Introduction

Increasingly, computed tomography (CT) imaging has become an accepted and more utilized non-invasive method in skeletal biology. For sex estimation and classification, CT data have been used to generate 3D skeletal models (3DCT) from which morphological features of the skull have been assessed. Furthermore, 3DCT is one method that may be used in conjunction with discrete 3D coordinate data points, which are commonly employed for craniometric assessment of sex.

Several studies have assessed the precision of 3DCT acquisition of landmarks as compared to traditional caliper measurements and coordinate data collected by use of a digitizer on actual skulls, and no significant differences were found (Hildebolt et al. 1990; Williams & Richtsmeier 2003). Additionally, no significant differences were found in tests of observer error for landmark designation (Richtsmeier et al. 1999), suggesting that coordinate data from CT scans can be reliably used for sex estimation.

The purpose of this study was to assess the validity of craniometric landmark generation from 3DCT scans for sex determination. Three areas were examined — the skull, the mandible and the orbits. Size and shape differences between the sexes were explored with 3D geometric morphometric analysis.

Materials and Methods

The present analysis was conducted on a sample of post-mortem CT scans with documented sex, collected by the Department of Forensic Medicine, University of Copenhagen, although the total sample size was 108 individuals (M=54, F=54) although this varied by individual analysis. Individuals were scanned at a voltage peak of 120 kVp with slice thickness varying between 0.5mm and 2.0mm.

Segmentation and rendering of the data was done using Materialise Mimics medical imaging software to create 3DCT models of the skull for each individual. From the 3DCT, landmarks of the skull (n=21), mandible (n=19) and orbits (n=16) were placed on the 3D rendered skulls. The coordinate data for each landmark and for each individual were then exported from Mimics to PAST (Paleontological Statistics) software (Hammer et al. 2001) and SPSS statistical software programs for further analyses.

The landmark data for each analysis were subjected to a Procrustes transformation and were then analyzed using discriminant function analysis with a leave-one-out approach to assess determination of sex.

Results

The results of the discriminant function analysis for each of the three areas is presented graphically and in tabular format. The cross-validated accuracies are a more realistic reflection of the ability to reliable predict sex from the suite of landmarks.

Discussion and Conclusions

In general, all areas show discrimination of sex in excess of 80% accuracy. However, when cross-validated using leave-one-out analysis, accuracy is more conservative between 79.1% and 81.8%. For both the orbital and mandibular landmarks, females classified slightly better than males. Based on the greater displacement of the landmarks shown in Figure 4, males were generally more prognathic in the mouth region and tended to have larger shape differences in the width of the foramen magnum and in cranial breadth than females (Klaes & Williams 2011).

While good levels of accuracy were observed using 3D landmarks on the cranium, such data need to be collected in digital format (using a digitizer or 3D renders from CT data) and subsequently processed before being of practical use. This perhaps makes it less convenient when a quick assessment of a single individual in the lab or field is desirable, but remains of value for broader studies of sexual dimorphism in populations or when a highly detailed osteobiography of remains is warranted.

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