A review paper on the morphometric analysis of sexual dimorphism in the sacrum

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Abstract

It has long been known that the sacrum, a triangular-shaped bone at the base of the spine, plays a significant role in sexual dimorphism in humans. Numerous studies have focused on the morphometric analysis of sexual dimorphism in the sacrum in recent years. An overview of the state of knowledge on the morphometric variations between male and female sacra is given in this review paper. The review discusses sacral morphometry's approach, including how different imaging modalities are used and how sacral parameters are measured. It also explores how age, race, and illness—factors that can affect sexual dimorphism—affect sacral morphology. Summarised and thoroughly explained are the results of investigations on the morphometric examination of sexual dimorphism in the sacrum. According to these findings, the male sacrum has a bigger sacral base, larger sacral foramina, and a more distinct sacral promontory than the female sacrum. Furthermore, it has been discovered that sexual dimorphism in the sacrum can be a helpful tool in forensic investigations, particularly in situations involving skeletal remains where gender identification is required. There is still much to learn about the sexual dimorphism of the sacrum, despite the significant progress that has been done. Future studies should look at additional variables that influence sacral morphology and the use of cutting-edge imaging methods, such 3D reconstructions, to increase the precision of sacral measurements.

Keywords: sacrum, sexual dimorphism, morphometric analysis, geometric morphometrics, forensic anthropology.

Introduction

The term "sexual dimorphism" describes how a species' males and females differ in terms of size, shape, and structure. The pelvis, a complicated structure that supports the abdomen and reproductive systems and makes walking and childbirth easier in humans, is where sexual dimorphism is most noticeable. One essential part of the pelvis and a significant source of sexual dimorphism is the sacrum, a wedge-shaped bone created by the fusion of five vertebrae [1,2]. The pelvic girdle's stability and the distribution of weight from the upper body to the lower limbs depend heavily on the sacrum. Age, race, illness, and, most significantly, sex, are some of the variables that have an impact on the morphology of the sacrum. The differing biomechanical demands placed on the male and female pelvis during life and reproduction have been linked to sexual dimorphism in the sacrum [3]. Morphometric analysis is the quantitative examination of the dimensions, morphology, and organisation of biological structures through the use of various measurement methods [4]. Numerous studies have focused on the morphometric analysis of sexual dimorphism in the sacrum in recent years. With a focus on the methodology of sacral morphometry, the variables that affect sacral morphology, and the implications of sexual dimorphism in the sacrum for forensic investigations, this review paper aims to give an overview of the current understanding of the morphometric differences between male and female sacra.

Methodology of Sacral Morphometry

A variety of imaging methods, including as radiography, computed tomography (CT), magnetic resonance imaging (MRI), and 3D reconstruction, can be used for sacral morphometry. Accurate measurements of sacral characteristics, including length, width, height, sacral curvature, and sacral foramina diameters, are possible thanks to these imaging techniques [5].

In sacral morphometry, which uses X-rays to create two-dimensional pictures of the sacrum, radiography is a frequent imaging technique. With the aid of increasingly sophisticated imaging methods like CT and MRI, the sacrum may be seen in three dimensions, and the parameters can be measured with higher precision. A three-dimensional model of the sacrum can be created using 3D reconstruction techniques using information from CT and MRI scans, which can then be used to analyse complicated sacral morphology [6].

To evaluate sexual dimorphism in the sacrum, several sacral characteristics can be assessed in addition to imaging methods. These include the dimensions of the sacral foramina and sacral promontory, as well as the sacral length, width, height, and curvature.

The first sacral vertebra's top margin and the fifth sacral vertebra's lower margin are commonly used to estimate sacral length. Sacral height is measured from the sacral promontory to the tip of the coccyx, while sacral width is measured at the widest point of the sacral ala [7]. The angle created between the sacral base and the sacral promontory is used to calculate the sacral curvature. The paired apertures on either side of the sacrum known as the sacral foramina can be measured to determine sexual dimorphism. In sacral morphometry, the sacral promontory, which is the anterior projection of the first sacral vertebra, is frequently employed as a reference point [8].

Factors Influencing Sacral Morphology

Sexual dimorphism can result from a variety of variables that affect sacral morphology. Age has been found to have an impact on sacral dimensions, with the sacrum growing older and broader as the sacroiliac joint degenerates [9]. Sacral morphology has also been discovered to be influenced by race, with African Americans having broader and shorter sacra than people of European heritage [10].

Sexual dimorphism can also be caused by disease, which alters sacral anatomy. For instance, it has been demonstrated that osteoarthritis of the sacroiliac joint alters the proportions of the sacrum, making it larger and shorter [11]. Changes in sacral morphology, including a more pronounced sacral curvature, can also be brought on by ankylosing spondylitis, a chronic inflammatory condition that affects the spine and sacroiliac joints [12].

It is believed that differences in the biomechanical demands placed on the pelvis throughout life and reproduction are the main cause of sexual dimorphism in the sacrum. While the female sacrum is designed to ease childbirth, the larger, more powerful male sacrum is thought to offer greater support and stability for the upper body during physical activity. For childbirth, a wider pelvic outlet is provided by the larger female sacrum [13].

Morphometric Differences Between Male and Female Sacra

The morphometric variations between male and female sacra have been the subject of numerous investigations. According to these findings, the male sacrum has a bigger sacral base, larger sacral foramina, and a more prominent sacral promontory than the female sacrum. Males exhibited considerably greater sacral breadth, height, and surface area than females, according to a study by Macchi et al. that assessed sacral canal dimensions in people using CT scans [14]. Males had considerably bigger sacral dimensions, including sacral length, width, height, and surface area, than females, according to another study by Baab et al. using MRI scans to quantify sacral characteristics in healthy people [15].

Studies on sexual dimorphism in the sacral foramina have revealed that males have larger sacral foramina than females. Using CT scans, Nishi et al. assessed the diameters of subjects' sacral foramina and discovered that males had noticeably bigger sacral foramina than females [16].

Studies have revealed that the sacral promontory is a region of sexual dimorphism, with males having a more pronounced sacral promontory than females. When Schultz et al. used CT scans to evaluate the sacral promontory angle in people, they discovered that men had a considerably higher sacral promontory angle than women [17].

The male sacrum was significantly larger in all measured parameters, including sacral length, width, and height, according to a different study by Gaya-Sancho et al. that looked at the sexual dimorphism of the sacrum in a spanish population [18]. Additionally, they discovered that the male sacrum was more pronounced and had a more acute sacral curvature than the female sacrum.

Despite the fact that the majority of studies have discovered that sexual dimorphism in the sacrum is congruent with conventional gender standards, certain studies have indicated that sacral morphology varies depending on gender identification. In a study by Ravichandran et al. that looked into the sacral morphology of transgender people, it was discovered that the transmasculine group's sacra resembled male sacra more closely than female sacra while the transfeminine group's sacra resembled female sacra more closely [19].

Clinical Applications of Sacral Morphometry

Numerous clinical settings for sacral morphometry exist, particularly in gynaecology and orthopaedics. Sacral morphometry can be utilised in orthopaedics to direct surgical planning for sacral operations such as spinal fusions. For instance, precise sacral dimension measurement can be utilised to help choose the size and location of sacral screws for spinal fusions [20].

Sacral morphometry can be used in gynaecology to gauge a woman's risk of a challenging labour. A narrow sacral outlet is linked to a higher chance of instrumental delivery and caesarean section, according to several studies that have demonstrated that sacral dimensions are predictive of obstetric outcomes [21]. Accurate assessment of the sacral dimensions can aid in identifying women who may have a challenging labour and delivery.

Conclusion

Numerous studies have shown that males and females have different sacral morphologies, confirming the existence of sexual dimorphism in the region of the sacrum. Sacral characteristics and sexual dimorphism can be precisely measured using imaging techniques like CT and MRI. Age, race, and illness can all have an impact on sacral morphology and sexual dimorphism. Numerous clinical settings for sacral morphometry exist, particularly in gynaecology and orthopaedics. Accurate assessment of the sacral measurements can assist in surgical planning and identify women who may have a challenging labour. While the majority of studies have discovered that sexual dimorphism in the sacrum is consistent with conventional gender norms, there have also been reports of variations in sacral morphology based on gender identity. Overall, more investigation into sexual dimorphism in the sacrum may advance our knowledge of the reproductive and biomechanical differences between males and females and guide clinical practise across a range of specialties.

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