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Original Article

Characterizing Sex Using Anthropometric Variables of the Human Hip Bone Remains from Museum Collections in Ilorin, Kwara State, Nigeria

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Abstract

BACKGROUND AND AIM: Sex estimation is an important step for identification and construction of biological profile of skeletal remains which leads to identification in forensics. The hip bone is the one of the most frequently used bones in sex estimation. In this study, we examined human hip bones sourced from the museum collection of the Department of Anatomy at the University of Ilorin to assess their suitability for determining sex in skeletal remains.
METHODOLOGY: Eighty-nine (89) hip bones were collected, analyzed and classified as either male or female based on morphology, total pelvic height, iliac width, pubic length, spinosciatic length, acetabular diameter, vertical acetabular diameter, ischiopubic length, ilium length, ischial length, ischiopubic and coxal indices. The purposive sampling method was employed in this study, in which bones meeting the inclusion criteria were selected.
RESULTS: Results after statistical analysis indicated that pubic length, acetabular diameter, ischial length, and Ischiopubic index showed statistically significant differences, all of which were significantly higher in males compared to females ($p<0.05$). However, when comparing between males and females using pelvic height, iliac width, spinosciatic length, vertical acetabular diameter, ischiopubic length, ilium length, and coxal index did not show statistical significance with values ($P>0.05$).
CONCLUSION: Based on these findings, it can be said that the hip bone is a standard, ideal and useful bone in sex estimation. The variability in hip bone for estimation based on race, nationality or ethnicity in Nigeria and relationship between age and pevimetry for both sexes should be given attention and further investigated.

Keywords:
Sex estimation, Hip bone, Forensics, Identification

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INTRODUCTION

Sex determination by analyzing pelvic bones involves using human skeletal remains to determine or compute an individual's gender by examining the pelvic bones and their distinctive characteristics (Leskovar *et al.,* 2023; Baca *et al.,* 2022). It is widely acknowledged that the pelvis, when accessible, is widely recognized as the most dependable indicator (Battan *et al.,* 2023) and the most accurate bone for sex determination (Senol *et al.,* 2023; Baca *et al.,* 2022).

Measuring the hip bone for sex estimation is preferred over simple observation because it provides quantitative data through anthropometric measurements, enhancing accuracy and reliability while accounting for variability (Berner *et al.,* 2020). This approach allows for more precise sex estimations and offers a scientifically robust approach to sex estimation (Klales *et al.,* 2020). Anthropometric measurements can be standardized and replicated across various studies and populations, facilitating comparative analysis. By quantifying specific dimensions such as pelvic width, researchers can achieve greater accuracy in sex determination (Swift *et al.,* 2023). Moreover, these measurements help mitigate subjective interpretation and reduce bias that may arise from visual observation, as pelvic features exhibit significant variation within and between sexes (Davidson *et al.,* 2023). Standardized Measurements promote objectivity, minimizing inconsistencies in sex estimation using the hip bone (Klales, 2021).

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Measurements promote objectivity, minimizing inconsistencies in sex estimation using the hip bone (Klales, 2021).

The hip bone is composed of three bones: the ilium, ischium, and pubis. During birth, these three bones are initially separated by hyaline cartilage. They come together at a Y-shaped section of cartilage within the acetabulum. By the end of puberty, the three bones would have merged, and by age 25, they will have undergone ossification (Tesch *et al.,* 2021).

Identifying unidentified skeletal remains has proven to be a substantial challenge for forensic anthropologists, especially in situations that involve mass disasters and the extensive decomposition of human remains (Ambers *et al.,* 2023; Fabbri *et al.,* 2023).

Sex estimation contributes to streamlining the assessment of numerous other skeletal characteristics, such as estimating the age at the time of death, ascertaining racial background, evaluating stature (Şener, 2023; da Silva *et al.,* 2023) and delving into intricate biological factors like pathological conditions, environmental impacts, and dietary habits (Wu, Yin, 2022; Yazdanian *et al.,* 2022).

Hip bone sex estimation lacks population specificity, unlike other parts of the skeletal (Vacca, 2022). Sex estimation is more dependable when the entire skeleton is available for examination, but in forensic cases, human skeletal remains are frequently compromised by conditions like incompleteness, lack of integrity, burning, or damage (Krap, 2022; Pilli, 2022).

MATERIALS AND METHODS

Eighty-nine (89) adult, undamaged, dry, complete human hip bones were randomly selected from a total of ninety-eight (98) bones for this study from the Department of Anatomy Museum Collection at the University of Ilorin, located in Ilorin, Kwara State, Nigeria. Each bone was then classified according to its morphology as either male or female, as well as left or right. After examining the eighty-nine (89) hip bones, for gender difference forty-five (45) were determined to be male pelvic bones while forty-four (44) were determined to be females using morphological characteristics based on key features like shape of the pubis and obturator foramen, acetabular diameter and greater sciatic notch shape while for positional difference forty-five (45) were identified to be left sided while forty-four (44) were identified to be right sided. All the bones were fully developed (adult) bones and showed no signs of disease or birth defects.

Purposive sampling method was used, where appropriate bones that fit into the inclusion criteria were selected. For this study, hip bones that were undamaged, dry and completely ossified with known gender were included.

Damaged, deformed, malformed or broken hip bones were excluded during measurements in order to produce accurate and authentic measurements and results. The side to which the bone belonged to was determined using visuals, positions and the direction where parts of each bone faced. It also involved the determination of anterior (pubic bone), posterior (ischial tuberosity), lateral (acetabulum) or superior (iliac crest) parts. For the right hipbone, the anterior faces left, lateral faces right, superior faces medially to the left. For the left hipbone, anterior faces right, lateral faces left and the superior faces medially to the right.

Anthropometric parameters were measured using an analog vernier caliper. They include: total pelvic height, iliac width, pubic length, spinosciatic length, acetabular diameter, vertical acetabular diameter, ischiopubic length, ilium length, ischial length. Ischiopubic index was calculated as the percentage of the ratio of pubic length to ischial length while coxal index was calculated as the percentage of the ratio of iliac breadth to pelvic height.

Total pelvic height was measured from the internal lip of the iliac crest to the ischiopubic ramus (Arora, 2013).

Iliac width was measured as the distance between the anterior superior iliac spine and the posterior superior iliac spine of each pelvic bone (Arora, 2013).

Pubic Length was measured from the pubic crest to the other side of it on the pubis (Gupta *et al.,* 2017).

Spinosciatic length was measured as the distance from the anterior inferior iliac spine to the deepest point of the greater sciatic notch (Gómez-Valdés *et al.,* 2011).

Acetabular diameter was measured from the midpoint of the upper part of the acetabulum, passing through the center to the bottom of it (Indurjeeth *et al*., 2019)

Acetabular depth was measured from the midpoint of the upper part of the acetabulum, passing through the center to the bottom of it (Indurjeeth et al., 2019).

Ischiopubic length was measured from the top of the acetabular notch to the ischiopubic ramus of the pubis (Schaefer *et al*., 2009).

Ilium length was measured as the distance from the outer edge of the iliac crest to the top part of the acetabular notch (Solomon *et al*., 2008).

Ischial length was measured as the distance between the superior part of the acetabular notch to the inferior part of the ischial tuberosity of the ischium (Vlak *et al*., 2008).

Ischiopubic index was calculated using the formula:

$$Ischiopubic\ index = \frac{Pubic\ length}{Ischial\ length} \times 100$$ (Singh and Potturi, 1978)

Coxal index was calculated using the formula:

$Coxal\ index = \frac{Ilican\ breadth}{Pelvic\ height}\ X\ 100$ (Singh and Potturi, 1978)

After all the measurements were done, data was statistically analyzed using IBM statistical package for social sciences (IBM SPSS) statistics verson 21 (manufactured by international business machine corporation). Sex determination of the hip bones was assessed using unpaired student's t-test. A value of $p<0.05$ was considered statistically significant. Mean and standard deviations were calculated for each parameter of both the genders and sides.

RESULTS

Table 1: Parameters measured based on gender difference and the corresponding p-values

Parameter	Males (N=46)	Females (N=43)	P-value
Total Pelvic Height (cm)	19.42±1.18	19.21±1.35	0.420
Iliac Width (cm)	14.18±1.30	14.25±1.06	0.774
Pubic Length (cm)	3.50±0.38	3.29±0.37	0.012*
Spinosciatic Length (cm)	7.08±0.58	6.92±0.60	0.188
Acetabular Diameter (cm)	5.51±0.34	5.33±0.38	0.017*
Vertical Acetabular Diameter (cm)	5.98±0.36	5.90±0.36	0.323
Ischiopubic Length	8.38±0.58	8.36±0.57	0.903
Ilium Length	11.54±0.61	11.35±0.81	0.209
Ischial Length	8.51±0.52	8.24±0.62	0.033*
Ischiopubic Index	98.61±0.52	101.69±0.62	0.013*
Coxal Index	73.10±6.52	74.25±3.40	0.304

*=p<0.05 statistically significant

Pubic length, acetabular diameter, Ischial length and Ischiopubic index were significantly higher ($P<0.05$) in males than females (Table 1). Total pelvic height, iliac width, spinosciatic length, vertical acetabular diameter, ischiopubic length, ilium length and coxal index of the males and females did not show any statistically significant differences ($P>0.05$; Table 1). There were also no statistically significant differences ($P>0.05$) in all the parameters measured between the right and left sides (Table 2).

Table 2: Parameters measured based on positional difference and the corresponding p-values

	Left (N=44)	Right (N=45)	P-value
Total Pelvic Height (cm)	19.37±1.21	19.26±1.33	0.694
Iliac Width (cm)	14.10±1.40	14.32±0.923	0.385
Pubic Length (cm)	3.35±0.38	3.43±0.40	0.416
Spinosciatic Length (cm)	6.95±0.56	7.05±0.62	0.416
Acetabular Diameter (cm)	5.46±0.39	5.38±0.33	0.304
Vertical Acetabular Diameter (cm)	6.00±0.35	5.88±0.37	0.416
Ischiopubic Length	8.43±0.55	8.31±0.59	0.319
Ilium Length	11.45±0.70	11.43±0.75	0.878
Ischial Length	8.42±0.59	8.33±0.59	0.458
Ischiopubic Index	100.42±5.29	100.33±6.56	0.816
Coxal Index	72.88±6.29	74.47±3.72	0.153

DISCUSSION

From the findings of this study, it was observed that the value of total pelvic height was not significantly different between males and females. This finding is in agreement with reports by Camacho *et al*. (1993) observed the mean of pelvic width values and determined that there was no significant difference of mean between males and females, while it is at variance with reports by other researchers (Davivongs, 1963; Segebarth–Orban, 1980; Steyn, Iscan, 2008; Arora, 2013) who observed a significant increase in total pelvic height, pelvic width and iliac width between males and females.

Iliac width in this study was not statistically significant different between males and females. This finding is at variance to reports by scientists who observed a significant increase in iliac width in males compared to females (Segebarth–Orban, 1980; Steyn, Iscan, 2008). This indicates that iliac width values may not be a reliable factor for sex estimation of hip bones.

The analysis revealed a statistically significant difference ($p<0.05$) in pubic length between females and males, despite males showing a higher mean value. This study proposes that females display variations in pubic body growth at a younger age compared to males, contrary to previous findings that suggested differential growth only in late adolescence or early adulthood. This aligns with research by Sutherland and Suchey (1991), who indicated that the divergence in pubic body growth between genders begins in early childhood. As a result, pubic length values can be reliably utilized for determining the sex of hip bones of Nigerian origin. Furthermore, the unpaired t-test indicated no significant difference in pubic length between the left and right hip bones.

The value derived from the spinosciatic length was not significant when comparing males with females although the mean value was higher in males than females. This suggests that spinosciatic length values may not be dependable for determining the sex of hip bones. Statistical analysis through an unpaired t-test indicated that there was no significant variation in spinosciatic length between the left and right hip bones.

The result showed that the acetabular diameter was significant ($P<0.05$) in males compared to females although the mean value was higher in males than females. This disagrees with reports by Mukhopadhyay (2012) who observed that bones with sciatic notch and acetabular height index equal or greater than 93 (or 93 when expressed as a percentage) was definitely higher in female compared to males. This indicates that acetabular diameter values can be used for determining the sex of hip bones. The unpaired t-test showed no significant variation in acetabular diameter between the left and right hip bones.

The vertical acetabular diameter values, despite being higher in males on average, were not statistically significant according to the unpaired t-test. This suggests that vertical acetabular diameter values may not be dependable for determining the sex of hip bones. Additionally, the statistical analysis revealed no significant variation in vertical acetabular diameter between the left and right hip bones.

The ischiopubic length showed no statistically significant difference ($P>0.05$), although the average value was higher in males than females. These results align with previous studies (Milne, 1990; Patriquin *et al*., 2005; Dixit *et al*., 2007). They found insignificant differences in ischiopubic length between sexes. However, contrary to the findings of some researchers (Attah *et al*., 2015; Oladipo *et al*. 2014; Ekanem *et al*., 2009; Igbigbi and Msamati, 2000, Segebarth–Orban, 1980; and Wahburn, 1949), this study did not observe significant differences in ischiopubic length between male and female hip bones. These differences in the ischiopubic length values cannot be reliably applied for sex determination of hip bones of Nigerian origin; however it is reliable in North Eastern Nigeria according to works done by Attah *et al*. (2015) and not reliable in this study. Similarly, in a separate study conducted by Mobb and Wood (1977) involving eight primate taxa, including Homosapiens, Colobus, Presbytis, Cercopithecus, Gorilla, Pan, Papio, and Cercocebus, pubic length was found to be greater in females compared to males overall. However, it is worth noting that females of Gorilla, Pan, Papio, and Cercocebus exhibited less pubic growth compared to their male counterparts.

The value derived from the ilium length was not significant when compared between male and female bones although the mean value was higher in males than females. This does not corroborate Afrianty *et al.* (2013) who reported that females had higher iliac length when compared to males. This suggests that ilium length values may not be dependable for determining the sex of hip bones from Nigerian individuals. Statistical analysis through an unpaired t-test indicated that there was no significant variation in ilium length between the left and right hip bones.

In this study, the results indicated that the average ischial length was statistically significant ($P<0.05$) in males compared to females, despite males having a higher mean value. This finding is consistent with observations by Attah *et al*. (2015) and Ekanem *et al*., (2009), who also noted greater ischial length in males compared to females. It can be inferred that ischial length can reliably assist in determining the sex of hip bones across multiple ethnic groups in Nigeria.

Schultz (1949) compared ischial length across a series of primates and humans, except for sub-adult Chimpanzees, noting a significant difference favoring males in all species. These findings were supported by Rissech *et al*. (2003), who observed longer ischial length in boys, especially those over five years old, indicating sex-based growth differences. However, they found that males and females had similar length means until ages 15-19.The results of this study were consistent with findings in other populations, such as those of Washburn (1949) and in Australian Aborigines (Davivongs, 1963), but contradicted the findings of Boucher (1957), who reported no differences in ischial or pubic lengths. In our research, statistical analysis using an unpaired t-test showed that there was no significant variation in ischial length based on position between the left and right sides of the hip bones.

The findings of this study revealed that the ischiopubic index was statistically significant ($P<0.05$) in males compared to females, despite females having a higher mean value. Reports by Rissech and Malgosa (2007) confirmed that the ischiopubic index was a reliable variable for sub-adult sex determination and age assessment. Studies by Ekanem *et al*. (2009), Sachdeva *et al*. (2014), Oladipo *et al*. (2014) and Igbigbi and Msamati (2000) all supported these findings, noting that the ischiopubic index was significantly higher in females compared to males. This suggests that the ischiopubic index can be confidently used for sex determination among individuals of Nigerian origin and across various ethnic groups in the country.

Findings in this study showed that coxal index was not significant between the male compared with the female although the mean value was higher in females than males. This discovery contradicted other published findings (Singh and Potturi, 1978; Shah *et al*., 2011), who emphasized the significance of the Coxal index (CI) and Genoves' sciatic notch index (GSI) in determining sex based on hip bones. This implies that Coxal index values may not reliably indicate the sex of hip bones of Nigerian origin, unlike in the Indian population where they are considered dependable for this purpose. Minor racial differences in hip bone structure between these regions may account for the variation in index values.

The Coxal index based on positional differences (left and right) did not show significance between the hip bones on the left and right sides. These results are consistent with earlier research (Garson, 1881), where no significant difference in the Coxal index between the right and left sides of the hip bone among populations such as the Andamenese, Peruvian, New Caledonian, and Savage Islander, was reported. This suggests an overall greater robustness of the right hip bone.

The various parameters examined in this study underscored the significance of certain factors for sex estimation, notably highlighting the importance of the Ischiopubic Index, Acetabular diameter, Pubic length, and Ischial length as significant and critical determinants. Conversely, Pelvic height, iliac width, Spinosciatic length, vertical acetabular diameter, ischiopubic length, Ilium length, and Coxal index values were found to be unreliable for sex estimation of hip bones of Nigerian origin. The indices utilized in this study were the Ischio-pubic and Coxal indices; no novel indices were devised for this research. Variations observed within each group may be attributed to factors such as diverse ethnic backgrounds, socioeconomic statuses, health conditions, and levels of physical maturity. Here, we offered a comprehensive analysis of sexually dimorphic parameters, which could prove invaluable in determining sex even when only fragmented remains of hip bones are available for assessing the sex of deceased and decomposed skeletons.

CONCLUSION

In accurately estimating sex using pelvic bone, it's crucial to consider multiple features together. Given the variability in pelvic bone and pelvic morphology across different races, nationalities, or ethnicities, a comprehensive approach is essential. From this study, parameters such as pubic length, acetabular diameter, ischial length, and ischiopubic index have been validated as useful indicators for sex estimation. Additionally, it's recommended to explore other measurements like Genov's sciatic index and the study of preauricular surfaces for further investigation as potential parameters for sex estimation using pelvic bone. Utilizing anthropometric measurements instead of relying solely on visual observation is paramount in sex estimation and identification. This approach ensures quality assurance, reliability, increased accuracy, precision and accounts for variability across populations.

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