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TECHNICAL NOTE

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Metric Assessment of the "Mastoid Triangle" for Sex Determination: A Validation Study

ABSTRACT: Recently, a metric approach to skeletal sex determination was published by Paiva and Segre which is based on the summation of two triangular areas defined by three distinct craniometric landmarks: Porion, Mastoidale, and Asterion. According to the authors, values for the total triangle $\geq$1447.40 mm^2 are characteristic for male crania, while values $\leq$ 1260.36 mm^2 are indicative of female skulls (95% confidence). In order to evaluate the method's validity, two sex- and age-documented samples of different provenience were analyzed ($N = 197$). The results show that while the indicated measurements display significant sex differences, the technique is of little practical meaning where a single individual must be independently classified. It is hypothesized that differences in the expression of sexual dimorphism as well as a population-specific variability of the asterion location undermine the value of the mastoid triangle as a sex determinant.

KEYWORDS: forensic science, mastoid triangle, craniometry, skeletal sex determination, forensic anthropology

When it comes to skeletal sex determination, metric analyses are often found to be of superior value as they are not only more objective but also provide greater statistical weight than nonmetric traits (1). Recently, Paiva and Segre (2) introduced a technique that seems to embody all the positive attributes of a morphometric approach to sex determination: easy applicability with little observer error and high predictive value. The technique is based on measuring the distance between three easily identifiable craniometric landmarks (Porion, Mastoidale, and Asterion), the subsequent calculation of a triangular area between them, and the summation of the left and right triangle to yield a total area, which is then used to identify sex. According to the authors, values for the total area greater than or equal to 1447.40 mm^2 are characteristic for male crania, and values $\leq$ 1260.36 mm^2 are indicative of female skulls (95% confidence).

While there is ample evidence that the mastoid process and surrounding area can be a useful criterion for the purpose of sex determination (3–6), the general shape and size of the process is only of tertiary value (7). In addition, recent studies in neurosurgery have questioned the reliability of the asterion as a stationary landmark (8–10). Hence, given both the poor value of the mastoid process as a sex indicator and the apparent variability of the asterion position, the merit of the technique appears highly questionable.

The aim of the current study is to evaluate the validity of the "total mastoid triangle area" as a sex determinant by using two independent age- and sex-documented samples. Appraisal of the method focused on laterality, usefulness in discriminating between the sexes, and issues of population-specificity.

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Materials and Methods

In order to evaluate the method's effectiveness, two sex- and age-documented samples of different provenience were analyzed. Selection of cranial specimen excluded those with traumatic lesions or Wormian bones within the defined landmarks. Similarly, skulls with partially fused ectocranial sutures surrounding the asterion were omitted.

The German forensic sample consisted of 97 skulls from the Institute of Forensic Medicine, Mainz, Germany. This sample constitutes a group of European individuals—most of them German—who fell victim to violent deaths between the years of 1960 and 1984. This explains the underrepresentation of female specimens, with 25 females and 72 males. The documented mean age of death for the female subsample was 36 years, and 43 years for the male subsample. The Portuguese cemetery sample consisted of 100 crania from the Institute of Anthropology, Coimbra, Portugal. This collection represents part of a documented burial population, which was excavated in the mid-1950s. Most of the individuals died in the early 20th century. Owing to the extensive number of available specimens, equal numbers of male and female skulls could be sampled. Male age of death was *c*. 43 years, and female age of death clustered around 50 years. A *t*-test for independent samples showed that age differences between the sexes ($p = 0.424$) as well as between the two samples failed to achieve statistical significance ($p = 0.131$). Summary statistics are provided in Table 1.

The technique established by Paiva and Segre (2) is based on the reduction of the three dimensional, temporal bone morphology to a two-dimensional image via photocopying. The authors then proceed to measure three distances, thus enabling the calculation of a triangle area. Both the left and right "mastoid triangles" are defined by the Porion (*po*; the superior surface of the external auditory meatus), the Mastoidale (*ms*; the lowest craniometric point at the mastoid process), and the Asterion (*ast*; the

TABLE 1—*Sample-specific demographics.*

Sample	Sex	*N*	Age Mean	Age Standard	Age Minimum	Age Maximum
German forensic sample	Males	72	43.5	16.8	19	79
	Females	25	37.7	19.9	16	91
Portuguese cemetery sample	Males	50	43.4	21.0	15	100
	Females	50	49.6	23.7	15	92

Age differences between the sexes or the samples did not achieve statistical significance.

craniometric point at the junction of the lamboid, the occipitomastoid, and the parietomastoid suture). For a detailed view of these landmarks, see Fig. 1. The triangle area is calculated by using Heron's formula:

$$\text{with sides of length a, b, c;}$$
$$A = \sqrt{(s(s-a)(s-b)(s-c))}$$

$$\text{and } s = \frac{(a+b+c)}{2}.$$

While the original publication is clear in its description of how the skull is to be positioned on the copy machine in order to obtain two-dimensional images, replication of the procedure did not yield satisfactory images. Therefore, direct assessment of the linear projective distances between the landmarks, a common osteometric practice, was used. Distances were taken with a sliding calliper and recorded in millimetre. In order to avoid interobserver bias, all measurements were assessed by a single observer (A. K.).

A preliminary analysis (Q–Q plots) showed that all values were normally distributed. Hence, all differences between samples and sexes were assessed using Student's *t*-test (for independent samples), while a paired *t*-test was used to determine differences in laterality. In addition, a two-factor analysis of variance (ANOVA) was conducted in order to examine data that are classified on multiple independent variables. In the case at hand, it provided a useful tool to study the main effects of each of the independent variables (sex, sample origin), but also the interaction effects between the two. Furthermore, ANOVA incorporates measures of effect size. When evaluating sexual dimorphism, effect size has been shown to be of superior value. While a factor can have an effect, that is statistically significant, this effect can be minute. Here, partial Eta-squared (η_p^2) was chosen, as it is independent of the number of factors in the model. It thus reflects the contribution of each factor or interaction, as if it were the only variable. In a final step, a linear discriminant analysis was used to distinguish between the two groups (i.e., sexes) using characteristics on which the two are expected to differ. Groups are forced to be as statistically different as possible by forming a weighted linear combination, which result in the best separation between the two sexes. All statistical computations were based on SPSS 12.0.

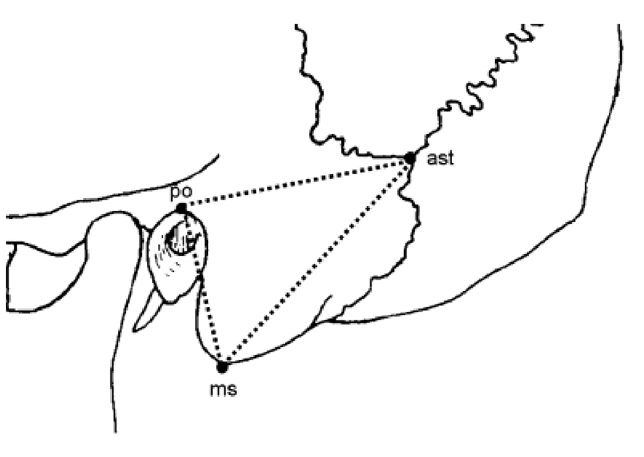

FIG. 1—*Lateral view of the cranium depicting the left mastoid triangle area as defined by the landmarks Porion (*po*), the Mastoidale (*ms*), and the Asterion (*ast*).*

Results

Table 2 presents the values for left and right measurements as well as the results of the triangle calculations by sample and sex. With respect to the original sex-specific means, as given by Paiva and Segre (2), the male sample means for the German and Portuguese skulls remained considerably below the published threshold of 1505.32 mm^2. In contrast, the two female sample means clustered closely around the 1221.24 mm^2 benchmark. While it is possible that some of the observed variation is due to diverging methodology (direct measurement vs. measurement on a two-dimensional grit), the values listed in Table 2 also point toward population-specific differences that will have to be explored in greater detail.

Side Differences

Table 3 summarizes the results of a paired *t*-test used to detect differences in laterality. As is apparent from the table, the German forensic sample did not show evidence of significant side differences in any of the individual measurements or the resultant areas. In contrast, the Portuguese cemetery sample showed a significant asymmetry in the left versus right *po–ms* length in males, with right *po–ms* measurements slightly exceeding their left counterparts (see Table 2). This phenomenon was also somewhat apparent

TABLE 2—*Summary statistics for individual measurements (in mm or mm^2, respectively) with respect to sex and sample.*

Sex	*po–ms* Left	*po–ms* Right	*ms–ast* Left	*ms–ast* Right	*po–ast* Left	*po–ast* Right	Area Left	Area Right	Area Total
German forensic sample									
Males									
Mean	30.9	30.9	50.2	50.5	48.4	48.6	716.7	717.6	1434.3
Minimum	24.0	23.0	38.0	35.0	40.0	42.0	538.8	488.4	1053.8
Maximum	36.0	40.0	59.0	63.0	54.0	58.0	879.9	984.9	1801.2
Standard	2.6	3.1	4.0	4.8	3.5	3.3	81.1	94.5	162.9
Females									
Mean	29.2	28.9	49.4	49.4	46.2	46.3	659.4	655.9	1315.4
Minimum	23.0	22.0	42.0	38.0	37.0	40.0	462.3	455.4	950.5
Maximum	35.0	37.0	61.0	60.0	53.0	52.0	870.7	920.2	1657.3
Standard	3.4	3.6	5.1	5.5	4.4	3.7	123.3	129.1	245.9
Portuguese cemetery sample									
Males									
Mean	30.9	31.5	49.1	49.5	47.1	47.7	699.9	718.9	1418.9
Minimum	25.0	25.0	38.0	30.0	38.0	40.0	523.7	372.9	902.6
Maximum	38.0	38.0	59.0	59.0	53.0	59.0	958.7	958.7	1917.4
Standard	3.7	3.7	4.9	5.2	3.3	3.8	115.8	118.3	227.2
Females									
Mean	27.8	28.4	46.0	45.8	44.9	45.1	599.5	609.5	1209.1
Minimum	22.0	23.0	35.0	33.0	35.0	39.0	416.9	424.6	864.9
Maximum	34.0	34.0	56.0	56.0	50.0	51.0	840.0	840.0	1680.0
Standard	2.8	2.6	4.3	4.6	3.6	2.9	91.9	85.7	165.8

po, Porion; *ms*, Mastoidale; *ast*, Asterion.

TABLE 3—*Paired t-test: side differences by sample and sex.*

Measurement	Sex	German Forensic Sample			Portuguese Cemetery Sample		
		T	df	*p*	*T*	df	*p*
po–ms	Males	0.291	71	0.772	− 2.547	49	0.014
	Females	0.693	24	0.495	− 1.947	49	0.057
ms–ast	Males	− 0.613	71	0.542	− 0.904	49	0.371
	Females	− 0.113	24	0.911	0.384	49	0.703
po–ast	Males	− 0.558	71	0.579	− 1.512	49	0.137
	Females	− 0.152	24	0.880	− 0.414	49	0.681
Area	Males	− 0.111	71	0.912	− 2.369	49	0.022
	Females	0.295	24	0.771	− 1.102	49	0.276

po, Porion; *ms*, Mastoidale; *ast*, Asterion.

in the female subsample, where side differences did not achieve statistical significance. However, more importantly, the Portuguese cemetery sample also documented a noticeable asymmetry between the left and right mastoid triangle in males. A microanalysis (not shown) revealed that these side differences remained stable regardless of age.

Sex Differences

Divergence between the sex-specific means was evaluated by a nonpaired *t*-test. The results are shown in Table 4. With the exception of the *ms–ast* distance in the German forensic sample, all differences achieved statistical significance. The latter was observed regardless of side, but could be confounded by the underrepresentation of females in the forensic sample. Overall, sex differences appeared to be more pronounced in the burial sample, which is apparent from the lower *p*-values. This is highly indicative of disparities in the population-specific degree of sexual dimorphism.

Sample Differences

While the sample means (see Table 2) suggest that the morphometrics from the German forensic sample almost always exceeded those derived from the Portuguese cemetery sample, a nonpaired *t*-test failed to support this assumption (see Table 5). Statistical analyses could only verify that the left and right *ms–ast* distance as well as the left triangular area in female crania achieved statistical significance.

While the results of the nonpaired *t*-test only attest to minute differences between the samples, the box plots provided in Fig. 2, which summarize the median, upper and lower quartiles, and minimum and maximum values of the two collections, show that the two samples diverge conspicuously on all measures. Overall,

TABLE 4—*Non-paired* t-*test: sex-specific differences by measurement, area, and sample.*

Measurement	Side	German Forensic Sample			Portuguese Cemetery Sample		
		T	df	*p*	*T*	df	*p*
po–ms	Left	2.724	95	0.008	4.664	98	0.000
	Right	2.561	95	0.012	4.888	98	0.000
ms–ast	Left	0.815	95	0.417	3.347	98	0.001
	Right	0.889	95	0.376	3.755	98	0.000
po–ast	Left	2.450	95	0.016	3.269	98	0.001
	Right	2.911	95	0.004	3.834	98	0.000
Area	Left	2.640	95	0.010	4.803	98	0.000
	Right	2.542	95	0.013	5.293	98	0.000

po, Porion; *ms*, Mastoidale; *ast*, Asterion.

TABLE 5—*Non-paired* t-*test: sample-specific differences by measurement, triangular area, and sex.*

Measurement	Side	Males			Females		
		T	df	*p*	*T*	df	*p*
po–ms	Left	0.137	120	0.891	1.813	73	0.074
	Right	− 0.952	120	0.343	.832	73	0.408
ms–ast	Left	1.270	120	0.207	2.968	73	0.004
	Right	1.016	120	0.312	2.982	73	0.004
po–ast	Left	1.905	120	0.059	1.386	73	0.170
	Right	1.391	120	0.167	1.510	73	0.135
Area	Left	0.940	120	0.349	2.364	73	0.021
	Right	− 0.067	120	0.946	1.859	73	0.067

po, Porion; *ms*, Mastoidale; *ast*, Asterion.

Fig. 2 demonstrates obvious differences in the magnitude of the two samples' inherent sexual dimorphism. When the female subsamples are compared, the forensic sample is not only much closer in its relevant means to the corresponding male subsample, it also appears to show a greater range of individual measurements. This, however, could also be attributable to a sampling artifact, given the collection's underrepresentation of females.

In order to uncover the underlying disparities in sexual dimorphism, differences between males and females were analyzed using a two-way ANOVA, with both sex and sample as fixed factors. Table 6 summarizes the results and reveals a highly significant interaction between sexual dimorphism and sample origin. With only two exceptions, both sample and sex as well as their interaction had a significant effect on the analyzed cranial measurements. With respect to the combined effect of sample and sex, the values for η_p^2 demonstrate that the interaction of these two variables had the greatest effect on the measurement (∼98+%), followed by sex (6–15%) and sample (1–4%). From this, we can conclude that both sex and sample are related to the outcome of the measurement. However, this relationship is not a simple one, but one that must be interpreted in terms of the interaction of sex joint with sample.

Classification by Discriminant Function

Table 7 shows the classification results for the total sample as well as the two subsamples for the linear discriminant function. In addition, a leave-one-out classification is available as a form of cross-validation. The latter gives an estimate of what the classification results would be in the population.

As is obvious from Table 7, the overall accuracies gained by the application of a discriminant function did not exceed 65%. In the German forensic sample, accuracy was mostly determined by the number of male skulls correctly identified (61% vs. 52% females). In the Portuguese cemetery sample, on the other hand, more females were correctly assessed (72% vs. 60% males). These contrasting results show that the method does not have an inherent sexing bias. Rather, the already established population-specific differences in sexual dimorphism have a high explanatory value.

With an overall accuracy of merely 65%, the model established by the discriminant function does not yield the appropriate 25% improvement over the rate of accuracy achievable by chance alone. This indicates that the value of the triangle area as a sex marker is only marginal.

Discussion

The results of the current study are highly indicative of a population-specific variability in the mastoid triangle area, which

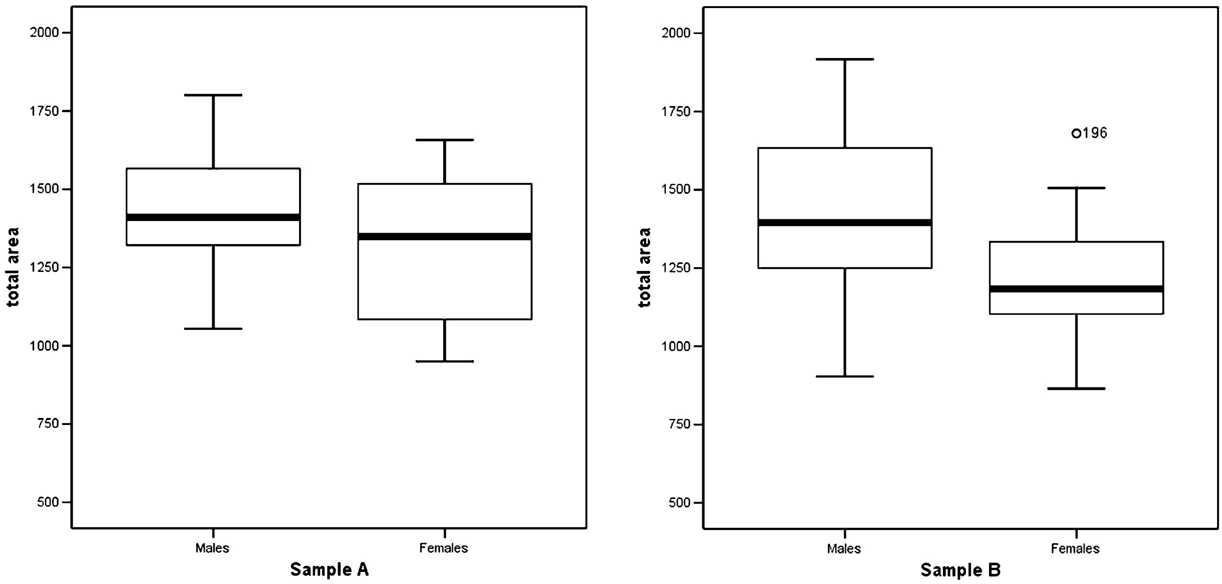

FIG. 2—*Box plots for the total area by sex (95% CI). The plot on the left denotes the German forensic sample (sample A); the plot on the right describes the Portuguese cemetery sample (sample B).*

confounds its value as a sex indicator. Differences in (a) the magnitude of the sexual dimorphism as well as (b) population-specific asterion location variability have a high explanatory value in this context. Hence, the technique is of little practical meaning where a single individual must be independently classified.

(a) The results of the current study showed that the Portuguese cemetery sample displayed a greater sexual dimorphism than in the German forensic sample, which is to be expected, given the sample origin. The Portuguese sample consisted of the remains from a burial population, with cases drawn from close vicinity. The latter is highly indicative of similar lifetime environmental conditions. Hence, these individuals represent a comparatively homogeneous group from a discrete temporal and/or spatial zone. In contrast, the German forensic sample encompasses victims of violent death, who did not share a common sociodemographic background. The sample's only common denominator is the fact that they had all died in the state of Rhineland-Palatinate, of which Mainz is the regional capital. Furthermore, inspection of the relevant autopsy reports reveals that the individuals were not drawn from a single source population, but are ethnically diverse with origins from various parts of Germany as well as Europe. The German forensic sample therefore represents a disparate group of individuals, whose only common factor is their collectiveness in unnatural death. It has been shown that such sample heterogeneity significantly contributes to a reduction in sexual dimorphism (11). Next to heterogeneity, population-specific variability in sexual

TABLE 6—*Summary ANOVA results of triangle comparisons between sex and sample origin.*

Mesurement	Effect	*F* ratio	df	*p*	η_p^2
po–ms	Sample	.177	1	0.675	0.001
	Sex	31.646	1	0.000	0.140
	Sample × sex	6539.631	3	0.000	0.990
ms–ast	Sample	8.397	1	0.004	0.041
	Sex	12.359	1	0.001	0.060
	Sample × sex	8044.872	3	0.000	0.992
po—ast	Sample	5.943	1	0.016	0.030
	Sex	24.262	1	0.000	0.111
	Sample × sex	14789.223	3	0.000	0.996
Area	Sample	2.855	1	0.093	0.015
	Sex	33.872	1	0.000	0.149
	Sample × sex	3232.700	3	0.000	0.980

po, Porion; *ms*, Mastoidale; *ast*, Asterion; ANOVA, analysis of variance.

TABLE 7—*Classification after linear discriminant function: accuracy by sample and sex.*

		Predicted Group Membership		Total	% Correctly Classified
Sample	Sex	M	*F*		
Combined					
Original					
Count	M	78	44	122	65.0
	F	25	50	75	
%	M	63.9	36.1	100.0	
	F	33.3	66.7	100.0	
Cross-validated					
Count	M	78	44	122	65.0
	F	25	50	75	
%	M	63.9	36.1	100.0	
	F	33.3	66.7	100.0	
German					
Original					
Count	M	44	28	72	58.8
	F	12	13	25	
%	M	61.1	38.9	100.0	
	F	48.0	52.0	100.0	
Cross-validated					
Count	M	44	28	72	58.8
	F	12	13	25	
%	M	61.1	38.9	100.0	
	F	48.0	52.0	100.0	
Portuguese					
Original					
Count	M	30	20	50	66.0
	F	14	36	50	
%	M	60.0	40.0	100.0	
	F	28.0	72.0	100.0	
Cross-validated					
Count	M	30	20	50	66.0
	F	14	36	50	
%	M	60.0	40.0	100.0	
	F	28.0	72.0	100.0	

dimorphism has to be addressed. As has become evident from the ANOVA analyses, the proportion of total variability attributable to sex and/or sample origin varied considerably. This is highly suggestive of additional confounders, which have been well documented for cranial morphology (12–14). As is evidenced by studies on the facial skeleton, population variation arises through various ontogenetic processes. On top of these developmentally determined pathways, environmental and epigenetic influences, such as climate, activity patterns, and masticatory function, add to the apparent diversity (15). In addition, cranial growth vectors may exhibit age- (16) as well as sex-specific idiosyncracies (17). Lastly, while temporal variation in craniofacial morphology cannot be excluded, it is believed that the time aspect of about 50 years is negligent, given the potential influence of the above-mentioned covariates.

(b) A second confounder, which may have led to a reduction in sex differences, appears to be associated with the asterion and its anatomic relationship with other identifiable cranial structures, most noticeably the mastoid process (10). The apparent displacement of the asterion has had significant ramifications for the use of this marker in neurosurgery (8–10). The observed location variability seems to reflect population-specific trends, as sophisticated craniometric studies have shown that the asterion is more anteriorly or posteriorly placed depending on population affiliation (18). Asterion variability may also explain some of the findings related to laterality. Differences in bilateral measurements had caused Paiva and Segre (2) to calculate a total area (i.e., the sum of left and right mastoid triangle) instead of a unilateral value derived from either the left or right temporal bone. In this context, stenosis of the asterion might have some explanatory value. Premature fusion of the asterion sutures has been found to cause posterior plagiocephaly (19). As suture closure commences endocranially and proceeds ectocranially, fused endocranial sutures may not be apparent upon ectocranial inspection, and differential fusion patterns in the asterion may therefore go unnoticed. Such latent deformations would not only explain the observed asymmetries in left and right measurements, but premature or eccentric suture fusion could also alter cranial growth and shape, with the modified growth vectors affecting all resultant morphometrics—independent of sex or sample origin.

Conclusion

The study at hand failed to replicate the excellent results previously reported by Paiva and Segre (2). Using two sex- and age-documented samples of different provenience, a forensic sample and a burial population ($N = 197$), the current results indicate that the technique is of little practical meaning where a single individual must be independently assessed. Classification results generated by discriminant function analysis showed that only 65% of all individuals could be correctly identified. Interestingly, the quality of the estimate was not biased against one sex but varied with sample origin. While it cannot be excluded that this also reflects a sampling artifact (due to an underrepresentation of females in the German forensic sample), it seems that population-specific differences in the magnitude of sexual dimorphism offer a higher explanatory value. A two-way ANOVA (with both sex and sample as fixed factors) supports this hypothesis, as the interaction of sex and sample had the highest effect on morphometric outcome. It is therefore concluded that the value of the mastoid triangle as a sex marker is highly questionable, when used to assess individual skulls without population reference.

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References

1. France DL. Observational and metric analysis of sex in the skeleton. In: Reichs KJ, editor. Forensic osteology. Advances in the identification of human remains. Springfield: Charles C. Thomas, 1986:163–86.
2. Paiva LAS de, Segre M. Sexing the human skull through the mastoid process. Rev Hosp Clin 2003;58:15–20.
3. Giles E, Elliott O. Sex determination by discriminant function analysis of crania. Am J Phys Anthrop 1963;21:53–68.
4. Helmuth H. Einige Maße des *Processus mastoideus* beim Menschen und seine Bedeutung für die Geschlechtsbestimmung. Z Morph Anthrop 1968; 60:75–84.
5. Ferembach D, Schwidetzky I, Stloukal M. Recommendations for age and sex diagnoses of skeleton. J Hum Evol 1980;9:517–49.
6. Hsiao TH, Chang HP, Liu KM. Sex determination by discriminant function analysis of lateral radiographic cephalometry. J Forensic Sci 1996;41: 792–5.
7. Rogers TL. Determining the sex of human remains through cranial morphology. J Forensic Sci 2005;50:493–500.
8. Day JD, Tschabitscher M. Anatomic position of the asterion. Neurosurgery 1998;42:198–9.
9. Sripairojkul B, Adultrakoon A. Anatomical position of the asterion and its underlying structure. J Med Assoc Thai 2000;83:1112–5.
10. Avci E, Kocaogullar Y, Fossett D, Caputy A. Lateral posterior fossa venous sinus relationships to surface landmarks. Surg Neurol 2003;59: 392–7; discussion 397.
11. Cunha E, van Vark GN. The construction of sex discriminant functions from a large collection of skulls of known sex. Int J Anthropol 1991;6: 53–66.
12. Howells WW. Cranial variation in man. Cambridge: Harvard University Press, 1973.
13. Frayer DW, Wolpoff MH. Sexual dimorphism. Ann Rev Anthropol 1985; 14:429–73.
14. O'Higgins P, Johnson D, Moore W, McAndrew T. Determination of race and sex of the human skull by discriminant function analysis of linear and angular dimensions. Forensic Sci Int 1989;41:41.
15. Vioarsdóttir US, O'Higgins P, Stringer C. A geometric morphometric study of regional differences in the ontogeny of the modern human facial skeleton. J Anat 2002;201:211–29.
16. Israel H. The dichotomous pattern of craniofacial expansion during aging. Am J Phys Anthropol 1977;47:47–51.
17. Carels CE. Gelaatsgroei: mannen en vrouwen verschillen. Ned Tijdschr Tandheelkd 1998;105:423–6.
18. Ross H, McKeown AH, Konigsberg LW. Allocation of crania to groups via the "new morphometry." J Forensic Sci 1999;44:584–7.
19. Jimenez DF, Barone CM, Argamaso RV, Goodrich JT, Shprintzen RJ. Asterion region synostosis. Cleft Palate-Craniofacial J 1993;31: 136–41.

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