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TECHNICAL NOTE

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Metacarpal Sexual Determination in a Spanish Population

ABSTRACT: Anthropologists and forensic pathologist determine the sex of skeletons by analyzing quantitative and qualitative characters in the bone remains. Generally, the skull and os coxae are the elements most used, but they are not always preserved. In such cases, the investigator needs to have available other techniques based on different remains. The aim of the present work is to develop and describe discriminating functions for sex determination in a recent Spanish population using metacarpal morphology. A sample of bones corresponding to a contemporary Spanish population deposited at the Complutense University of Madrid (UCM) was analyzed. This sample comprised 697 metacarpals, corresponding to 79 adult individuals (37 men and 42 women). These allowed us to obtain 120 unifactorial discriminant functions. We selected the 10 equations, one for each metacarpal from both hands, that provided the best sexual discrimination. The correct sex classification rank progressed from 81%, for right (R) metacarpals IV and V, to 91%, for left (L) metacarpal II. The results suggest that metacarpals are structures that can be used for sex determination in paleoanthropological and forensic identifications.

KEYWORDS: forensic science, forensic anthropology, human identification, sexual determination, metacarpals, hand bones, discriminant functions, Spanish population

In human society, each day sees accidental deaths and criminal activities requiring investigative techniques that are precise enough to identify the deceased. Examples where this is important are aviation catastrophes, floods, fires, homicide, terrorist acts, etc., in which fragmented or incomplete skeletal remains are often present. In these cases, forensic analysts have available a number of pieces of skeletal evidence from which they must obtain the maximum biological information, and sex identification is an essential step in their professional activity. Indeed, in most cases, clarification of the events that took place, and hence later juridical decisions, will depend on the precision and the reliability of their work. For this reason, it is crucial to obtain the best information from the remains (1,2).

These theoretical principles are not only useful in the medical-forensic area, but can also be applied in the archeological world, especially in the field of life-style reconstruction of ancient populations. Bone remains permit information about the different mechanisms of human adaptation to the environment to be collected, and they provide reliable data about cultural mores and/or sicknesses in ancient human populations (3). Currently, skeletal analysis is fundamental for reconstructing sex distribution in necropolises, and sex determination is a primary aspect of anthropological interest in any personal identification in the forensic field.

The sex of the person to which a skeleton once belonged can be estimated by analysis of the qualitative (4–6) and quantitative (7–16) morphological characteristics of all the osseous remains. The practical utility of discrete traits of the skull, os coxae, mandible, etc., is undeniable, although some authors prefer to use discriminant equations because of their objectivity and reproducibility (9–12,15). Unfortunately, technical application would be limited to the specific population from which the bone remains were obtained (3,12,17). This methodical limitation of the mathematical functions is related to the variability of a population with respect to body size and it is therefore crucial to have functions for each bone of the skeleton in different human populations.

During the last 10 years or so, our team has obtained sexual determination functions for a Spanish population of known sex and age from the os coxae (10), tibia (18), femur (11,12), fibula (19), ulna (20), and radius (13). The aim of the present work is to obtain discriminant equations for the metacarpals of the current Spanish population. Unfortunately, it is sometimes the case that complete bone structures or structures in a perfect state of preservation are not available, and hence our aim is to generate discriminant functions with the least number of variables possible for this European population, which can be used when any of the epiphyses are preserved and at the same time provide maximum reliability in sex diagnosis.

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Material and Methods

In this work, we analyzed a total of 697 metacarpals (342 males and 355 females) corresponding to 79 adult individuals (37 men and 42 women). The skeletal collection is deposited at the Complutense University of Madrid (UCM) and it corresponds to a contemporary Spanish of European origin population of known

TABLE 1—*Variables used in the present study.*

Number	Variable	Denomination	Author
1	ML	Maximum length	Smith (48) (Metacarpal I); Smith (47) (Metacarpal II–V)
2	MLDPE	Mediolateral diameter of proximal epiphysis	Scheuer and Elkington (22)
3	APDPE	Antero-posterior diameter of proximal epiphysis	Scheuer and Elkington (22)
4	ECD	Epicondylar diameter	Scheuer and Elkington (22)
5	MLDDE	Mediolateral diameter of distal epiphysis	Smith (47)
6	APDDE	Antero-posterior diameter of distal epiphysis	Scheuer and Elkington (22)
7	MLDM	Mediolateral diameter at midshaft	Falsetti, (37) (Metacarpal I and V); Kusec et al. (24) (Metacarpal II–IV)
8	APDM	Antero-posterior diameter at midshaft	Smith (47)

The numerical code refers to the contents of Fig. 1.

sex and age (20–91 years) whose members died between 1975 and 1985.

The quantitative analysis was implemented considering only metacarpals that did not show evident pathological lesions such as fracture, osteoarthritis, arthritis, or perimortem traumatic alterations. A total of eight morphological variables were collected, attending to the dimensions of both the epiphyses and diaphyses. Thus, from the forensic and archeological points of view, we established useful discriminant equations, even with incomplete bone remains. The designations of the variables are shown in Table 1, the morphological localization being indicated visually in Fig. 1.

Each of eight anatomical dimensions was measured on three independent occasions by one of the authors (P. B.), after which the values were averaged to reduce intraobserver error. A Sylvac digital caliper accurate to 0.01 mm was used as the measuring instrument.

The usefulness of discriminant functions largely depends on the normality of the data distribution and the equality of the covariance matrices. After having verified the normality in sample distribution, here, we performed a study of laterality by sexes using analysis of variance (ANOVA) with a view to recording possible bimanual morphological differences. We also analyzed the existence of significant differences between the means of both sexes for each of variables analyzed, applying the one-way ANOVA procedure of the SPSS software, version 11.0 (SPSS Inc., Chicago, IL).

The sexual dimorphism index (SDI) of the sample was estimated by index $100 \times (Mm/Mf)$, Mm and Mf being the average of the male and female series, respectively, for each variable. The mathematical analysis with the purpose of obtaining the univariant discriminant functions was carried out using the DISCRIMINANT procedure of the SPSS software, version 11.0 (SPSS Inc.). The degree of correspondence in sex determination was obtained using a cross-validation method in which each metacarpal was classified by functions derived from all cases of the sample, with the exception of that metacarpal.

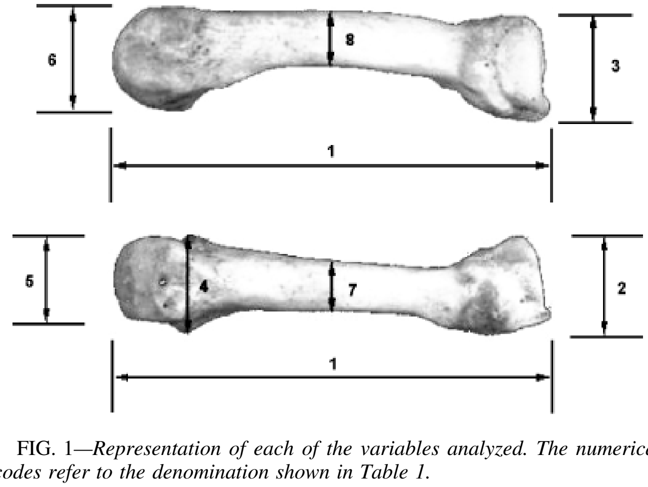

FIG. 1—*Representation of each of the variables analyzed. The numerical codes refer to the denomination shown in Table 1.*

Results

Tables 2 and 3 show the descriptive statistics obtained according to the sex of the individual. The first one (Table 2) shows the male series and it shows that right-hand metacarpals are generally larger than those of the left hand. Theoretically, this was expected because of a bimanual functional difference in which use of the right side often predominates. However, significant differences were only seen for the ECD variable of metacarpal III, and this made it unnecessary to consider laterality criteria, with the exception of the above variable. Likewise, on four occasions, the mean values for the left hand were slightly higher. This was the case for the variables APDPE of metacarpal I, ML and APDDE of metacarpal III, and APDDE of metacarpal IV. However, the differences do not exceed the limit of statistical significance. Table 3 shows the means of the female series and in general the results are similar to those found for the males. The right-handed metacarpals had slightly larger longitudinal and transverse dimensions, with the exception of the ML of metacarpal I and the APDDE of left metacarpal III, although significant differences were only seen for the MLDDE of metacarpals II and IV, the APDPE of metacarpal III, and the MLDPE of metacarpal IV. These would be the four variables for which it would be necessary to consider laterality in the women.

On average, the male metacarpal dimensions are higher than the female series. So, the statistic analysis (ANOVA) of average sexual differences for each variable reached values of statistical significant ($p < 0.001$). Table 4 shows the SDI for five metacarpals analyzed considering laterality and both sides together. The dimorphism index is always greater than 100, as expected. The SDI reaches the maximum value for the DPDM of left metacarpal I; in men, this variable is 17.6% greater than in women. The minimum value corresponds to the ML of right metacarpal V, with a difference of only 8.0%. With both sides together, the maximum and minimum values correspond to the same variables, with levels of 17.1% and 8.8%, respectively.

Our results indicate a marked sexual dimorphism in the series analyzed, suggesting that the transverse dimensions are sexually more dimorphic than the longitudinal ones. However, a different trend is seen when the epiphysis or shaft are considered. In the former case, the medio-lateral diameters prove to be the most dimorphic, while in the midshaft of the bone the greatest dimorphism is seen for the antero-posterior diameter. On average, upon analyzing eight variables, and considering five metacarpals at the same time, it is clear that the lowest SDI corresponds to the ML

TABLE 2—*Univariate statistics in the male series.*

Males—UCM		Metacarpal I			Metacarpal II			Metacarpal III			Metacarpal IV			Metacarpal V		
Variable	Side	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD
ML	L	31	46.11	2.75	32	67.55	3.12	33	66.60	3.49	31	57.21	3.00	32	53.66	2.98
	R	34	46.49	2.32	35	67.73	3.29	34	66.01	3.65	36	56.95	3.00	32	53.68	2.62
	Pooled	65	46.31	2.52	67	67.64	3.19	67	66.30	3.56	67	57.07	2.98	64	53.67	2.79
MLDPE	L	29	16.25	1.18	33	18.28	1.04	33	14.57	1.21	30	12.57	1.14	32	14.21	0.97
	R	31	16.47	0.92	34	18.55	1.30	34	14.69	1.20	35	12.87	1.23	33	14.31	0.90
	Pooled	60	16.36	1.05	67	18.42	1.18	67	14.63	1.19	65	12.73	1.19	65	14.26	0.93
APDPE	L	27	16.63	1.26	32	17.65	1.27	33	16.78	1.04	29	12.58	0.98	30	11.38	0.93
	R	30	16.57	1.13	34	18.19	1.24	33	17.09	1.16	35	12.70	0.89	32	11.82	0.88
	Pooled	57	16.60	1.18	66	17.93	1.28	66	16.94	1.10	64	12.65	0.93	62	11.61	0.92
ECD	L	30	16.30	1.30	32	14.99	0.99	33	14.67	0.96	32	12.87	0.74	29	11.99	0.90
	R	31	16.41	1.10	34	15.30	0.95	35	15.19	1.18	35	13.13	0.84	33	12.14	0.81
	Pooled	61	16.35	1.19	66	15.15	0.98	68	14.94	1.10	67	13.01	0.80	62	12.07	0.85
MLDDE	L	30	14.70	1.05	34	14.19	0.86	31	13.86	1.01	28	12.01	0.98	28	11.63	0.84
	R	31	14.70	0.88	32	14.76	0.80	32	14.19	1.03	36	12.14	0.96	33	11.78	0.77
	Pooled	61	14.70	0.96	66	14.40	0.88	63	14.03	1.02	64	12.08	0.96	61	11.71	0.80
APDDE	L	29	14.26	1.24	33	14.54	0.99	31	14.63	0.96	28	13.09	0.74	28	11.85	0.69
	R	30	14.27	1.24	31	14.74	0.98	32	14.54	1.0	36	13.02	0.88	33	12.09	0.70
	Pooled	59	14.27	1.23	64	14.64	0.98	63	14.58	0.98	64	13.05	0.81	61	11.98	0.70
MLDM	L	32	11.99	1.11	36	8.47	0.54	34	8.50	0.48	32	6.83	0.64	33	7.78	0.78
	R	35	12.28	1.00	35	8.68	0.56	35	8.53	0.55	36	6.97	0.68	32	8.00	0.83
	Pooled	67	12.14	1.06	71	8.57	0.56	69	8.52	0.51	68	6.90	0.66	65	7.89	0.81
APDM	L	32	9.04	0.77	36	9.32	0.68	34	9.35	0.70	32	7.72	0.67	33	7.14	0.72
	R	35	9.10	0.77	35	9.60	0.72	35	9.58	0.71	36	7.89	0.63	32	7.35	0.70
	Pooled	67	9.07	0.76	71	9.46	0.71	69	9.47	0.71	68	7.81	0.65	65	7.24	0.71

The table indicates the number of cases analyzed (*n*), the average (*m*), and standard deviation (SD). Also shown are the averages corresponding to the left side (L), the right side (R), and both sides (Pooled). For abbreviation of variables see Table 1.
UCM, Complutense University of Madrid.

(10%), while the most dimorphic dimension is MLDDE (14%). On considering the average degree of dimorphism per metacarpal, it can be seen that in the Spanish sample analyzed, the SDI decreases in the following order I > IV > II > III > V.

The unifactorial statistics point to a marked dimorphism in the series analyzed. This suggests the usefulness of metacarpals in evaluating differences between the sexes. However, the laterality analysis only revealed a reduced number of bimanual differences,

TABLE 3—*Univariate statistics in the female series.*

Females—UCM		Metacarpal I			Metacarpal II			Metacarpal III			Metacarpal IV			Metacarpal V		
Variable	Side	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD	*n*	*m*	SD
ML	L	33	41.61	2.31	37	61.67	2.78	36	60.50	2.89	34	51.76	2.21	31	48.96	2.18
	R	29	41.57	2.32	36	61.86	2.91	35	60.61	2.80	33	52.45	2.19	35	49.69	2.17
	Pooled	62	41.59	2.30	73	61.76	2.83	71	60.56	2.83	67	52.10	2.21	66	49.35	2.19
MLDPE	L	32	14.51	1.07	37	15.84	0.80	37	13.00	0.77	34	11.06	0.85	31	12.39	0.82
	R	29	14.80	0.79	36	16.11	0.96	34	13.12	0.78	31	11.39	1.09	36	13.03	0.82
	Pooled	61	14.65	0.95	73	15.98	0.89	71	13.06	0.77	65	11.22	0.98	67	12.73	0.88
APDPE	L	30	14.42	1.07	37	15.76	0.87	37	14.85	0.81	34	10.97	0.75	31	10.34	0.92
	R	26	14.59	1.14	35	16.29	0.94	35	15.15	0.91	33	11.38	0.69	36	10.81	1.04
	Pooled	56	14.50	1.10	72	16.01	0.94	72	15.00	0.87	67	11.17	0.75	67	10.59	1.01
ECD	L	35	14.33	1.11	38	13.69	0.99	36	13.29	1.19	33	11.67	0.89	31	10.81	0.90
	R	30	14.75	1.09	34	13.86	0.94	36	13.65	1.18	32	11.93	0.87	35	11.00	0.76
	Pooled	65	14.52	1.11	72	13.77	0.97	72	13.47	1.19	65	11.80	0.89	66	10.91	0.83
MLDDE	L	35	12.60	0.98	36	12.65	0.83	36	12.29	1.01	33	10.27	0.71	31	10.26	0.88
	R	30	12.70	0.81	31	12.85	0.91	32	12.46	0.86	33	10.74	0.75	36	10.60	0.78
	Pooled	65	12.65	0.90	67	12.74	0.87	68	12.37	0.94	66	10.51	0.76	67	10.44	0.84
APDDE	L	35	12.63	1.17	35	13.27	1.02	36	13.33	1.08	34	11.54	0.68	31	10.80	0.77
	R	29	12.65	1.16	31	13.38	1.05	32	13.22	1.27	33	11.73	0.77	36	11.04	0.79
	Pooled	64	12.64	1.16	66	13.32	1.03	68	13.28	1.16	67	11.64	0.72	67	10.93	0.78
MLDM	L	33	10.48	1.10	38	7.48	0.62	37	7.66	0.63	34	6.06	0.64	31	6.93	0.73
	R	30	10.88	1.05	36	7.62	0.55	36	7.72	0.57	32	6.25	0.63	36	7.18	0.68
	Pooled	63	10.67	1.09	74	7.55	0.58	73	7.69	0.60	66	6.15	0.64	67	7.06	0.71
APDM	L	33	7.69	0.85	38	8.35	0.75	37	8.40	0.66	34	6.70	0.65	31	6.39	0.79
	R	30	7.82	0.90	36	8.63	0.78	36	8.70	0.65	32	6.90	0.75	36	6.64	0.58
	Pooled	63	7.75	0.87	74	8.49	0.77	73	8.55	0.67	66	6.80	0.71	67	6.52	0.69

The table indicates the number of cases analyzed (*n*), the average (*m*), and standard deviation (SD). Also shown are the averages corresponding to the left side (L), the right side (R), and both sides (Pooled). For abbreviation of variables see Table 1.
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TABLE 4—*Sexual dimorphism (SDI) by right, left, and pooled side by metacarpals.*

Sexual Dimorphism		SDI				
Variables	Side	M I	M II	M III	M IV	M V
LMMC	L	110.829	109.531	110.079	110.522	109.586
	R	111.838	109.495	108.912	108.587	108.038
	Pooled	111.352	109.521	109.489	109.540	108.758
MLDPE	L	111.963	115.347	112.085	113.588	114.694
	R	111.295	115.163	111.979	112.951	109.840
	Pooled	111.706	115.280	112.062	113.445	112.000
APDPE	L	115.359	112.042	112.984	114.745	110.130
	R	113.516	111.669	112.823	111.616	109.293
	Pooled	114.470	111.955	112.934	113.232	109.584
ECD	L	113.738	109.496	110.388	110.310	110.925
	R	111.228	110.400	111.283	110.093	110.342
	Pooled	112.597	110.024	110.899	110.268	110.616
MLDDE	L	116.668	112.205	112.797	116.958	113.382
	R	115.730	114.888	113.903	113.021	111.099
	Pooled	116.233	113.556	113.422	115.020	112.141
APDDE	L	112.932	109.551	109.805	113.376	109.793
	R	112.842	110.183	109.937	110.972	109.500
	Pooled	112.897	109.871	109.841	112.143	109.642
MLDM	L	114.418	113.196	110.926	112.697	112.233
	R	112.844	113.911	110.552	111.439	111.527
	Pooled	113.778	113.565	110.747	112.180	111.708
APDM	L	117.596	111.581	111.271	115.227	111.784
	R	116.401	111.279	110.171	114.453	110.655
	Pooled	117.058	111.454	110.757	114.960	111.025

For abbreviation of variables see Table 1.

especially in the male series. This suggests a reduced and not very significant effect of the theoretical functional laterality at least in this Spanish series.

The analytical design permitted us to obtain 120 discriminant equations from only one variable (40 for the right side, 40 for the left side, and 40 for both sides together). Table 5 shows 10 functions—those offering the greatest percentage of correspondence between the true sex and the estimated sex—for 10 metacarpals. Methodological use of the ten functions is easy: it consists in substituting the values obtained for each variable in the function. Values above 0 will suggest a male diagnosis, while less than 0 values will correspond to females. Table 5 shows the lowest value from which we are able to diagnose a metacarpal as belonging to a male.

The correspondence probability in sex determination of each variable is reasonably distinct. In Table 5, we can see the results obtained for the UCM series. The percentage of correspondence for the sample analyzed by combining both sexes and the proportion of male and female metacarpals whose sex was incorrectly assigned by cross-validation can be seen. Evidently, the results indicate that epiphysis variables offer more reliable sex diagnoses. The proximal epiphysis appears as the most suitable variable for sex determination in four left metacarpals (I, II, III, and V) and two right metacarpals (II and III). Only right metacarpal I shows a shaft function as the most suitable variable for sex identification. The percentages of correspondence exceed 81% success in all cases. The highest value (91.4%) appears for function (3), based on the MLDPE of left metacarpal II and the lowest one (81.2%) for functions (8) and (10), based on the APDDE of right metacarpal IV and MLDDE of right metacarpal V.

Likewise, the probability of misclassification is not the same if the male and female series are analyzed separately (Table 5). Equations (2), (7)–(9) show an excess of female metacarpals diagnosed as belonging to males. The rest of the functions afford the opposite results; female diagnoses predominate even though the metacarpals are really male. Function (9) is the one with the greatest equilibrium in the distribution of diagnostic error (1:1.04), while function (3) shows a close sixfold higher rate (5.6:1).

Discussion

The results of this study indicate that metacarpals are useful bones for sex assessment in a Spanish population. This is undoubtedly the consequence of the differences in body size between both sexes. Many authors have reported that the mean human male skeletal dimensions generally exceed those of females (3,21,22). It has also been suggested that in modern populations, sex differences reach an average close to 7–8% (23). Thus, it would appear that the logical statistical analysis carried out for the UCM skeletal series indicates that all male metacarpal dimensions are significantly greater than those of females.

The results of the laterality analysis point to the existence of a differential development between the right and the left sides. In general, on comparing both extremities, one might be led to think that asymmetry in the lower limbs would be less pronounced than in the upper limbs because everybody uses legs to walk but one's arms, especially the hands, are used for more diverse activities. Kusec et al. (24) indicate the presence of bilateral symmetry in metacarpal dimensions in the population of Pag Island in Croatia. However, owing to the greater physical right-handed activity, even before birth (25), it would seem logical to assume the existence of a preferential morphological development for this hand in our species, especially in the case of the metacarpals (26). The results obtained in our Spanish series are in agreement with the expected behavior. However, the number of significant

TABLE 5—*Coefficients and the discriminant functions of the metacarpals based on a single variable.*

Metacarpal	Variables	Cases	Discriminant Functions	Male if	Percentage of Correspondence	Percentage Misclassified Male	Percentage Misclassified Female
I L	1. AP diam. proximal epih.	57	$0.859 \times$ APDPE − 13.286	> 15.47	86.0	18.5	10.0
I R	2. Maximum length	63	$0.431 \times$ ML − 19.063	> 44.23	85.7	11.8	17.2
II L	3. ML diam. proximal epiph.	70	$1.084 \times$ MLDPE − 18.418	> 16.99	91.4	15.2	2.7
II R	4. ML diam. proximal epiph.	70	$0.880 \times$ MLDPE − 15.220	> 17.30	88.6	17.6	5.6
III L	5. AP diam. proximal epiph.	70	$1.079 \times$ APDPE − 17.064	> 15.76	86.8	18.2	8.6
III R	6. AP diam. proximal epiph.	68	$0.965 \times$ APDPE − 15.531	> 16.09	87.1	21.2	5.4
IV L	7. AP diam. distal epiph.	62	$1.413 \times$ APDDE − 17.295	> 12.24	88.7	10.7	11.8
IV R	8. AP diam. distal epiph.	69	$1.211 \times$ APDDE − 15.023	> 12.41	81.2	16.7	21.2
V L	9. ML diam. proximal epiph.	63	$1.111 \times$ MLDPE − 14.788	> 13.31	87.3	12.5	12.9
V R	10. ML diam. distal epiph.	69	$1.297 \times$ MLDDE − 14.478	> 11.16	81.2	21.2	16.7

It also appears classification accuracy of the functions. For abbreviation of discriminant functions see Table 1.

differences was unexpectedly smaller. Thus, five out of 80 comparisons made (40 for each sex) exceeded the 0.05 level of statistical significance. This value only represents 6.25% of all the comparisons, with an unequal distribution by sex because the males had a proportion of 2.5% (1/40) while females reached 10% (4/40). The meaning is evident, if one rules out the statistical weight caused by pronounced variability between both sexes; the almost complete absence of asymmetry in the metacarpals of the series analyzed permits the assumption of a physical activity in which the use of both hands prevents the development of bimanual differences. It seems reasonable to think that the usual activity of the individuals analyzed would have required regular use of both hands.

The SDI confirms the results of previous statistical comparison by sexes. Male metacarpals have larger dimensions than females ones, in particular if transversal variables are considered. Actually, the mediolateral and antero-posterior diameters offer a higher SDI than the maximum length. Our results are in accordance with observations referring to both metacarpals (22) and different long bones (12,27–34). These results, if the transversal variables are considered, could be due to the mechanical response of the bone owing to the greater muscular demand of males. Such a hypothesis would be supported by the work of DiBennardo and Taylor (28), France (29), and Ruff (35), who suggest that epiphyseal dimensions are more conditioned than the longitudinal variables because of functional stress and physical activity. Black (27), however, offered an alternative, proposing that during development, males would generate a larger amount of cortical bone and that when they reach adulthood their bones would have a rhythm of osseous remodeling different from that seen in female bones.

The degree of preservation of shaft and epiphysis depends on morphological and structural factors and on taphonomic parameters. It is clear that this degree of preservation would be different from one skeletal series to another. Accordingly, we believe that it is essential to obtain discriminant functions that will allow the determination of sex in any type of nondeteriorated osseous fragment. Our design focused on equations with a single variable because archeological or forensic material rarely contains whole unfragmented bone structures. Different authors (9) have indicated that it is often possible to find a more measurable epiphysis than the shaft in the long bones. Our experience in the forensic and archeological fields also confirms this.

Zanella and Brown (36) have estimated the applicability of discriminant functions by comparing the correspondence results of the equations of Scheuer and Elkington (22), Falsetti (37), and Stojanowski (38), addressing a sample of metacarpals from subjects in the United States. Their results indicate that correct sex identification depends on both the method chosen and metacarpal analyzed. In fact, the biological origin of a sample is undoubtedly a limiting factor in the use of the mathematical equations (3,12,17). Similarly, the secular change in metacarpal dimensions could be also another limiting factor.

For the above reasons, we elaborated discriminant equations for the current Spanish population. To date, anthropologists and forensics have lacked mathematical functions for metacarpals based on contemporary Spanish series of known sex and age.

Our functions indicate that the highest correspondence between the true and the estimated sex corresponds to the epiphysis, especially the proximal one. These results agree with those of Scheuer and Elkington (22) because the diameters of epiphyseal areas show the most pronounced dimorphism. With 81–91% correct classification percentages, our values are slightly higher than those of Stojanowski's (38), which were obtained applying from two to five variables (79–85% range), and they are insignificantly lower than those of Falsetti's (37), which were obtained by combining five variables as a whole (84–92% range) in the Terry Collection. In the UCM sample, metacarpal II offers the best discrimination between both sexes, as reported elsewhere (24,37,39).

Comparisons of the percentages of correspondence obtained in different skeletal series are undoubtedly always difficult (17). Additionally, sexual dimorphism would be different among populations, among variables, and also among bones. The statistical methods used to obtain the equations are not always the same. Owsley and Webb (40) analyzed some problems concerning the probability of misclassification in relation to the method of calculation by means of resubstitution or using the jack-knife method. The results of these authors revealed that on average the differences between both methods are 3%. Calcagno (41) obtained a similar value: around 2.2%. The jack-knife method was not used by Schulter-Ellis et al. (42), Nakahashi and Nagai (43), Liu Wu (44), Cunha and Van Vark (45), Iscan et al. (33,46), and other authors, in the calculation of their functions, but Smith (47) used this method in the Terry and Huntington osteological collections of the Smithsonian Museum of Natural History. Stojanowski (38) evaluated similar aspects and proposed cross-validation as the best method.

Finally, the aim of the present work was to present a series of mathematical models that allow the sex of an individual to be diagnosed from his or her metacarpals, even though they are fragmented or partial. We believe that the equations obtained afford acceptable results for the Spanish population, and they are readily applicable in the absence of other bone structures. The gradual application of functions to real-life forensic cases or in judicial autopsies will undoubtedly permit the degree of definitive agreement to be reached. We consider that these discriminant functions could potentially be used with archeological and cremated material. In archeological contexts, it is relatively common to find metacarpals in good states of preservation. It could be further suggested that in many cremations that occurred in Iberia, the bones of the hands are the only vestiges that remain almost completely intact and not deformed, because—traditionally—long bones would have been broken up intentionally so that they could fit into sepulchral pots. The recording of morphological metacarpal dimensions in this kind of burial would permit the sex of the deceased to be estimated and this would facilitate the ensuing forensic identification of the individual. Thus, we have gained new possibilities of application in the sex determination of Spanish populations.

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