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Original communication

Sex estimation from foramen magnum dimensions in an Indian population

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ABSTRACT

Identification of skeletal remains is vital in forensic investigations. The need for methods to estimate sex from cranial fragments becomes apparent when only a part of skull is brought for identification. The present research is an attempt to study the sexual dimorphism of the anteroposterior diameter, transverse diameter and area of foramen magnum in a population of costal Karnataka region using statistical considerations. Ninety adult dry skulls of known sex (50 male and 40 female) were included in the study. Morphometric analysis of foramen magnum was conducted using vernier calipers and the area of foramen magnum was calculated. The anteroposterior diameter, transverse diameter and area of foramen magnum are found to be significantly larger in males than females. Binary Logistic Regression (BLR) analysis was performed to derive models for estimation of sex from the different measurements of foramen magnum and Receiver Operating Characteristic (ROC) curve was drawn for the predicted probabilities obtained from BLR analysis. The predictability of foramen magnum measurements in sexing of crania was 65.4% for transverse diameter and 86.5% for the anteroposterior diameter. For the area of foramen magnum that was calculated using the formula derived by Radinsky and Teixeria, the predicted probabilities were observed to be 81.6% and 82.2% respectively. When anteroposterior and transverse diameter were used together in BLR analysis the predictability of sex increased to 88%. However, considering the overlapping in the male and female values for the foramen magnum measurements it is suggested that its application in sex estimation should be restricted to cases where only a fragment of base of the skull is brought for examination. In such cases, the anteroposterior diameter and area of the foramen magnum can be employed as better tools for sexing the skulls than the transverse diameter of the foramen magnum.

1. Introduction

The successful identification of the deceased is vital to any forensic investigation. One of the principal biological traits to be estimated from skeletal remains is the sex of the individual. Anthropological analysis is the mainstay in estimation of sex of unknown skeletal remains. Skeletal sex estimation relies on the sexually dimorphic expression of bony characteristics that are produced through different patterns, rates and periods of adolescent growth.[1] Sex can be estimated from a gross examination of the skeleton using metric and morphological techniques. Krogman in an admittedly biased study estimated sex with 100% accuracy when the whole skeleton was present, 98% from pelvis and cranium, 95% with only pelvis or pelvis and long bones, and 80–90% when only long bones or skull alone is brought for examination.[2] Later Stewart stated a sexing accuracy of 90–95% from whole skeleton, pelvis, or one hip bone, and 80% accuracy from skull alone.[3,4] Sex estimation in the human cranium is generally based on size differences and robusticity.[1,5] The differences are population specific and can be influenced by genetic, environmental and social factors.[6,7] Various studies have been done in the past to estimate the sex with reasonable accuracy by employing different measurements of cranium.[8–11] In a study on evaluation of accuracy and precision of cranial morphological traits for estimation of sex, William and Rogers considered more than 80% as the acceptable limits of accuracy.[12]

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Sex estimation becomes more difficult if only fragments of a skull are brought for medicolegal examination. Such fragmented skulls may be encountered in cases of physical insults such as fire, explosions or violence. The basal region of the occipital bone is covered by a larger volume of soft tissue. Owing to its thickness and relatively well-protected anatomical position, the basal region of the occipital bone is more likely to survive the physical insults than the other parts of skull. Thus, studies on estimation of sex using the occipital bone may prove useful in cases of identification of significantly disrupted remains.[5] Teixeria published an initial study on estimation of sex based on the size of foramen magnum.[13] Subsequent studies on this subject have been conducted on British,[5] Central European[14] Turkish[15,16] and Indian populations[17–19] using different statistical considerations. Gapert et al[5] used discriminant function and regression analysis on an eighteenth and nineteenth century British sample. The discriminant functions developed in the study predicted correct sex in 70.3% of all cases. Gruber et al[14] did not find any sexual dimorphism in the diameters of foramen magnum in Central European dry specimen dating from Pleistocene to modern times. Uysal et al have reported statistically significant sex differences in the width of foramen magnum diameters by using three-dimensional computed tomography (3DCT) measurements[16] and Gunay and Altinkok[15] based on correlation coefficient analysis concluded that the area is not a useful indicator for sex estimation in a Turkish population. In previous studies on Indian populations, Routal et al[17] and Sayee et al[18] utilized identification points (IP) and demarking points (DP) analysis while Deshmukh and Devershi[19] used univariate analysis. These studies did not find the foramen magnum measurements as reliable sexing criteria.

The principle aim of the present research is to study the sexual dimorphism of the anteroposterior diameter, transverse diameter and area of foramen magnum in a population from coastal Karnataka region using statistical considerations and to evaluate whether the foramen magnum morphometry can be reliably employed as a tool for forensic identification when only a fragment of base of the skull is brought for identification.

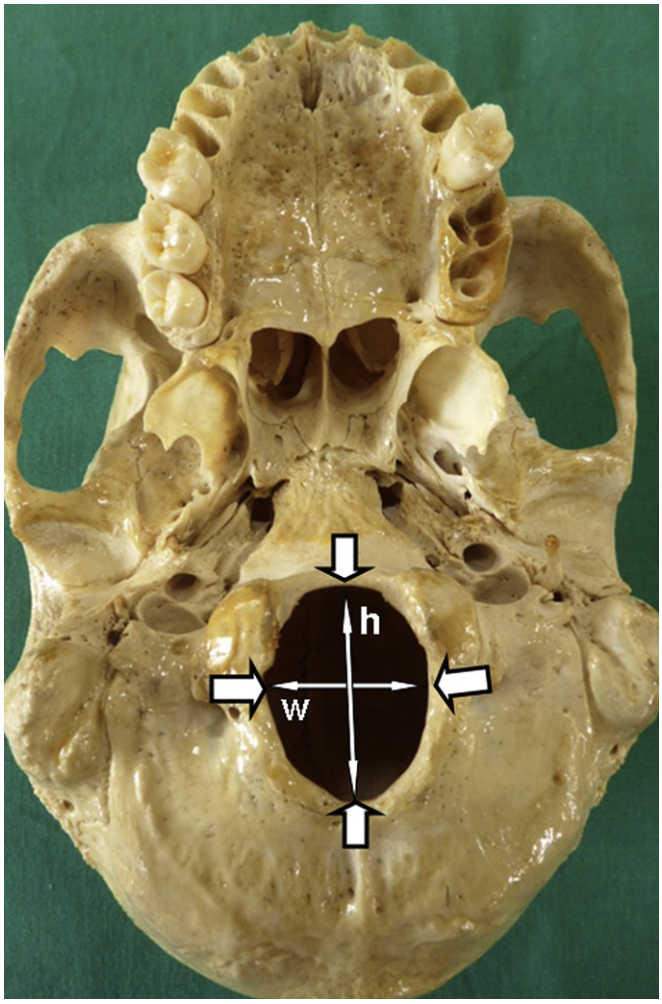

Fig. 1. Landmarks of foramen magnum illustrated on the base of skull.

2. Materials and methods

The present research was a short term time bound project conducted in the Department of Forensic Medicine, Kasturba Medical College, Mangalore. Ninety adult dry skulls (50 males and 40 females) were included in the study. The skulls were free from any fracture or other deformities. Morphometric analysis on the occipital bones was conducted with Vernier calipers (Lianying 0005) graduated to the last 0.01 mm.

2.1. Techniques for taking anthropometric measurements and measuring the area of the foramen magnum

Landmarks on the foramen magnum are described in Fig. 1.

2.1.1. Foramen magnum length/Anteroposterior diameter (h)

Foramen magnum length/Anteroposterior diameter (h) is the distance between Basion and Opisthion. Basion is the point where the anterior margin of the foramen magnum is intersected by the mid–saggital plane and Opisthion is the point at which the mid–saggital plane intersects the posterior margin of the foramen magnum.

2.1.2. Foramen magnum breadth/Transverse diameter (w)

Foramen magnum breadth/Transverse diameter (w) is the distance between the lateral margins of the foramen magnum at the point of greatest lateral curvature.

The prongs of the vernier calipers were placed over the described landmarks, fixed manually with the screw provided and the length and breadth of foramen magnum were recorded over the graduated metallic scale on the calipers itself.

2.1.3. The area of the foramen magnum (A)

The area of the foramen magnum (A) was calculated using formula derived by Radinsky[20] and Teixeria.[13]

$$\text{Radinsky's formula}: A = 1/4 \times \pi \times w \times h$$
$$\text{Teixeria's formula}: A = \pi \times \{(h + w)/4\}^2$$

(In the formula, 'π' was substituted as 22/7).

Before taking up the study, the measurements (h) and (w) were taken on 10 skulls by two observers (RBYP and TK) and tested for inter-observer error in measurements. TK measured the same skulls again for 'h' and 'w' two days later to find the intra-observer error in measurements. Both inter-observer and intra-observer error were estimated using paired t-test. No significant inter-observer error ($t = -0.557$, $p = 0.591$ for 'h', and $t = -1.464$, $p = 0.177$ for 'w') and intra-observer error ($t = -0.361$, $p = 0.726$ for 'h', and $t = -1.152$, $p = 0.279$) were found for the measurements of foramen magnum.

The data was analyzed using SPSS (Statistical Package for Social Sciences, version 11.0) computer software (SPSS, Inc., Chicago, IL, USA). Male–female differences in measurements were tested using