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Comprehensive evaluation of the greater sciatic notch for sexual estimation through three-dimensional metric analysis using computed tomography based models

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ABSTRACT

The greater sciatic notch is an effective indicator for sexual estimation, which is the initial process to identify unknown skeleton. Visual assessment is the mainstream of analysis methods; however, the subjectivity of researchers is also questioned. Metric method using three-dimensional models reconstructed from radiographic images can ensure reproducible and stable measurement of the greater sciatic notch. In this study, the greater sciatic notch was analyzed in various manners, including distances, angles, and dimensions, with the aid of an automatic measurement program and a landmark verification system. Among 28 items, 15 measurements showed more than 85% accuracy. Measurements related to the posterior part of the greater sciatic notch near the posterior inferior iliac spine particularly showed higher accuracy (93.1%). To test this observation, "arithmetic posterior angle of the greater sciatic notch", a generalized form of partial angle of the greater sciatic notch, was designed. It showed more than 90% accuracy. When the results of the three-dimensional measurements were applied to classify dry bones, it proved to be valid in contemporary Korean population. The method and results of this study can be referenced in wider use of the greater sciatic notch analysis.

1. Introduction

Sexual estimation is the primary procedure for any forensic anthropological and paleoanthropological analyses. Bones of the pelvic girdle exhibit great sexual dimorphism due to functional difference with regard to parturition [1]. The pubis is particularly known to be a good indicator for sexing, and the studies by Phenice and others observed sexual dimorphism in the pubic region for non-metric analysis [2–7]. However, the pubis from burials has low preservation rate because of its fragility, which prevents its usage for sex estimation [8,9]. In cases of loss of the pubis, other parts of the os coxae, such as the ilium, can be used for sex estimation.

The greater sciatic notch (GSN) is a posterior inferior part of the ilium. The GSN forms the greater sciatic foramen with ligaments and gives a passage for the piriformis muscle, superior gluteal nerve, and vessels [10]. The GSN shows sexual dimorphism in immature population, such as adolescents and fetuses, and adults [11–14]. A few studies showed valid result albeit the ilium is not completely fused with the other parts of the hip bone – the pubis and ischium – until the late teens or early twenties [15]. A number of researchers adopted the composite arch method proposed by Genovés; the method utilizes the anterior segment of the auricular surface along the outline of the GSN [16,17]. Other GSN studies adopted the sole analysis of the GSN with various methods including visual assessment [9,17,18].

The GSN is generally wide and shallow in female while narrow and deep in male. An ordinal scale system with five values was developed to facilitate more accurate analysis of the GSN than simple male/female classification [9,15]. However, this scoring system has a relatively wide range of "intermediate" value that cannot be clarified as whether female or male. The overlapping score, which Walker described as Score 2 in his study, has also the possibility to fluctuate with age group or population specificity of the studied samples [9]. On the other hand, by

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using a metric method, a researcher can obtain more palpable result with smaller overlap between two sexes.

Metric analysis of the GSN can involve various types and manners of measurement. A straightforward approach is measuring distances between landmarks and angle of the GSN. Several studies were conducted on dry bone samples from various skeletal collections worldwide [11,19–21]. A two-dimensional approach of metric analysis adopts radiographs of the pelvic area as its material [22].

A newer method is geometric morphometric analysis, which uses the outline of the GSN. In the geometric morphometric method, the contour of the GSN is taken from dry bones or their photographs with several points. The contour line of each sample then undergoes a process that draws out generalized contour of sample groups [23–27].

In addition, Biwasaka et al. [28,29] performed sex estimation in a unique way; they use the contour of the GSN by finding the best-fit circle to each GSN in a Japanese population. In their studies, they quantified the wideness of the GSN comparing the radius of the best-fit circle to splice curve between sexes. This method showed the availability of sex estimation using the GSN without indicating the landmark. The researchers also compared measurement values from dry bones and 3D models calculated from computed tomography (CT) scan data. This process ensured the feasibility of the computer-assisted metric method using the reconstructed 3D models from CT images.

Using 3D models has a few advantages in the aspect of reproducibility of measurement. Measurement research on the dry bone collection has been an important part of forensic and biological anthropology. However, taking measurements on the actual bones can be erroneous since the measurement process is performed with handheld instruments such as sliding calipers or protractors. In computer-assisted measurements, the entire process is performed via computer programs using coordinate information of each landmark and planes, which are created from landmark information. Automatic measurement can guarantee accuracy of measurement along reproducibility as coordinate information of landmarks can be recorded for reassessment [30]. In this study, we aimed to analyze the distance and angle measurements of the GSN on 3D models of a Korean population. Utilizing those various measurements, we also clarified which part of the GSN is more sexually dimorphic and suggested new method of discriminant analysis of sexes.

2. Materials and methods

2.1. Sample acquisition

A total of 202 three-dimensional models of os coxae stored at the Catholic Institute for Applied Anatomy were analyzed (female: 101, male: 101). Whole body multi-slice CT images were obtained from Korean cadavers. All samples were from adults with age range of 21–66 (mean age: 51.39 ± 11.01 years). Due to difficulty of collecting participants or patients data, we opted for cadaver donation of College of Medicine, The Catholic University of Korea. The subjects without visible deformation of the pelvic area were selected from donated cadavers.

The domestic law of Republic of Korea regulates cadavers to be donated with informed consent and handled under ethical process. The written consent embraces ranges of donation; dissection for anatomical research and education, sample production using body parts and donation of whole skeleton. Every college of medicine should abide the law identically. Thus institutional review board of the Catholic University of Korea discounted cadaveric studies for its review. Catholic Institute for Applied Anatomy's cadaveric collection satisfies qualification as educational and research material abiding the national law.

We performed CT scans of the subjects in condition before any treatment such as embalming or dissection was done, at St. Mary's Hospital of the Catholic University of Korea. CT acquisition was performed by SOMATOM Definition AS+, in anatomical position (tube voltage: 120 kV, tube current: 224 mA, slice thickness: 0.6 mm, reconstruction thickness: 0.6 mm, spiral pitch factor: 0.70, field of view: 256.00 mm, reconstruction kernel: B30f) (Siemens, Erlangen, Germany). Acquisition of 3D models from CT images was performed using Mimics (version 15.0; Materialise, Leuven, Belgium). The separation of the hip bone from adjacent structures was roughly conducted using the program with the default range of Hounsfield Unit (226–3071 HU) of the bone. Complete separation of articulation with the neighboring femur and os coxae was performed by a single researcher.

2.2. Standard plane creation

To create verifying and measurement planes, which ensure objective measurement of the GSN, procedures of setting standard planes were performed ahead of the GSN landmark indication. The standard planes facilitate in locating the os coxae in a position based on anatomical position. Standard planes are created with observer indicated landmarks and in relation between each plane which is programmed ahead of measurement process. The sagittal plane of the hip bone was initially created with three points on the surface of the pubic symphysis. This plane passes the three points at a time and covers the pubic symphysis without anywhere more protruding than the three points (Fig. 1). Next, the coronal plane was made with two points and a perpendicular plane which is the sagittal plane. The two landmarks were the most protruding points on the anterior superior iliac spine and the pubic tubercle. These landmarks were aligned to be on the coronal plane. Finally, the transverse plane was designed to be a plane perpendicular to both the sagittal and coronal planes. The transverse plane

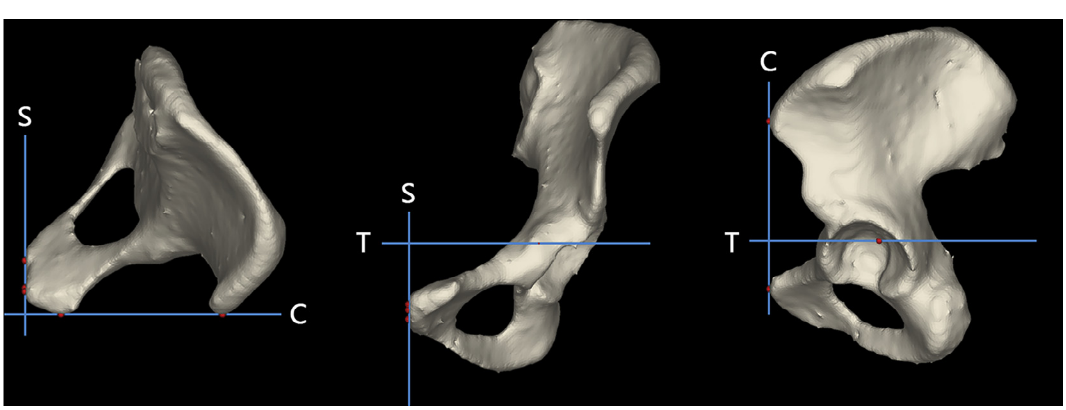

Fig. 1. Relationships of standard planes. S: sagittal plane, C: coronal plane, T: transverse plane. Points used for creation of standard planes were indicated by red dots. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)