A6 Sex Determination Using Discriminant Analysis of Upper and Lower Extremity Bones: A New Approach Using the Volume and Surface Area of Digital Models

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The goal of this presentation is to propose a new approach for sex determination using the volume and surface area of digital bone models.

This presentation will impact the forensic science community by revealing a new sex determination method using the volume and surface area of bones. Using this method, the ulna has the highest accuracy for sex determination (94%). When utilizing the surface area of multiple bones, the maximum accuracy rate of 99.4% was achieved.

This study analyzed 3D digital models of selected upper and lower limb bones. The volumes and surface areas were calculated and used for sex determination. In addition, discriminant analysis of the volume and surface area of the bones was performed to determine sex.

This study used 110 Computed Tomography (CT) images taken from donated Korean cadavers (55 females and 55 males) to create 3D models of the following upper and lower elements: the clavicle, the scapula, the humerus, the radius, the ulna, the innominate, the femur, the patella, the tibia, the talus, and the calcaneus. The average ages of the female and male samples were 54 years and 55 years, respectively; the average heights were 156cm and 165cm, respectively. Elements showing signs of surgery or deformity were excluded from the study. A medical image-processing program, Mimics® version 16.0, was used to construct the 3D models and determine the surface area and volume of the bones. The 3D models were constructed on the basis of the outer perimeter of the cortical bone and the inner marrow space was not expressed. There were no significant differences between the 3D models and actual bones (p=0.79). Significant sex differences were found in all bones with respect to volume and surface area (p<0.01). The order of volume was the same in female and male (femur > innominate > tibia > humerus > scapula); however, the order of the surface area was different. The largest surface area in males was the femur and in females was the innominate (p<0.01).

The accuracy of sex determination ranged from 72.3%-94.5% in univariate discriminant function analysis for single bones. Regarding the use of volume for sex determination, the radius, humerus, and ulna (in ascending order) were more than 90% accurate; meanwhile, for surface area, the humerus, clavicle, radius, and ulna (in ascending order) were more than 90% accurate. Interestingly, the ulna has the highest accuracy for sex determination (94%).

Discrimination analysis using pairs of bones was over 90% accurate when surface area and volume were used for sex determination. Of 66 combinations, 32 were more than 90% accurate when using volume. Again, the ulna showed the highest accuracy; the combination of ulna with femur, tibia, or fibula showed an accuracy of 95.7%. Regarding surface area, 38 of 66 combinations were more than 90% accurate. The combination of ulna and the clavicle or patella was 95.4% accurate. Thus, paired bones were more accurate than single bones.

When using the surface area of multiple bones, a maximum accuracy of 99.4% was achieved. The equation is as follows: (discriminant equation of surface area; female<0<male)=0.060×clavicle+0.020×scapula+0.045×humerus+(-0.049)×radius+0.093×ulna+(-0.023)×innominate+0.091×patella+(-0.052)×fibula+0.043×talus−11.548. Overall, this study shows that bone volume and surface area can be used for sex determination.

This study revealed that using the surface area for sex determination is more accurate than using volume. Surface area can be calculated regardless of the expression of bone marrow space, broadening its applicability. Study limitations include no broken and/or damaged bones can be used and the samples were limited to Korean individuals. Regardless, the derived sex determination equation using the surface area of various limb bones was 99.4% accurate. Therefore, together with the traditional sex determination methods, this equation can be used for sex determination from available CT, Magnetic Resonance (MR), or 3D scan data. Furthermore, this method is expected to automatically determine sex from existing digitized bone data and make it easier to research other populations.

Sex Determination, Bone Volume, Surface Area

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