IDENTIFICATION OF SEX USING CRANIAL BASE MEASUREMENTS

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ABSTRACT

It is well known that the skull provides elements for sex identification. Twenty-two bones form the cephalic cranium and they are divided into *neurocranium* and *splancnocranium*. This research aimed to study different characteristics between skulls from both sexes by evaluating the following measurements: mastoid notch to incisive foramen (right and left side); mastoid notch to mastoid notch; and incisive foramen to basion. In order to do so, two hundred skulls were selected (100 males and 100 females), with information about the age of the subjects (20-55 years old), sex and ethnic group known according to records at the *Imaculada Conceicao Cemetery*, located in the city of Campinas, Sao Paulo State, Brazil. Measurements were taken using a digital calliper. The results were subjected to a statistical analysis (logistic regression and discriminate function) and showed dimorphic characteristics within the measurements. A formula with 79.9% accuracy was established for sex identification (*logito* = 25.2772 – 0.1601 x incisive foramen to basion – 0.0934 x mastoid notch – mastoid notch). The authors have concluded that the method is efficient and suitable for anthropology and forensic purposes. The research also showed that the analysis may be carried out using a practical computer program.

(J Forensic Odontostomatol 2007;25:7-11)

Key words: cranial base, skull measurements, sex characteristics, forensic dentistry

INTRODUCTION

Skulls of children and teenagers show only slightly pronounced qualitative characteristics which provide little information for sex identification.[1-3] After puberty, hormones, environment and muscle activity contribute to human skeleton development. Different characteristics between sexes may be noticed such as prominences, bone crests, apophysis and other structures showing sexual dimorphism. Such aspects are more noticeable in males, with the females showing more delicate and less pronounced details.[4-9]

Arbenz[10] stated that the human growth process normally ends between 22 and 25 years of age, and it may be influenced by nutrition, ethnic origin and socio-economic status. However, the accuracy of sex identification depends on the number and nature of the bones examined. According to Simonin[11] examination of a single bone aspect may lead to a result that can be different in the same bone. Therefore as much information as possible must be collected from the bone to increase the accuracy of the findings.

Comas[4] and Coma[1] also found that cultural activities must be considered when evaluating characteristics, especially those concerning work distribution and activities amongst the social group in question. They concluded that it is rare when identification of sex cannot be established. This is in accordance with the findings of Correa-Ramirez[12], who concluded that it is possible to achieve a level of 75 to 80% accuracy by cranium examination alone.

There are different anthropometric characteristics among ethnic groups which must be known in order to identify sex.[1] Due to a 500-year history of miscegenation, pure races in Brazil have become almost extinct. Nowadays different anthropological characteristics are less distinct than during the colonization period. The use of the *skin colour* rather than *ethnic group* in population surveys demonstrates this fact.[10, 13]

Research about sex identification is very important since it may eliminate approximately fifty percent of the subjects in human identification processes. Qualitative studies of skulls may establish the sex of the subject. However, the skulls sometimes lack important parts such as *neurocranium* and *splancnocranium* due to circumstances associated with the condition of the remains, such as victims of crime or disaster. This may represent a problem for sex prediction.

Considering that the cranial base is preserved in most cases, and anthropometric studies of this specific portion do not exist, this study aimed to investigate the different characteristics between sexes using the base of the skull.

MATERIALS AND METHODS

Sample selection consisted of 200 skulls of both sexes. Height, skin colour and age (20 to 55 years) were previously known and all data were collected, with permission, from the *Imaculada Conceicao Cemetery*, in the city of Campinas, State of Sao Paulo, Brazil. The research was approved by the Ethical Committee of the Dentistry School of State University of Campinas, which follows international guidelines for human research.

The skulls were selected according to location and the criteria of age and integrity. Skulls showing severe growth anomalies (eg: plagiocephaly) were excluded.

Distance measurements were taken using a digital calliper*, as follows:

- Distance between the anterior root of the mastoid notch and the incisor foramen on both sides,
- Distance between the left anterior root of the mastoid notch and the right anterior root of the mastoid notch,
- Distance between the Basion point (median point located in the anterior region of the magnum foramen) and the oral point (located in the palate, in the line tangent to the lingual borders of the upper central incisor alveolar process) (Fig.1).

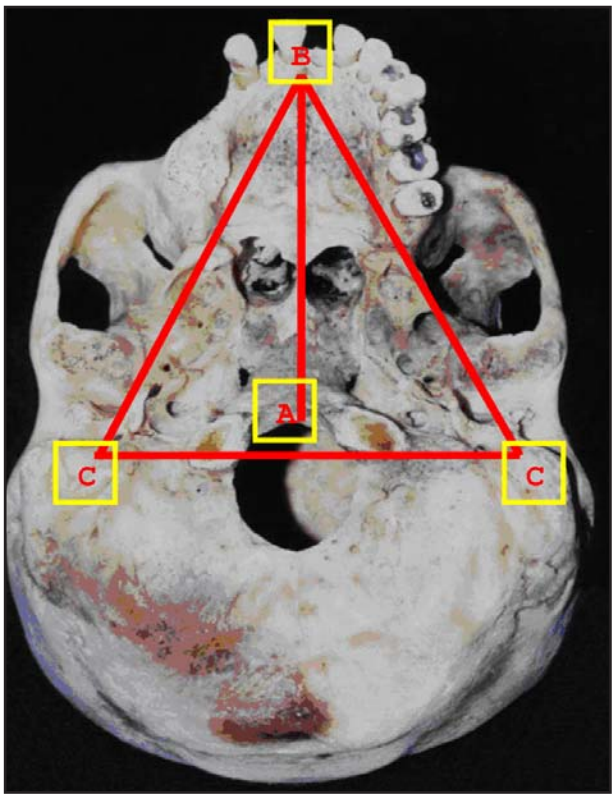
The measurements were repeated three times, after which all bones were sent to the ossuary or crematorium. Data was analysed using statistical software.** A Student t-test was performed to detect differences amongst groups relating to sex. A logistic regression was used to estimate the sex of the subject after being adjusted to a binary linear model using the variables “sex” and “distances”.

RESULTS

Data were collated for 4 measurements: right mastoid notch to incisive foramen (Table 1), left mastoid notch to incisive foramen (Table 2), right mastoid notch to left mastoid notch (Table 3) and Basion to incisive foramen (Table 4). In all cases the average distance was smaller for females than males. Moreover, for each measurement the confidence limits do not overlap between males and females, making these measurements good variables for sex prediction. The t-test confirmed the results presented in Tables 1 to 4. In addition, the standard deviation values were similar for both groups, indicating that errors during measurement were also of a similar nature.

A logistic regression model was constructed to include measured variables from the Stepwise method.[14-17] The variables “mastoid–mastoid notch” and “incisor foramen–basion point” achieved the minimal significance level. The other variables were at some point included in the model but excluded due to their low significance. The following function was determined:

Power Value = 25.2772 – 0.1601 x incisor foramen–basion point – 0.0934 x mastoid–mastoid notch



Measurements:
A – Basion (median point seen with the cranium at basal position, located in the anterior region of the magnum foramen);
B – Incisor point (central point located in the palate, in the line tangent to the lingual borders of the alveolar processes of the upper central incisors);
C – Mastoidal notch.

Fig.1: *Cranial base measurements taken in order to predict sex*

* Mitutoyo Sul America Ltd., São Paulo, Brazil.
**SAS Institute Inc., Cary, NC, USA, Release 8/2/2001

Table 1: *Descriptive Statistic from mastoid notch to incisive foramen (mm) – right side*

Sex	Max	Min	Mean	SD	Superior limit	Inferior limit	*p*value
F	112.0	85.0	102.04	5.48	103.60	100.48	0.0001
M	123.0	93.0	106.89	5.65	108.06	105.74	

Table 2: *Descriptive Statistic from mastoid notch to incisive foramen (mm) – left side*

Sex	Max	Min	Mean	SD	Superior limit	Inferior limit	*p*value
F	114.0	85.0	102.10	5.92	103.80	100.40	0.0001
M	123.0	93.0	106.82	5.66	107.97	105.67	

Table 3: *Descriptive Statistic from right to left mastoid notch (mm*)

Sex	Max	Min	Mean	SD	Superior limit	Inferior limit	*p*value
F	106.0	79.0	96.15	7.12	98.14	94.17	0.0001
M	118.0	87.0	102.44	7.23	103.9	100.97	

Table 4: *Descriptive Statistic from incisive foramen to basion (mm)*

Sex	Max	Min	Mean	SD	Superior limit	Inferior limit	*p*value
F	98.0	46.0	83.80	7.98	86.05	81.56	0.0006
M	106.0	76.0	88.35	5.81	89.55	87.14	

(incisor foramen–basion point is the distance between incisor foramen and basion point, mastoid–mastoid notch is the distance between right and left mastoid notches)

Using the *power* value the probability was estimated by calculating the variables for females, using the following formula:

$$P = \frac{e^{power}}{(1+ e^{power})}$$

Changing the *power* in the formula for female cranium probability, an accuracy of 79.9% was established in those measured.

DISCUSSION

A number of methods have been described for sex determination including clinical examination, anthropometrical measurements, tooth growth and eruption, radiographic analysis of medullar bone, microscopic bone examination and sexual chromatin analysis (Barr corpuscles).[18-23]

However, most of these methods are unknown and/or ignored by the majority of Forensic Institutes in Brazil, or are performed with no standardized method. In order to regulate the situation it is necessary for a responsible board to investigate, as well as to standardize, the identification processes.[12]

Brazilian anthropological studies focussed on determination of sex have only just started to be performed. According to Brazilian Law, as well as Dentistry Ethical Code, it is one of the Clinicians' responsibilities to estimate sex as part of identification processes. However, few dentistry schools prepare students for this type of professional activity. Moreover, authorities frequently prevent scientific research in cemeteries throughout the country.[24] Without knowing national skull measurements, scientific investigators are forced to use international tables, which may lead to uncertain results.[24, 25]

Anthropological measurements offer a simple and cost-effective method for determination of sex. However, anthropology can only be used in subjects free of growing pathologies.[26,27] It is better applied to subjects aged between 20 and 55 years old, since teenagers and elderly people can produce atypical bone characteristics.[28,1,25] Another limitation presented by anthropological methods is that hermaphrodites or pseudo – hermaphrodites can lead to incorrect results in sex identification. It must also be recognized that biological sex is not necessarily equated with life-style gender.

Advances in biological science have highlighted the use of DNA as a means of determining not only sex, but identity if comparative material is available. It is, however, not always possible to harvest DNA and the cost of such an examination must be taken into account.

The results of this study are supported by those of other such studies.[29,12,30,26,24] Kahanoha[24] and Carvalho *et al.*[29] obtained similar results but in those studies, qualitative exams were used without specific quantitative measurements which would give more reliability and reproducibility.

A qualitative examination is possible as long as the study always deals with the same population[31] and it must be noted that in a sample of 100 subjects, 10% could be hyper-males, 10% hyper-females and 10-15% uncertain.[1, 25]

One should only provide an identification certificate after detailed and rigorous microscopic, anthropological and DNA exams. Such certificates must be detailed with results based upon reliable

scientific studies and national sampling. Despite their complexity, such certificates allow us to accurately identify the subject and avoid manipulation of results.

CONCLUSION

According to the methodology used in this study, the following conclusions have been drawn:

1. Sexual dimorphism exists for the evaluated anthropometric measurements.
2. A mathematical formula has been created with a reliability of 79.9%, which can be used in Anthropological and Forensic institutes in Brazil.

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