Original Article

Evaluation of effectiveness of cranial morphological characteristics for sex estimation in a Brazilian sample

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Forensic physical anthropometry allows the determination of animal species and estimates sex, ancestry, age and height. **Aim:** To analyze the effectiveness of a cranioscopic/morphological evaluation for sex estimation with a sample of the Brazilian mixed-race population by conducting a qualitative visual assessment without prior knowledge of sex. **Methods:** This is a blind cross-sectional study that evaluated 30 cranial characteristics of 192 skulls with mandible, 108 male and 84 female individuals, aged 22 to 97 years, from the Osteological and Tomographic Biobank. The qualitative characteristics were classified and compared to the actual sex information of the Biobank database. The statistical analysis was used to calculate de Cohen's kappa coefficient, total percentage of agreement, sensitivity and specificity of visual sex classification. **Results:** Of the 30 cranial variables analyzed, 15 presented moderate degree of agreement, achieving value of Kappa test between 0.41−0.60: Glabella (Gl), Angle and lines (At), Mental eminence (Em), Mandible size (Tm), Cranial base (Bc), Mouth depth (Pb), Nasal aperture (Anl), Supraorbital region (Rs), Orbits (Orb), Mastoid processes (Pm), Alveolar arches (Aa), Zygomatic arch (Az), Orbital edge (Bo), Supraorbital protuberances (Pts), and Supramastoid crests and rugosity (Crsm). The Facial physiognomy (Ff) presented substantial reliability (0.61-0.80) with 89.8% sensitivity for male sex and 70.2% specificity. **Conclusions:** Cranial morphological characteristics present sexual dimorphism; however, in this study only 15 variables showed moderate degree of agreement and can be used in sex estimation. Only one variable (Ff) 81.2% total agreement with substantial reliability. Quantitative methods can be associated for safe sex estimation.

Keywords: Sex characteristics. Forensic anthropology. Skull. Mandible.

Introduction

In an anthropological examination for forensic purposes, the determination of sex, species, ethnic group and estimated age and height are essential as such information help build an individual's biological profile[1,2] and subsequent identification.

Musilová et al.[2] (2016) e Durić et al.[3] (2005) portrayed that the pelvis is the structure of the human skeleton that presents the highest degree of sexual dimorphism, being the most reliable bone for sex estimation. According to Musilová et al.[2] (2016) the pelvis responds with evolutionary adaptation to bipedal locomotion and birth mechanisms, enabling parturition of children with relatively big brains.

But, in situations where the skeleton is not complete[4] or when the pelvis is not fully recovered, sex estimation can be achieved by performing a cranial analysis. As mentioned by Spradley and Jantz[4] (2011), the skull has a high correct classification of sex, of 90-91%.

In a skull examination, an anthropologist may use quantitative (metric) and/or qualitative (non-metric) methods[2,5,6].

Lewis and Garvin (2016)[7], Biancalana et al. (2015)[8], Godde (2015)[9], Tallman and Go (2018)[10], Walker (2008)[11] and Langley et al. (2018)[12] are some authors which estimated the sex based on the skull morphology. This qualitative analysis is based on visual examination of the presence or degree of expression of morphological characteristics[7], but despite its subjectivity[8-11,13], may be the only possible method in cases of bone fragmentation[7]. An examination of non-metric traits also ensures an easy and fast analysis, without requiring any devices[7,10,12].

In general, bone aspects such as prominences, crests and apophyses are more notable in men, while women have more delicate and less pronounced characteristics[14].

Walker (2008)[11] stated that the accuracy of sex determinations based on visual inspection depends on the osteologist's familiarity with the population being studied. And Franklin et al. (2013)[15] mentioned that the forensic practitioner should access an osteological database for their specific geographic jurisdiction.

This changes in skull shape and size are population-specific[11,15], and can be explained because each population is submitted to its own forces of evolution[1,9,10]. Environmental interventions[8,10,15], nutritional status[8,9], temporal changes[8-12] and biomechanical processes related to neck, face and head movement[9] can alter cranial morphological aspects, smoothing or enhancing the robustness of some characteristics.

In view of these situations, this study aimed to analyze the effectiveness of a cranioscopic/morphological evaluation (a qualitative visual assessment without prior knowledge of sex) with a sample of the Brazilian mixed-race population, for sex estimation.

Materials and methods

This study was approved by the Research Ethics Committee (CAAE nº 38522714.6.0000.5418).

The main sample consisted of 192 human skulls without alterations that impaired the analysis of morphological characteristics, 108 were male and 84 were female skulls,

aged between 22 and 97 years, with median age of 57 years, from the Osteological and Tomographic Biobank. The year of death of this sample varied from 2006 to 2010.

The skulls of individuals who were 22 years or older at the time of their death were analyzed, excluding skulls of individuals who had not reached puberty as they show slightly pronounced qualitative characteristics, providing little information for sex estimation[12,14].

All analyses were performed by a single rater. The researcher was previous calibrated analysing all the dichotomous variables (male or female) in 10 skulls, obtaining 100% of consensual agreement between itself and a gold rater. The calibration has not been made through a statistical test. And the sample used for calibration was not included in the main sample.

Then the main sample of 192 skulls was evaluated, of which 30 cranial anatomical structures that were analyzed by this rater through visual inspection, using a non-metric method without prior knowledge of sex. Table 1 shows the morphological characteristics analyzed in this study.

Table 1. Morphological characteristics of skulls according to sex.

Acronym	Description	Female	Male
Pe	Weight	Less heavy	Heavier
At	Angle and lines	Less angled, round and thin	More angled and pronounced lines
Iof	Frontal bone inclination	Vertical	Inclined
Pts	Supraorbital protuberances	Level	Pronounced
Rs	Supraorbital region	None to moderate	Medium to excessive
Gl	Glabella	Flat and not very delimited	Prominent
Bo	Orbital edge	Thin and sharp	Thick
Fc	Canine fossa	Not very deep	Deep
Pm	Mastoid processes	Small, little protruding in lower plane	Robust, protruding in lower plane
Rcrm	Condyle protuberance in relation to the mastoid	With greater protuberance	Without greater protuberance
Mcsp	Skull movement on a flat surface	Does not move when supported	Moves when supported
Sd	Digastric groove	Not very deep and narrow	Deep and wide
Az	Zygomatic arch	Thinner and shorter	More robust and wide
Enl	Nasal spine	Less prominent	More prominent
Anl	Nasal aperture	Less tall and wide, with rounded edges	Taller and wider, with sharp edges
Ff	Facial physiognomy	Indicates female	Indicates male
Orb	Orbits	Tall and round	Low and angular
Ct	Temporal crests	Slightly marked	Marked
Lns	Superior nuchal lines	Slightly marked	Marked
Rpn	Nuchal plane surface	Slightly marked and smooth	Rough

continuation

Crsm	Supramastoid crests and rugosity	Just perceptible	Marked
Aa	Alveolar arches	Small	Raised
Td	Tooth size	Smaller	Larger
Tm	Mandible size	Smaller	Larger
Emd	Mandible thickness	Smaller	Larger
Cm	Mandibular condyles	Smaller	Larger
Am	Mandibular angle	More obtuse	Straighter
Em	Mental eminence	Pointed, rounded	Square
Pb	Mouth depth	Narrow and not very deep	Larger and deeper
Bc	Skull base	Level and delicate	Rough and strong

The visual analysis of all 30 variables generated a subjective differentiation between female and male skulls (nominal qualitative variable). Based on the knowledge of actual sex of the individuals, the degree of agreement was measured using Kappa test, considering the significance level α=0.05, the levels of strength of agreement measure by Cohen's kappa are interpreted as proposed by Landis and Koch[16] (1977): almost perfect (0.81−1.00), substantial (0.61−0.80), moderate (0.41−0.60), fair (0.21−0.40), slight (0.00−0.20), or poor (<0.00).

The percentage of correct sex was calculated using frequency tables (Crosstab) and the Cohen's kappa coefficient, total percentage of agreement, sensitivity, specificity visual sex classification were calculated. It was used SPSS Statistics version 25 statistical package (IBM Corporation, Chicago, USA) for data processing.

Results

The frequency and percentage of skull's real sex are described in Table 2. The sample was relativily balanced with 56.3% of male and 43.8% female.

32.8% of the sample consisted of skulls which age range was between 26−50 years old, 33.3% between 51−70 years and 30.7% over 70 years old. And 96.5% of the skulls analysed presented the year of death 2010.

Table 2. Frequency and percentage of actual sex classification, range age and death's date of the skulls.

Sample		Frequency	
		n	%
Actual sex	Female	84	43.8
	Male	108	56.3
Age range	≤ 25	6	3.1
	26 a 50	63	32.8
	51 a 70	64	33.3
	over 70	59	30.7
Death date	2006	1	0.5
	2009	6	3.1
	2010	185	96.4

Due to the sample consisted of skulls aged older than 22 years, the authors performed the skull concordance tests without separating them by age.

Table 3 shows the frequency and percentage of sex classification based on a subjective analysis of different variables.

Through Kappa test, variables Pe (k=0.08) and Ct (k=-0.04), should not be used to determine sex, as they do not present statistical significance in the agreement test (p>0.05).

Table 3. Frequency and percentage of sex classification based on a subjective rater analysis of different variables.

	Sex	
	Male N (%)	Female N (%)
Pe	111 (57.8)	81 (42.2)
At	117 (60.9)	75 (39.1)
Iof	135 (70.3)	57 (29.7)
Pts	141 (73.4)	51 (26.6)
Rs	136 (70.8)	56 (29.2)
Gl	123 (64.1)	69 (35.9)
Bo	108 (56.3)	84 (43.8)
Fc	99 (51.6)	93 (48.4)
Pm	127 (66.1)	65 (33.9)
Rcrm	108 (56.3)	84 (43.8)
Mcsp	77 (40.1)	115 (59.9)
Sd	104 (54.2)	88 (45.8)
Az	88 (45.8)	104 (54.2)
Enl	106 (55.2)	86 (44.8)
Anl	125 (65.1)	67 (34.9)
Ff	122 (63.5)	70 (36.5)
Orb	141 (73.4)	51 (26.6)
Ct	148 (77.1)	44 (22.9)
Lns	152 (79.2)	40 (20.8)
Rpn	151 (78.6)	41 (21.4)
Crsm	144 (75.0)	48 (25.0)
Aa	96 (50.0)	96 (50.0)
Td	69 (35.9)	32 (16.7)*
Tm	121 (63.0)	71 (37.0)
Emd	130 (67.7)	24 (32.3)
Cm	138 (71.9)	54 (28.1)
Am	106 (55.2)	86 (44.8)
Em	98 (51.0)	94 (49.0
Pb	132 (68.7)	60 (31.3)
Bc	135 (70.3)	57 (29.7)
Actual sex	108 (56.3)	84 (43.8)

*Absent structures did not allow sex classification.

Although the variable tooth size (Td) has been visually analyzed, its statistical analysis was not made due to several skulls had no tooth.

The other variables showed statistically significant agreement from slight to fair level. Among these variables, Lns and Am had a slight level of agreement (0.00−0.20); Emd, Iof, Cm, Mcsp, Enl, Fc, Rpn, Sd and Rcrm showed a fair level of agreement (0.21−0.40); Gl, At, Em, Tm, Bc, Pb, Anl, Rs, Orb, Pm, Aa, Az, Bo, Pts and Crsm presented a moderate level of agreement (0.41−0.60). And only Ff presented substantial level of agreement (0.61−0.80).

Table 4 shows the degree of agreement according to Kappa test and the p-value of all morphological variables, and the 16 variables with the best agreement degrees are highlighted with †symbol.

Table 4. Percentage of total agreement, Cohen's kappa coefficient and 95% CI kappa of variables in relation to actual sex.

	Total agreement (%)	Cohen's Kappa coefficient	IC 95% Kappa
Pe	54.7	0.08	-0.06 − 0.217
At	81.7	0.60*†	0.49 − 0.72
Iof	71.4	0.40*	0.27 − 0.52
Pts	73.5	0.44*†	0.31 − 0.56
Rs	76.1	0.49*†	0.37 − 0.61
Gl	80.7	0.60*†	0.49 − 0.71
Bo	72.9	0.43*†	0.32 − 0.58
Fc	72.4	0.34*	0.21 − 0.47
Pm	73.4	0.45*†	0.32 − 0.58
Rcrm	62.5	0.24*	0.10 − 0.37
Mcsp	66.2	0.34*	0.21 − 0.46
Sd	65.6	0.30*	0.17 − 0.44
Az	72.9	0.46*†	0.34 − 0.58
Enl	66.7	0.32*	0.20 − 0.46
Anl	75.5	0.49*†	0.37 − 0.61
Ff	81.2	0.61*†	0.50 − 0.72
Orb	74.5	0.46*†	0.34 − 0.58
Ct	51.1	-0.04	-0.12 − 0.12
Lns	62.5	0.19*	0.07 − 0.31
Rpn	68.3	0.32*	0.19 − 0.44
Crsm	72.9	0.42*†	0.30 − 0.54
Aa	74.0	0.48*†	0.36 − 0.60
Tm	77.6	0.54*†	0.42 − 0.66
Emd	70.8	0.39*	0.26 − 0.52
Cm	70.9	0.38*	0.26 − 0.51
Am	59.4	0.18*	0.04 − 0.32
Em	79.1	0.58*†	0.47 − 0.69
Pb	77.0	0.52*†	0.40 − 0.64
Bc	76.6	0.51*†	0.40 − 0.62

*Indicates significance in the Kappa's test (p<0.05);
† Represent the variables with the best agreement degrees (k>0.40).

Table 5 shows the percentage of correct sex through Crosstab of 16 (sixteen) variables that presented statistically significant moderate and substantial agreement (k>0.40; p<0.05). The visual sex classification of Ff, At and Gl variables presented more than 80% of total agreement. The visual sex classification of Ff variable showed 89.8% sensitivity and 70.2% specificity for male sex classification. The At showed 87% sensitivity and 72.6% for male sex specificity and Gl showed 89.8% sensitivity and 69.0% specificity. The visual classification was more sensitivity for male sex, whereas for the female classification the sensitivity was lower.

Table 5. The sensitivity, specificity for visual sex classification of the variables that presented moderate and substantial reliability in Cohen's kappa coefficient (k>0.40; p<0.05).

			Male N (%)	Female N (%)	Total
Gl[#]	Actual sex	Male	97 (89.8)*	11 (10.2)	108 (100.0)
		Female	26 (31.0)	58 (69.0)[†‡]	84 (100.0)
At[#]	Actual sex	Male	94 (87.0)*	14 (13.0)	108 (100.0)
		Female	23 (27.4)	61 (72.6)[†‡]	84 (100.0)
Ff[#]	Actual sex	Male	97 (89.8)*	11 (10.2)	108 (100.0)
		Female	25 (29.8)	59 (70.2)[†‡]	84 (100.0)
Em[#]	Actual sex	Male	91 (84.3)*	17 (15.7)	108 (100.0)
		Female	39 (46.4)	45 (53.6)[†‡]	84 (100.0)
Tm	Actual sex	Male	93 (86.1)*	15 (13.9)	108 (100.0)
		Female	28 (33.3)	56 (66.7)[†‡]	84 (100.0)
Bc	Actual sex	Male	99 (91.7)*	9 (8.3)	108 (100.0)
		Female	36 (42.9)	48 (57.1)[†‡]	84 (100.0)
Pb[#]	Actual sex	Male	98 (90.7)*	10 (9.3)	108 (100.0)
		Female	34 (40.5)	50 (59.5)[†‡]	84 (100.0)
Anl	Actual sex	Male	93 (86.1)*	15 (13.9)	108 (100.0)
		Female	32 (38.1)	52 (61.9)[†‡]	84 (100.0)
Rs[#]	Actual sex	Male	99 (91.7)*	9 (8.3)	108 (100.0)
		Female	37 (44.0)	47 (56.0)[†‡]	84 (100.0)
Orb[#]	Actual sex	Male	100 (92.6)*	8 (7.4)	108 (100.0)
		Female	41 (48.8)	43 (51.2)[†‡]	84 (100.0)
Pm[#]	Actual sex	Male	92 (85.2)*	16 (14.8)	108 (100.0)
		Female	35 (41.7)	49 (58.3)[†‡]	84 (100.0)
Aa	Actual sex	Male	77 (71.3)*	31 (28.7)	108 (100.0)
		Female	19 (22.6)	65 (77.4)[†‡]	84 (100.0)
Az	Actual sex	Male	72 (66.7)*	36 (33.3)	108 (100.0)
		Female	16 (19.0)	68 (81.0)[†‡]	84 (100.0)
Bo	Actual sex	Male	82 (75.9)*	26 (24.1)	108 (100.0)
		Female	26 (31.0)	58 (69.0)[†‡]	84 (100.0)
Pts[#]	Actual sex	Male	99 (91.7)*	9 (8.3)	108 (100.0)
		Female	42 (50.0)	42 (50.0)[†‡]	84 (100.0)

continuation

Crsm#	Actual sex	Male	100 (92.6)*	8 (7.4)	108 (100.0)
		Female	44 (52.4)	40 (47.6)†‡	84 (100.0)

Represent the variables with the best results;
* Sensitivity to Male sex classification;
† Specificity to Male sex classification;
‡ Sensitivity to Female sex classification.

The variable Orb showed 92.6% sensitivity for male sex, however, 51.2% of specificity. The Ff, Gl and At were the variables with the highest index of sensitivity and specificity.

The percentages of correct sex for the 10 morphological variables with the best agreement degrees are highlighted with a hash in the same Table 5 and are presented in the Figure 1; all of them had higher percentages in the determination of male in relation to female sex, that is, such characteristics are more evident and facilitate identification in male sex.

Figure 1. A: Glabella (Gl); B: Supraorbital region (Rs) and Supraorbital protuberances (Pts); C: Orbits (Orb); D: Mastoid processes (Pm); E: Angle and lines (At) and Facial physiognomy (Ff); F: Mental eminence (Em); G: Mouth depth (Pb); H: Supramastoid crests and rugosity (Crsm).

Discussion

In our study, using a balanced sample, although 30 cranial characteristics were analysed, only 15 variables achieved moderate agreement and one substantial agreement, but according to Cicchetti and Feinstein[17] (1990) a low kappa can occur at a high agreement.

It is remarkable that age is a variable that can influence the quantitative measurement of bone size. However, the present study classified each skull qualitatively and the sample consisted of skulls aged older than 22 years, not dealing with the stage before puberty, between 10 and 21 yearsold which can be a confounding bias in the identification of the gender. For this reason, the skulls concordance tests were performed without separating them by age.

As the sex of all skulls was indexed in the Biobank, it was possible to estimate the percentage of correct sex for female and male population, which was not obtained in the study by Biancalana et al.[8] (2015). Correct sex percentages for the 10 characteristics presenting the best agreement results were high, ranging from 47.6% to 92.6%. Being observed that this qualitative classification is more sensitivity for male sex.

As observed in other studies[2,7,13,18,19], glabella presented a high sexual dimorphism index, reaching 89.8% sensitivity and 69.0% of specificity for male sex classification, and a total agreement of 80.7%.

In a qualitative analysis of the glabella region similar to ours, Abdel Fatah et al.[13] (2014) and Walker[11] (2008) found correct sex classification of 82% and 82.6%, respectively.

Langley et al.[12] (2018), when analyzing non-metric cranial traits, observed that mental eminence was the only variable that did not present a reasonable to moderate agreement for sex estimation, and should be avoided for such purpose. Low accuracy of 45.03% was also obtained in the study by Durić et al.[3] (2005) for the size of mental eminence. In contrast, in our study, mental eminence was among the 10 best variables, with total agreement of 79.1%, having 84.3% of sensitivity for male sex and 53.6% for female sex. Similarly, Lewis and Garvin[7] (2016) and Walker[11] (2008) found correct sex classification for this variable of 75.0% and 76.6%, respectively.

In our study, regarding supraorbital protuberances (Pts), moderate agreement was observed (73.5%), while Lewis and Garvin[7] (2016), when evaluating the eyebrow region, obtained 96.7% of correct sex classification.

Nikita and Michopoulou[19] (2018) also analyzed the mastoid process profile and found for this variable, up to 75.2% and 74.5% correct classification for both sexes, similar to the percentages found by Walker[11] (2008), while our study found for this characteristic, 85.2% of sensitivity for male sex and 58.3% for female sex.

In a study conducted by Graw et al.[20] (1999), the analysis of the supraorbital margin shape allowed correct identification of sex, with about 70% accuracy, an index that is similar to what was observed by Walker[11] (2008), while Durić et al.[3] (2005) reported sharpness of the supraorbital margins as the least reliable indicator with 28.75% accuracy only. Regarding orbits (Orb), our study showed the best percentage (92.6%) of sensitivity for male sex.

In a qualitative study conducted with European skulls, Williams and Rogers[21] (2006) obtained high accuracy value for gonial angle (80.0%), which do not agree with the results of our study, as the strength of agreement for that variable was slight with a Cohen's Kappa coefficient of 0.18. In addition, the authors mentioned above[20] reported orbit shape and position, and forehead inclination should not be considered as reliable variables for sex determination. In contrast, in our study, the orbits showed moderate strength of agreement with 74.5% of total agreement and frontal bone inclination presenting a fair level of strength of agreement with 71.4% of total agreement.

When analyzing jaw robustness, Durić et al.[3] (2005) found high accuracy (70.93%) for sex determination. In our study, mandible variables reached different agreements, such as mandible size (presenting moderate agreement), mandible thickness and mandibular condyles (fair agreement), and mandibular angle (slight agreement). Similarly, Keen[22] (1950) reports that the angle of the mandible did not present a high index in sex differentiation.

In 2018, Tallman and Go[10] evaluated Asian skulls, qualitatively analyzing nuchal crest, mastoid process, supraorbital margin, glabella and mental eminence, and obtaining 57.9% correct classification for female and 92.4% for male sex.

Similarly, was observed in our study that the visual classification of the cranial characteristics was more sensitivity for male sex. And to increase the probability of correct sex determination, we agree with Loth and Henneberg[23] (1996) when they advise that a complete examination should be made of all available bones known to belong to an individual, combining qualitative and quantitative methodologies, to ensure improved certainty and reliability of forensic anthropological reports.

The percentages showed here are helpful for forensic practioners according to which preserved cranial trait is available in the skull that they are working on, and according to the population the skull is originated.

However, this study presents some limitations, as the analyses were performed by only one examiner, and although calibrated, by being a qualitative analysis it can be influenced by subjectivity, so the authors suggest that future studies use some examiners. Another limitation was common lighting and tables to analyze the skulls, being evaluated with the naked eye.

In conclusion, the visual classification of Ff variable presented the best sensitivity and specificity to male sex with substantial reliability. Next in decreasing order for the best qualitative evaluation of sex were the variables Gl, At, Em, Tm, Bc, Pb, Anl, Rs, Orb Pm, Aa, Az, Bo, Pts and Crsm which presented moderate agreement (41% to 60%). The visual classification was more sensitivity for male sex. However, for improved certainty and reliability in sex estimation, quantitative methods are recommended.

Acknowledgments

References

1. Krüger GC, L'Abbé EN, Stull KE, Kenyhercz MW. Sexual dimorphism in cranial morphology among modern South Africans. Int J Legal Med. 2015 Jul;129(4):869-75. doi: 10.1007/s00414-014-1111-0.

2. Musilová B, Dupej J, Velemínská J, Chaumoitre K, Bruzek J. Exocranial surfaces for sex assessment of the human cranium. Forensic Sci Int. 2016;269:70-7. doi: 10.1016/j.forsciint.2016.11.006.

3. Durić M, Rakocević Z, Donić D. The reliability of sex determination of skeletons from forensic context in the Balkans. Forensic Sci Int. 2005;147(2-3):159-64.

4. Spradley MK, Jantz RL. Sex estimation in forensic anthropology: skull versus postcranial elements. J Forensic Sci. 2011;56(2):289-96. doi:10.1111/j.1556-4029.2010.01635.x.

5. Celbis O, Iscan MY, Soysal Z, Cagdir S. Sexual diagnosis of the glabellar region. Leg Med (Tokyo). 2001;3(3):162-70.

6. Ulbricht V, Schmidt CM, Groppo FC, Júnior ED, Queluz DP, Júnior LF. Sex Estimation in Brazilian Sample: Qualitative or Quantitative Methodology? Braz J Oral Sci. 2017;16:1-9. doi:10.20396/bjos.v16io.8650495.

7. Lewis CJ, Garvin HM. Reliability of the Walker Cranial Nonmetric Method and Implications for Sex Estimation. J Forensic Sci. 2016;61(3):743-51. doi:10.1111/1556-4029.13013.

8. Biancalana, RC, Ortiz AG, de Araújo LG, Semprini M, Galo R, Silva RHA. Determinação do sexo pelo crânio: etapa fundamental para a identificação humana. Rev. Bras. Crimin. 2015;4(3): 38-43.

9. Godde K. Secular trends in cranial morphological traits: a socioeconomic perspective of change and sexual dimorphism in North Americans 1849-1960. Ann Hum Biol. 2015;42(3):253-9. doi:10.3109/03014460.2014.941399.

10. Tallman SD, Go MC. Application of the Optimized Summed Scored Attributes Method to Sex Estimation in Asian Crania. J Forensic Sci. 2018;63(3):809-14. doi:10.1111/1556-4029.13644.

11. Walker PL. Sexing skulls using discriminant function analysis of visually assessed traits. Am J Phys Anthropol. 2008;136(1):39-50. doi:10.1002/ajpa.20776.

12. Langley NR, Dudzik B, Cloutier A. A Decision Tree for Nonmetric Sex Assessment from the Skull. J Forensic Sci. 2018;63(1):31-7. doi:10.1111/1556-4029.13534.

13. Abdel Fatah EE, Shirley NR, Jantz RL, Mahfouz MR. Improving sex estimation from crania using a novel three-dimensional quantitative method. J Forensic Sci. 2014;59(3):590-600. doi:10.1111/1556-4029.12379.

14. Francesquini Júnior L, Francesquini MA, De La Cruz BM, Pereira SD, Ambrosano GM, Barbosa CM, et al. Identification of sex using cranial base measurements. J Forensic Odontostomatol. 2007;25(1):7-11.

15. Franklin D, Cardini A, Flavel A, Kuliukas A. Estimation of sex from cranial measurements in a Western Australian population. Forensic Sci Int. 2013;229(1-3):158.e1-8. doi:10.1016/j.forsciint.2013.03.005.

16. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977 Mar;33(1):159-74.

17. Cicchetti DV, Feinstein AR. High agreement but low kappa: II. Resolving the paradoxes. J Clin Epidemiol. 1990;43(6):551-8.

18. Garvin HM, Ruff CB. Sexual dimorphism in skeletal browridge and chinmorphologies determined using a new quantitative method. Am J Phys Anthropol. 2012;147(4):661-70. doi: 10.1002/ajpa.22036.

19. Nikita E, Michopoulou E. A quantitative approach for sex estimation based on cranial morphology. Am J Phys Anthropol. 2018;165(3):507-17. doi: 10.1002/ajpa.23376.

20. Graw M, Czarnetzki A, Haffner HT. The form of the supraorbital margin as a criterion in identification of sex from the skull: investigations based on modern human skulls. Am J Phys Anthropol. 1999 Jan;108(1):91-6. doi: 10.1002/(SICI)1096-8644(199901)108:1<91::AID-AJPA5>3.0.CO;2-X.

21. Williams BA, Rogers T. Evaluating the accuracy and precision of cranial morphological traits for sex determination. J Forensic Sci. 2006;51(4):729-35.

22. Keen JA. A study of the differences between male and female skulls. Am J Phys Anthropol. 1950;8(1):65-79.

23. Loth SR, Henneberg M. Mandibular ramus flexure: a new morphologic indicator of sexual dimorphism in the human skeleton. Am J Phys Anthropol. 1996;99(3):473-85.