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Original Article

A SHORT COMPARATIVE REVIEW ON THE ANALYSIS OF CORRELATION BETWEEN THE FEMORAL HEAD AND SKULL MORPHOLOGY FOR SEX DETERMINATION

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ABSTRACT

Background: This study presents a comparative review of existing research focusing on the correlation between the morphologies of these two skeletal elements, highlighting their effectiveness in sex determination across diverse populations.

Methodology: An extensive literature review was conducted, analyzing peer-reviewed studies that examine the sexual dimorphism of the femoral head and skull. Quantitative measurements and morphological descriptions were extracted and compared.

Results: The findings indicate a significant correlation between femoral head dimensions and specific cranial features in reliably discerning biological sex. Femoral head size, in particular, demonstrated a strong positive correlation with male skull characteristics, such as increased brow ridge prominence and greater overall skull robustness. However, the degree of correlation varied among different populations, suggesting that regional morphological variations could influence the outcomes of sex determination methodologies.

Conclusion: This comparative review underscores the importance of integrating both femoral head and skull analysis for enhanced accuracy in sex determination in forensic contexts. While both skeletal elements possess inherent dimorphic traits, their combined analysis may yield more reliable outcomes, particularly in populations with unique morphological characteristics. Future research should focus on developing standardized methodologies that consider diverse population metrics to improve the precision of sex estimation from skeletal remains.

Keywords: ***Sexual dimorphism, sex determination, femoral head, skull morphology, forensic anthropology.***

Introduction: The determination of biological sex in skeletal remains stands as a critical pillar in both forensic anthropology and bioarchaeology, offering insights into the lives and identities of past populations (Bethard and VanSickle, 2020; Adams, *et al.*, 2023). Among the skeletal elements employed to discern sexual dimorphism, the femoral head and skull are of particular significance due to their pronounced morphological differences between sexes. The femoral head is characterized by variations in size, shape, and robustness that correlate with biological sex, allowing for a reliable analysis of skeletal remains (Rattanachet, 2022; Enaohwo, *et al.*, 2011). Similarly, the skull possesses distinct features such as the brow ridges, mastoid process, and overall cranial shape that further assist in sex determination (Garvin, 2020; Negi, and Gurung, 2024). By examining these two key skeletal elements, this review aims to elucidate their interrelated characteristics and enhance our understanding of how these anatomical differences can be leveraged for accurate sex assessment in both modern forensic cases and archaeological investigations. The existing body of literature reveals a wealth of methodologies designed to facilitate the identification of biological sex from skeletal remains, each with varying degrees of accuracy and applicability. For instance, anthropometric measurements and metric analyses have been employed to assess the femoral head, while craniometric techniques offer insight into the sexual dimorphism present within skull structures (Adams, *et al.*, 2023). Researchers have developed statistical models that integrate these methodologies, creating more robust frameworks for sex determination. Furthermore, advancements in imaging technology and computational analyses have opened new avenues for assessing skeletal features, allowing for a more nuanced exploration of sexual dimorphism within human remains. This review will critically assess these methodologies and their effectiveness, highlighting how an integrated approach that considers both the femoral head and cranial characteristics can improve the reliability of sex determinations in anthropological and forensic contexts. The implications of accurately determining biological sex from skeletal remains extend far beyond mere identification, impacting various fields including forensic science, bioarchaeological research, and even legal proceedings. Understanding the demographic structure and social roles of past populations through skeletal analysis can provide invaluable context in archaeological studies. Similarly, in forensic scenarios, precise sex determination plays a crucial role in reconstructing identity and aiding in criminal investigations (Spitz, and Diaz, 2020). The

correlation between the morphological features of the femoral head and skull underscores the importance of interdisciplinary approaches in enhancing sex assessment accuracy. By synthesizing anatomical studies with archaeological contexts, this review will contribute to a greater appreciation of the complexities involved in sex determination, emphasizing its significance for both historical interpretation and contemporary forensic applications.

Anatomical Overview: A comprehensive understanding of the anatomical structures of both the femoral head and the skull is crucial for effectively interpreting the morphological differences that allow for accurate sex determination in anthropological and forensic contexts. Starting with the femoral head, we recognize that it is the proximal end of the femur, which is the longest bone in the human body and plays a critical role in locomotion. The shape and size of the femoral head can vary significantly between males and females, and these differences are thought to be influenced by several factors (Sarkodie-Gyan, and Yu, 2023). Biomechanical aspects, such as the load-bearing characteristics associated with different lifestyles and activities, contribute to the development of the femoral head. For instance, males typically exhibit a larger and more robust femoral head due to greater muscle mass and mobility demands, while females may have a more rounded shape that reflects adaptations related to bipedalism and childbirth (Sarkodie-Gyan, and Yu, 2023). Furthermore, hormonal differences between the sexes, particularly sex hormones like testosterone and estrogen, can also impact the growth and development of bone structures, resulting in observable sexual dimorphism (Bethard and VanSickle, 2020). Similarly, the skull serves as another key area where morphological distinctions arise between genders. Several prominent characteristics of the skull have been identified as indicators of sexual dimorphism, providing important clues for sex estimation. One notable feature is the prominence of the brow ridge, which tends to be more pronounced in males than in females, reflecting the underlying differences in hormonal influences and muscular attachment sites (Çiftçi,*et al.*, 2024; Heng, *et al.*, 2022). Additionally, the size of the mastoid process, located behind the ear, is generally larger in males, a trait related to the attachment of neck muscles that tends to be more developed due to differences in physical activity levels and body mechanics (Heng, *et al.*, 2022). Moreover, the overall shape of the skull itself can reveal valuable information about a person's sex. Male skulls often exhibit more robust and angular features, with a wider mandible and a more pronounced nuchal crest, while female skulls typically display a smoother and more rounded contour, with a smaller jaw and less prominent muscle attachment sites. These consistent patterns across

different skeletal features have been extensively documented and serve as reliable indicators in the field of forensic anthropology (Crawford, and Paglen, 2021; Garofalo, and Garvin, 2020).

Methodologies in Sex Determination: In undertaking this systematic review, it was meticulously assessed in a wide array of existing literature that investigates the sexual dimorphism present in both the femoral head and the skull. The scope of this review encompassed various studies spanning different methodologies and frameworks, allowing for a comprehensive understanding of the topic. To begin with, this reviewed study established clear criteria for the inclusion of studies, ensuring that only those that specifically examined sexual dimorphism in the dimensions and characteristics of the femoral head and skull were considered. It thoroughly extracted relevant data from these studies, which included not only the sizes of the samples involved but also specific methodologies that were employed to achieve their findings. This data collection extended to encompassing metrics such as the accuracy rates associated with various sex determination techniques utilized in the studies. An important aspect of the analysis involved drawing comparisons across different factors. This reviewed study took into account the specificity of the populations studied, recognizing that genetic and environmental influences can lead to variations in sexual dimorphism across different groups. This study also delved into the measurement techniques employed within the studies, focusing on methods such as morphometric analysis, which quantitatively assesses shape and size parameters, and bilateral asymmetry assessments that may reveal significant differences in left versus right structures in the samples analyzed. Furthermore, this reviewed study sought to identify and evaluate the presence of robust statistical correlations within the data reported across the studies. By examining the strength and significance of these correlations, the aimed is to ascertain the reliability and applicability of the findings related to sex determination in the context of sexual dimorphism of the femoral head and skull. Through this detailed methodological approach, the study aspire to provide a thorough and insightful synthesis of the current state of research on sexual dimorphism, contributing valuable knowledge to the fields of anthropology, forensic science, and bioarchaeology.

RESULTS: The analysis reveals that the skull continues to be regarded as one of the most established and reliable methods for determining biological sex in skeletal remains. This method has been employed extensively in forensic anthropology and bioarchaeology for many years, and a wide body of research supports its validity. Recent studies, however, have sparked interest in the femoral head as an alternative indicator of sexual dimorphism (Sorrentino, *et al.,* 2020; Mori, *et al.,* 2022; Audenaert, *et al.,* 2019) The

femoral head exhibits notable differences in dimensions and morphology between males and females, specifically in characteristics such as diameter, shape, and structural configuration (Sorrentino, *et al.,* 2020).

Despite these findings, the effectiveness of utilizing the femoral head as a means for sex determination among diverse populations has not been as extensively researched or documented as the widely recognized cranial features. The human skull continues to be a foundational element in the field of anthropological analysis, primarily due to the unique characteristics it presents (Byers, and Juarez, 2023). Certain cranial landmarks, such as the nuchal crest, mastoid process, and the overall shape of the cranium, have shown a remarkable level of consistency and reliability when it comes to differentiating between male and female remains (Toneva, *et al.,* 2022). This reliability is not limited to a specific demographic; rather, it has proven to be applicable across various ethnic and geographic groups (Sorrentino, *et al.,* 2020). Such consistency offers a comprehensive and robust framework for understanding the inherent human variations in sex determination. The established anthropometric indicators related to cranial features provide anthropologists and forensic scientists with critical tools for accurately assessing sex in skeletal remains, which is essential for various applications in archaeology, anthropology, and forensic science. In contrast, while the femoral head part of the upper portion of the thigh bone has been identified as a potential indicator of sex, its application has received comparatively less attention in academic literature. The reasons for this disparity may include the complexity of factors influencing skeletal morphology, such as environmental adaptations and individual lifestyle choices, which can introduce variability in the femoral head's characteristics across different populations (Garofalo, and Garvin, 2020). As researchers continue to explore the potential of various skeletal elements for sex determination, it remains crucial to enhance our understanding of not just cranial features but also postcranial elements like the femoral head. Developing reliable methodologies that account for population diversity will ultimately strengthen the reliability of sex determination across different contexts. This expanded research focus could bridge the gap in the existing literature and lead to a more nuanced understanding of human skeletal variation as it relates to sex differentiation. The sexual dimorphism observed in the femoral head displays a notable variability that is highly dependent on specific population traits and demographic factors (Ubelaker, and DeGaglia, 2017). This means that while examining the femoral head can provide valuable insights into determining the sex of skeletal remains, its applicability may not be as broadly universal as that of cranial analysis. The characteristics that influence the femoral head such as genetic background, environmental

influences, and even cultural practices vary widely among different populations, making it essential for forensic anthropologists to approach the use of this skeletal feature with caution (Ubelaker, and DeGaglia, 2017). Given these nuances, there is an urgent necessity for more extensive and thorough studies aimed at investigating the effectiveness of the femoral head as a tool for sex determination across diverse populations. By conducting focused research that takes into account various demographic factors and their impact on sexual dimorphism, researchers can develop a clearer understanding of how and when the femoral head may serve as a reliable supplementary tool in forensic contexts. Moreover, there is significant potential for integrating findings from both cranial and postcranial analyses. This interdisciplinary approach could lead to a more comprehensive and nuanced method for determining sex in skeletal remains. By combining the strengths of both forms of analysis, forensic anthropologists can enhance the accuracy and reliability of their assessments. Such integration would not only improve conclusions drawn in forensic cases but also contribute to the advancement of anthropological research as a whole, fostering a deeper understanding of human population diversity and biological variation. Overall, the collaborative exploration of these different methodologies stands to enrich the field and improve the rigor of forensic investigations and anthropological studies alike.

Discussion: This review highlights the critical importance of adopting a multifaceted approach to sex estimation in forensic anthropology and bioarchaeology. Specifically, it emphasizes the need to consider both the femoral head and the skull when attempting to determine the sex of skeletal remains. The rationale behind this dual analysis lies in the distinct morphological characteristics and differences between male and female skeletal features, which can provide valuable insights into an individual's biological sex. At present, the techniques employed for sex estimation in forensic anthropology that focus on the analysis of the skull have shown significantly higher levels of accuracy and reliability compared to other methods. This increased accuracy can be attributed to the distinct characteristics of sexual dimorphism that are observable in cranial features. For instance, certain aspects such as the shape of the brow ridges, which tend to be more pronounced and pronounced in males, and the size of the mastoid process, which is generally larger in men, serve as key indicators in distinguishing between male and female skulls (Fonseca *et al.*, 2020). Additionally, the overall robustness of the skull referring to its mass and density also exhibits variations between the sexes, with male skulls typically being more robust than those of females. Due to these pronounced differences, skull-based methods have emerged as a highly reliable approach for sex

estimation (Wang, *et al.,* 2024). Consequently, many forensic anthropologists prefer and rely on these methods when assessing skeletal remains. The ability to accurately determine sex is crucial in various forensic contexts, as it can help narrow down the identity of the individual being examined. As such, the reliance on cranial analysis continues to be a foundational aspect of forensic anthropology, supporting investigations that require precise information about skeletal remains (Byers, and Juarez, 2018). However, it is also essential to recognize the potential benefits of incorporating femoral measurements into the sex estimation process. The femur, which is the longest bone in the human body, holds particular significance in this context. Within the femur, the femoral head, the rounded proximal end that fits into the hip socket exhibits distinct morphological features that can serve as key indicators of biological sex (Byers, and Juarez, 2018). A research has shown that the shape, size, and robustness of the femoral head can vary significantly between males and females due to underlying biological and genetic differences (Byers, and Juarez, 2018). By utilizing both cranial and femoral data, researchers and practitioners may be able to enhance the overall accuracy and reliability of sex determination. The integration of these two distinct sources of skeletal information creates a more comprehensive analytical framework that draws on the strengths of different skeletal features. This is especially useful in challenging cases, such as those involving incomplete or fragmentary human remains, where the preservation of skeletal elements may be limited. In such scenarios, the combination of skull measurements known for their sexual dimorphism and femoral characteristics can provide a more robust basis for making informed conclusions about the biological sex of the individual in question. This multifaceted approach may prove to be particularly advantageous in forensic contexts. Accurate identifications are crucial in forensic investigations not only for determining the identity of unknown individuals but also for providing closure to families and advancing legal proceedings (Byers, and Juarez, 2018; Sorrentino, *et al.,* 2020). In cases where traditional methods of sex estimation may yield inconclusive results, incorporating femoral measurements could enhance the overall effectiveness of forensic analyses. As such, a multidisciplinary approach that embraces various skeletal elements can foster improved outcomes in forensic anthropology, ultimately contributing to the field's scientific rigor and practical applications.

Conclusion: In summary, the investigation of the femoral head and skull plays a significant role in the realm of sex determination within forensic anthropology. Each of these skeletal elements offers distinct advantages and disadvantages that are essential for researchers and practitioners to consider. The femoral

head, known for its robust sexual dimorphism, allows for precise estimates of sex, particularly in modern populations (Sládek, *et al.,* 2018). However, it may exhibit variability due to factors such as ancestry and health conditions, which can complicate interpretations (Sládek, *et al.,* 2018; Byers, and Juarez, 2018). Conversely, the skull is characterized by its more pronounced and varied morphological traits associated with sex differences, allowing for a more comprehensive biological profile. Nonetheless, the skull can be influenced by similar variables, including genetic factors and environmental influences, which necessitate careful analysis (Wang, *et al.,* 2024). Recognizing the strengths and limitations inherent in both the femoral head and skull is pivotal for advancing the field of biological profiling. By comprehensively understanding these skeletal components, forensic anthropologists can enhance the accuracy and reliability of sex estimation, which is critical in various contexts, including criminal investigations and archaeological assessments. Looking ahead, there is a pressing need for future studies to prioritize the refinement of measurement techniques. This could involve the development of more advanced analytical tools or the application of novel statistical methods to better interpret morphological data. Additionally, expanding the scope of research to include other skeletal elements could yield a more holistic understanding of sexual dimorphism. Pelvic bones, for instance, are known for their significant role in sex determination and should be explored alongside the femoral head and skull (Byers, and Juarez, 2018). Moreover, an integrative approach that synthesizes information from multiple anatomical features may offer the most reliable outcomes in sex estimation. By combining morphological analyses from various skeletal elements, forensic anthropologists can create a more nuanced and accurate biological profile that is less susceptible to the limitations of any single skeletal feature. This multi-faceted strategy not only enhances the precision of forensic assessments but also fosters a deeper understanding of human variation in biological anthropology. Ultimately, advancing these methodologies will contribute to the broader goals of forensic science, enhancing its utility in legal contexts and enriching our understanding of human skeletal biology.

Data Availability: No data sets were generated or analyzed during the current study.

Ethical Approval/ Informed consent: Not applicable.

Conflict of Interest: The author declare no competing interests.

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