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Age Effect in the Morphological Traits Performance for Sex Determination in Human Skulls and Mandibles

Efecto de la Edad en el Rendimiento de los Rasgos Morfológicos para la Determinación del Sexo en Cráneos y Mandíbulas Humanas.

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SUMMARY: In this study we tested the hypothesis that diagnostic performance of the morphological indicators for sexual dimorphism are reduced as they are applied in skull and mandibles of older subjects. We used 275 adult human skulls, 250 of these with mandible, all subjects with sex and age registry. Sixteen classic morphological indicators of sexual dimorphism were evaluated, this information was compared with the registry and results noted in terms of precision. The best general performance of morphological indicators of sexual dimorphism were recorded in the 31 - 40 and 61 - 70 years, age range groups. Lowest precision ws recorded in the group corresponding to subjects between 21 – 30 years. Our results do not support the proposed hypothesis and suggest a progressive and cumulative effect of factors that determine dimorphism expression.

KEY WORDS: Sexual dimorphism; Sex determination; Aging, Age; Skull.

INTRODUCTION

Performance in terms of precision and error of quantitative methods for sex determination have been extensively documented for most skeletal elements, the sensitivity of these diagnostic methods of sex, change according to the bone, while those that surpass the 90 % are considered useful. The skull occupies the second place in the expression of sexual dimorphism, immediately following the pelvis (Bidmos & Asala, 2003, Introna *et al.*, 1993, Introna *et al*., 1998; Suazo *et al.*, 2008a; Cantín *et al.*, 2009; Suazo *et al*., 2009a; Zavando *et al.*, 2009).

Sex determination is more exact in adults than in subadults as a result of the effect of sexual hormones, estrogen and progesterone on the development of morphological differences that have their maximum expression at the onset of puberty (Suazo *et al*., 2009b). Hormones control development and growth of bones; differences between the sexes occur as a result of different bone development velocities and forces. Women complete their development earlier than men who modify their appearance drastically during puberty. Consequently bio-morphological differences between the sexes manifest more evidently in adult skeletons (Krenzer, 2006; Suazo *et al*., 2008b).

For Baughan & Demirjian (1978), sexual dimorphism in the skull appears during puberty when 95% of cranium growth has already occurred, subsequently differences increase lineally until the balance range is attained in each sex after 25 years of age.

Socio-ecological differences are also observed (for instance nutrition, diet, climate, pathologies etc.) that model bone development and aspect (Park & Nowosielski-Slepowron, 1983; Suazo *et al*., 2008c).

Additionally bone structure is the function's logical consequence; bones are shaped according to their specific biomechanical needs. Muscle structure determines bone elevation, and with a stronger muscular insertion cortical thickness increases proportionally (Krenzer, 2006; Suazo *et al*., 2008d).

Along with the development of skeletal manifestation of dimorphism in the post pubertal stage, differences can also be found in the integuments covering the head bone. (Blanchette *et al.*, 1996; Suazo *et al.*, *2007)* Bulygina *et al*. (2006) note that sexual dimorphism in subjects presents at

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an early age. They found little correlation between morphology of newborn and adult subjects. However when analyzing these subjects in their third year of life they always described a high correlation with the adult shape, thus concluding that the inter individual differences in facial and skull shape are established during the first years of life.

The most commonly used morphological indicators of sexual dimorphism were evaluated by Rogers (2005) describing them precisely which was corroborated Suazo *et al.* (2009c), who reported that the best indicators were those that formed in relation to muscle forces that shape them. Therefore, age of the subjects at the time of sampling may be a relevant factor when determining performance of the morphological indicators for sexual dimorphism. Krogman & Iscan 1986 proposed to analyze only skulls of subjects between 25 and 55 years of age, since hormonal influence determining sexual dimorphism manifests in that age range, these authors indicated that sex determination in subjects under 25 years of age and older than 55 years of age implied greater levels of error. (Krogman and Iscan).

Considering this information, the purpose of this study is to evaluate the effect of age in the performance of skull morphological indicators of sexual dimorphism most commonly used.

MATERIAL AND METHOD

We designed a cross sectional study for evaluation of the diagnostic test. 275 human skulls of adult subjects were used from the collection of Universidade Federal de Sao Paulo, 250 all with mandible. Only skulls with complete sex and age registry were included and those presenting extensive destruction or apparent dysmorphism were not considered. Skulls and mandibles were classified in groups according to age. Table I notes distribution of skulls in the various age groups.

Table I. Distribution of skulls analyzed in the various age groups.

Range of age	Men	Women	Total
21-30	25	33	58
31-40	53	39	92
41-50	41	21	62
51-60	31	10	41
61-70	16	6	22
Total	166	109	275

Dimorphism Analysis. Sixteen indicators of classical morphological sexual dimorphism, as described by Krogman and Krogman & Iscan were analyzed: Size and architecture of the skull, forehead shape, frontal eminences, superciliary arches, orbital shape, piriform aperture, nasal bone, zygomatic bone, zygomatic arch, parietal eminences, mastoid process, occipital bone, occipital condyles, shape of the palate, general appearance of the mandible, and chin shape.

If one of the indicators was partially or completely destroyed, it was not considered and the remainder of indicators was evaluated.

All skulls were independently evaluated according to procedure described by Suazo *et al.*, 2009c, sex registry was concealed from the researchers. Results obtained were based on contrast between diagnosis and registry, which were expressed in terms of general precision and sensitivity for the diagnosis of men and women.

RESULTS

Best general performance of morphological indicators of sexual dimorphism were found in age ranges from 31 to 40 and 61 to 70 years, best precision was found in the group corresponding to subjects between 21-30 years. Details of general accuracy values are in Table II and are illustrated in Figure 1.

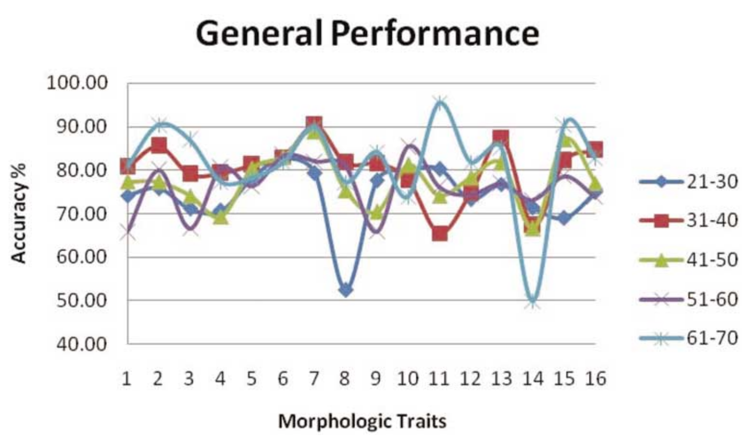

Fig. 1. Diagram of the distribution of precision percentage of the 16 indicators evaluated. 1. Chin shape; 2. General appearance of the mandible; 3. Piriform aperture; 4. Orbital shape; 5. Nasal bone; 6. Zygomatic bone; 7. Mastoid process; 8. Palate shape; 9. Frontal eminences; 10. Forehead shape; 11. Size and architecture of the skull; 12. Zygomatic arch; 13. Occipital condyles; 14. Parietal eminences; 15. Occipital bone; 16. Superciliary arches.

Table II. General precision of the 16 morphological indicators of sexual dimorphism grouped by age range.

Morphologic Traits	Age						
	21-30	31-40	41-50	51-60	61-70	Mean	SD
1. Chin shape	74.14	80.72	77.36	65.71	80.95	75.78	6.28
2. General appearance of the mandible	75.86	85.54	77.36	80.00	90.48	81.85	6.07
3. Piriform aperture	71.19	79.12	74.14	66.67	86.96	75.61	7.79
4. Orbital shape	70.69	79.35	69.35	80.49	77.27	75.43	5.09
5. Nasal bone	78.33	81.18	80.33	76.32	78.26	78.88	1.91
6. Zygomatic bone	82.76	82.98	83.05	83.33	81.82	82.79	0.58
7. Mastoid process	79.31	90.32	88.89	82.05	90.00	86.11	5.08
8. Palate shape	52.54	81.72	75.41	80.95	77.27	73.58	12.04
9. Frontal eminences	77.59	81.52	70.49	65.85	84.21	75.93	7.64
10. forehead shape	80.00	77.78	81.25	85.37	73.91	79.66	4.24
11. Size and architecture of the skull	80.33	65.52	74.19	76.19	95.45	78.34	10.99
12. Zygomatic arch	73.33	74.71	78.33	74.42	81.82	76.52	3.51
13. Occipital condyles	76.79	87.21	81.67	76.92	85.00	81.52	4.69
14. Parietal eminences	71.43	67.37	66.67	73.17	50.00	65.73	9.20
15. Occipital bone	68.97	82.22	87.10	78.57	90.48	81.47	8.34
16. Superciliary arches	75.00	84.62	77.05	73.81	82.61	78.62	4.76
Mean	74.27	80.12	77.66	76.24	81.66		
SD	7.00	6.50	6.07	6.09	10.25		

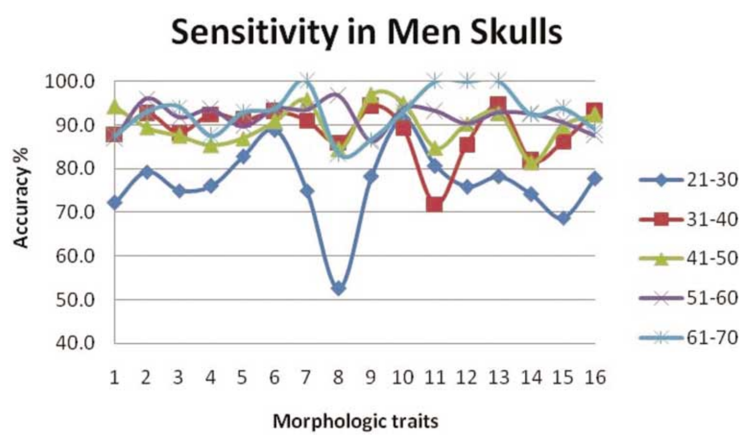

Fig. 2. Diagram of the distribution of precision percentage of the 16 indicators evaluated in skulls of men. 1. Chin shape; 2. General appearance of the mandible; 3. Piriform aperture; 4. Orbital shape; 5. Nasal bone; 6. Zygomatic bone; 7. Mastoid process; 8. Palate shape; 9. Frontal eminences; 10. Forehead shape; 11. Size and architecture of the skull; 12. Zygomatic arch; 13. Occipital condyles; 14. Parietal eminences; 15. Occipital bone; 16. Superciliary arches

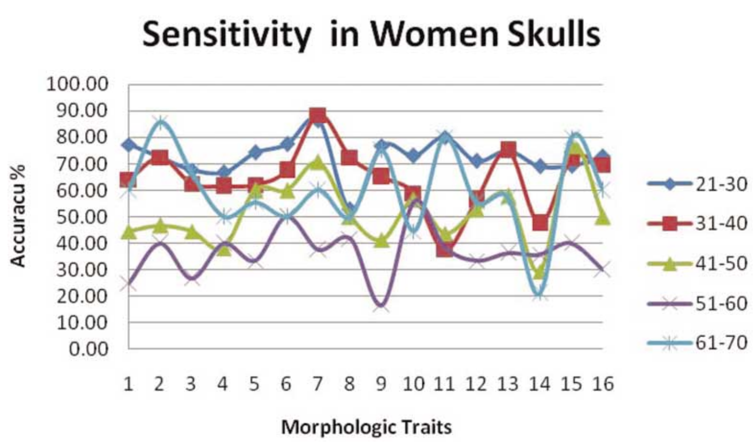

Fig. 3. Diagram of the distribution of precision percentage of the 16 indicators evaluated in skulls of women. 1. Chin shape; 2. General appearance of the mandible; 3. Piriform aperture; 4. Orbital shape; 5. Nasal bone; 6. Zygomatic bone; 7. Mastoid process; 8. Palate shape; 9. Frontal eminences; 10. Forehead shape; 11. Size and architecture of the skull; 12. Zygomatic arch; 13. Occipital condyles; 14. Parietal eminences; 15. Occipital bone; 16. Superciliary arches

In the skulls of men greater performance values were observed, and in this group a lineal and progressive increase of sensitivity values was observed from the younger group to that of greater age. Detail of performance values for

Table III. Sensitivity for men of the 16 morphological indicators of sexual dimorphism grouped by age range.

Morphologic Traits	Age						
	21-30	31-40	41-50	51-60	61-70	Mean	SD
1. Chin shape	72.2	87.9	94.3	87.0	87.5	85.8	8.1
2. General appearance of the mandible	79.3	92.6	89.5	96.0	92.9	90.0	6.4
3. Piriform aperture	75.0	88.1	87.5	91.7	94.1	87.3	7.4
4. Orbital shape	76.0	92.5	85.4	93.5	87.5	87.0	7.0
5. Nasal bone	82.8	91.1	87.0	89.7	92.9	88.7	3.9
6. Zygomatic bone	88.9	93.0	90.9	93.8	93.8	92.1	2.1
7. Mastoid process	75.0	91.0	95.7	93.5	100.0	91.0	9.6
8. Palate shape	52.5	85.9	84.4	96.7	83.3	80.6	16.6
9. Frontal eminences	78.1	94.2	96.9	86.2	86.7	88.4	7.4
10. forehead shape	91.3	89.3	95.1	93.8	92.9	92.5	2.3
11. Size and architecture of the skull	80.6	71.8	84.8	93.1	100.0	86.1	10.9
12. Zygomatic arch	75.9	85.5	90.2	90.3	100.0	88.4	8.8
13. Occipital condyles	78.1	94.4	92.7	92.9	100.0	91.6	8.1
14. Parietal eminences	74.1	81.8	81.4	92.6	92.3	84.4	7.9
15. Occipital bone	68.8	86.2	89.8	90.6	93.8	85.8	9.9
16. Superciliary arches	77.8	93.1	92.3	87.5	88.9	87.9	6.1
Mean	76.6	88.7	89.9	91.8	92.9		
SD	8.6	5.8	4.5	3.1	5.2		

Table IV. Sensitivity for women of the 16 morphological indicators of sexual dimorphism grouped by age range.

Morphologic Traits	Age						
	21-30	31-40	41-50	51-60	61-70	Mean	SD
1. Chin shape	77.27	64.00	44.44	25.00	60.00	54.14	20.06
2. General appearance of the mandible	72.41	72.41	46.67	40.00	85.71	63.44	19.28
3. Piriform aperture	67.74	62.50	44.44	26.67	66.67	53.60	17.74
4. Orbital shape	66.67	61.54	38.10	40.00	50.00	51.26	12.69
5. Nasal bone	74.19	62.07	60.00	33.33	55.56	57.03	14.93
6. Zygomatic bone	77.42	67.57	60.00	50.00	50.00	61.00	11.78
7. Mastoid process	86.36	88.46	70.59	37.50	60.00	68.58	20.94
8. Palate shape	52.63	72.41	50.00	41.67	50.00	53.34	11.43
9. Frontal eminences	76.92	65.00	41.38	16.67	75.00	54.99	25.66
10. forehead shape	72.97	58.82	56.52	55.56	44.44	57.66	10.20
11. Size and architecture of the skull	80.00	37.50	43.75	38.46	80.00	55.94	22.09
12. Zygomatic arch	70.97	56.25	52.63	33.33	55.56	53.75	13.45
13. Occipital condyles	75.00	75.00	57.89	36.36	57.14	60.28	15.97
14. Parietal eminences	68.97	47.50	29.41	35.71	21.05	40.53	18.59
15. Occipital bone	69.23	72.00	76.92	40.00	80.00	67.63	16.00
16. Superciliary arches	72.73	69.70	50.00	30.00	60.00	56.48	17.27
Mean	72.59	64.55	51.42	36.27	59.45		
SD	7.30	11.66	12.05	9.30	15.98		

morphological indicators of sexual dimorphism expressed in terms of sensitivity to diagnose men is noted in Table II and is illustrated in Figure 2.

In the skulls of women performance of indicators of sexual dimorphism analyzed was low at all ages. Contrary to what occurred in the skulls of men, sensitivity diminished from the younger group up to the group between 51 to 60 years, with a significant increase in the greater age group, although without attaining good performance. Detail of performance values of morphological indicators of sexual dimorphism analyzed in terms of sensitivity for women are observed in Table IV and illustrated in Figure 3.

DISCUSSION

In this study we tested the hypothesis that age influences in the performance of morphological indicators of sexual dimorphism in skulls. Particularly those that are expressions of the forces applied on certain bone surfaces, whereas the intensity of the forces and thickness of cortical bone decreased in older individuals (Lauretani *et al*., 2006; Russo *et al*., 2006), which would increase the classification error range. Our results do not support this hypothesis, we observed better levels of diagnostic precision in the groups of skulls of older individuals (61-70 years). This information differs with that indicated by Krogman & Iscan, who did not recommend evaluation of sexual dimorphism in individuals older than 55 years. Our results suggest a cumulative effect in the expression of dimorphism, consequently with the passage of time these characteristics become permanent. Nevertheless, an evaluation of the life history of the subject would be necessary as the effects of exercise and nutrition have been noted. (Suazo *et al*., 2008c).

Sexual dimorphism is the expression of functional modeling of the skull and face and starting from a male or female pattern that begins acquiring characteristic phenotypical features.

There is an over expression of bone elevations in this process; ridges, tubercles processes etc., that characterize men and differentiate them from women. This development is related with differences in size and muscle mass. (Wells, 2007). It is probable that emphasis which exists in the observation of major development areas may confuse the diagnosis, and some interpreted as male characteristics, namely for their size, underestimating women, thereby reducing diagnostic performance of the tests. Consequently, additional diagnostics along with others as observation of sexual chromatin or advanced morphometric methods is recommended. (Kimmerle *et al.*, 2008; Suazo *et al*., 2010; Toro *et al.*, 2010; Suazo *et al.*, 2011).

SUAZO, G. I. & ZAVANDO, D. Efecto de la edad en el rendimiento de los rasgos morfológicos. ***Int. J. Morphol., 30(1)***:296-301, 2012.

RESUMEN: En este estudio testeamos la hipótesis que el rendimiento diagnóstico de los indicadores morfológicos de dimorfismo sexual disminuía al aplicarlos en cráneos y mandíbulas de individuos de mayor edad. Utilizamos 275 cráneos humanos adultos, 250 de los cuales tenían mandíbula, todos con registro de sexo y edad. Se evaluaron 16 indicadores morfológicos clásicos de dimorfismo sexual, estos datos se contrastaron con el registro y los resultados se expresaron en términos de exactitud. El mejor rendimiento general de los indicadores morfológicos de dimorfismo sexual se encontraron en los rangos etarios de 31-40 y de 61-70 años, la menor exactitud se encontró en el grupo correspondiente a individuos de entre 21-30 años. Nuestros resultados no sustentan la hipótesis propuesta y sugieren un efecto progresivo y acumulativo de los factores que determinan la expresión de dimorfismo.

PALABRAS CLAVE: Dimorfismo sexual; Determinación de sexo; Envejecimiento; Edad; Cráneo.

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