest index, and relating to sex for three parameters (iliac crest arch,

iliac crest rise and distance from the upper point of the iliac crest to the anterior superior spine) and for the index. These measurements and index are useful for sex determination from *os coxae* or hip bone fragments in which the iliac crest is undamaged.

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