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Morphoscopic Approaches for Age and Sex Estimation of Unprofiled Hip Bones: a Study of Hip Bone Collections of Department of Anatomy Museum University of Port Harcourt, Nigeria

Loveday Ese Oghenemavwe[1], Augustina Nkem Oludiniwa[1]

[1]Department of Anatomy Faculty of Basic Medical Sciences College of Health Sciences University of Port Harcourt

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ABSTRACT

Introduction: the lack of biologically profiled skeletal remains is a major setback in the teaching of forensic anthropology in most Nigerian Universities. The purpose of the study therefore was to create biological profile of unidentified human hip bones in the Anatomy Museum of the University of Port Harcourt using several morphoscopic approaches.

Materials and Methods: 27 dry and fully ossified bones were used for this study, 16 of the bones were from University of Port Harcourt Anatomy museum and 11 were harvested from cadavers. Phenice and Bruzek methods were used for sex estimation while Suchey-Brooks method was used to estimate age. The accuracy of these methods was validated using hip bones of known sex.

Results: for the hip bones with known sex, the Phenice methods classified 81.82% of them accurately while the Bruzek had 100% accuracy. 2 of the bones with known sex were wrongly classed by the Phenice method. Of the 26 hip bones, the Phenice and Bruzek methods could not estimate sex for 14.82 % and 3.70% of the samples respectively. All the samples accurately classified as either male or female by the Phenice method were also classed in like manner by the Bruzek method. The visual assessment of the developmental stages of the symphyseal surfaces and the result of age estimation showed most of the hip bones are in the fourth phase.

Conclusion: the study showed multiple skeletal approaches would give higher assurance of accuracy in creating the biological profile of unknown hip bones.

Keywords: Hip bones; Sex estimation; Age estimation, Port harcourt; Anatomy museum.

Introduction

The hip bone is formed by union of the ilium, ischium and pubis at the acetabulum and together with the sacrum they form the bony wall of the pelvic cavity. It provides attachment for muscles, protect the viscera of the pelvis and support the weight of the body through the transfer of the weight of the upper part of the body from the axial skeleton to the lower appendicular skeleton. Most significantly, it supports the birth canal for females and this role of the hip bone in reproduction has made it a choice bone for several researches in sex estimation for biological profiling of unknown skeletal remains[1,2,3,4,5,6,7,8,9]. Studies have also shown the morphological changes associated with bony configuration of the symphyseal surface of the pubis as a person grow from infant to adulthood are well correlated with age[10,11,12].

Estimation of age and sex uses metric (quantitative) and morphoscopic (description of forms) methods. Over the years, researchers have focused on the formulation of methods that could be universally applicable. Phenice[4], developed a visual method for sexing the pubic bone using the ventral arc, sub-pubic concavity and medial aspect of the ischiopubic ramus. The initial study showed an accuracy level of 96% for sex estimation in all ancestral groups sampled. Howbeit, after the initial study, variations in the level of accuracy of the method in sex estimation have been reported for some population[8–13,14,15]. Bruzek[9], morphologically sexed hip bones by using eleven traits that reflect the functional morphology of ischiopubic and sacroiliac complexes.

There are some considerable difficulties in age and sex estimation from human bones of unknown origin as a result of variability that occurs in the expression of specific traits in different populations due to interaction of genetic and environmental factors. This underscores the need to establish population specific forensic reference values for the identification of skeletal remains. There are postulations that the application of several methods could increase the accuracy of identification.

As at today in Nigeria, Anatomy Departments of most Universities are still the major store house of skeletal remains, as most unclaimed dead bodies (cadavers) are released to the unit for the teaching

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of the gross anatomy of the human body to medical students. Skeletal tissues from these cadavers in most cases have reduced forensic value because of lack of basic pre-mortem and or peri-mortem data, and are consequently less useful in forensic studies and analysis. This situation has substantially impeded the practice and growth of forensic Anatomy and related forensic disciplines in Nigeria. To resolve this challenge, we set out to investigate if the application of multiple sex and age estimation methods could help us to create profile of these unidentified hip bones in the Anatomy Museum of University of Port Harcourt, Nigeria.

Materials and Methods

Twenty seven human hip bones where used for the study; sixteen were selected from the bone collection of the Anatomy Museum of the University of Port Harcourt and eleven were extracted from freshly dissected cadavers. The freshly harvested bones were used for validation as their sexes were already known, sexing of these set of hip bones was done blinding by experiences investigators who had no prior knowledge of the sex of the bones. The available records showed the bones of the museum were extracted from Nigerian indigenes as indicated by the source of cadavers, however, there were no records of sex, stature and age, the museum bones were harvested from cadavers between 2015 to 2018. The extracted bones were subjected to cold water maceration procedure to ensure the preservation of bony features. Only hip bones with intact anatomical features were selected for the study.

The freshly harvested bones were de-fleshed and immersed in water containing detergent for degreasing. The greasy and putrid water was changed periodically for 3-5 days for a period of 30 days. Further maceration was done by soaking the bones in water containing 5% sodium hydroxide for another two weeks. This further softened the flesh, cartilages and tendon still sticking to the periosteum. The clean bones were rinse properly in water and air dried. All the bone samples were then randomly tagged UP1 to UP27 for purpose of proper recording.

The Phenice[4] and Bruzek[9] methods were used for sex estimation while the Suchey-Brook method was used to estimate age. The Phenice method assessed the presence or absence of three traits namely; the ventral arc, sub-pubic concavity and medial aspect of the ischiopubic ramus.

Ventral arc: This is a bony ridge on the ventral aspect of the pubis. It is usually present in females and absent in males (see figure 1 a and b). The bone was placed such that the ventral surface was perpendicular to the assessor with the superior pubic ramus aligning horizontally and the area lateral to the pubic symphysis face was assessed.

Sub-pubic concavity: The sub pubic concavity in the female hip bone displays concavity of the ischio-pubic ramus along the medial edge from anterior view; this appears straight in males (See figure 2a and b). For assessment of the sub pubic concavity, the dorsal surface was held perpendicular to the investigator and the part under the symphyseal surface was assessed.

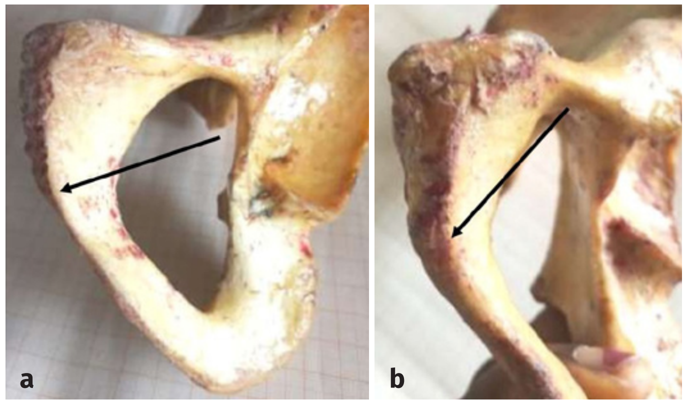


Figure 1: Ventral arc absent in males (a) and present in females (b)

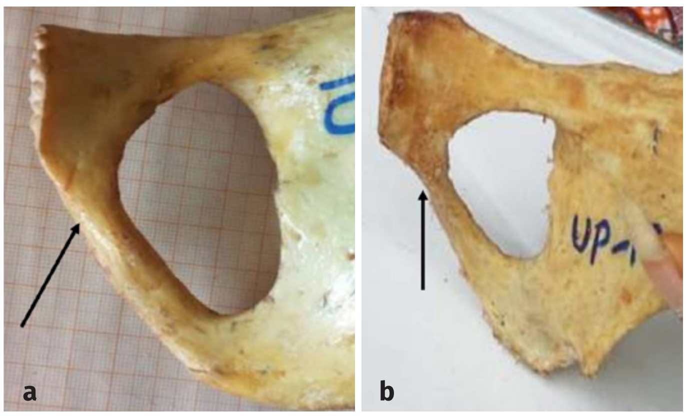


Figure 2. Shows the subpubic concavity absent in males (a) and present in females (b)

Medial aspect of ischiopubis ramus: The medial surface of ischiopubic ramus form sharp crest (narrow edge) in females but is flat and broad in males. The medial aspect of the ischiopubic ramus was assessed by holding the symphyseal face perpendicular to the investigator, with superior and inferior borders of symphyseal face vertically aligned; the part beneath the inferior edge of the symphyseal face was assessed (See figure 3 a and b).

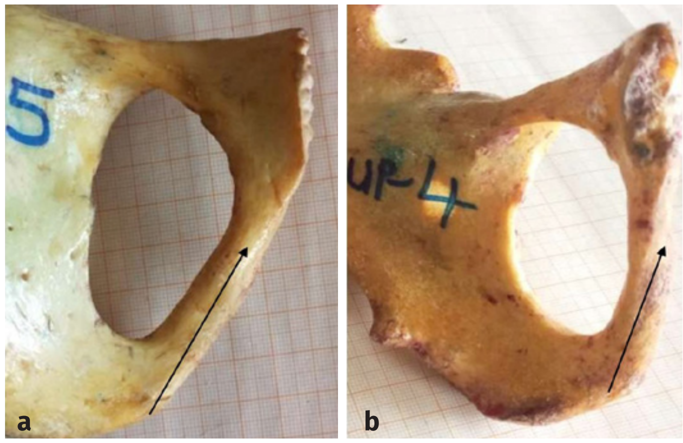
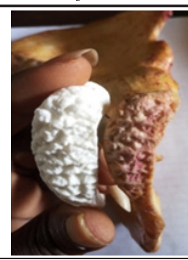


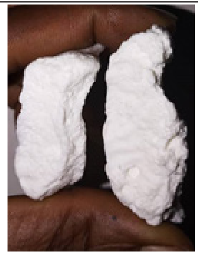
Figure 3. The medial aspect of ischio-pubic ramus broad in a males (a) and pinched in a females (b)

Bruzek method was used to investigate sexual dimorphism of the hip bones by evaluating eleven traits broadly divided into 5 groups. These traits are found in the preauricular area, greater sciatic notch and inferior pelvis and they reflect the functional morphology of the pelvic bone. Each trait was given a score as male (m), female (f) or indeterminate (i) as described by the author. The traits evaluated were; preauricular groove (T1), paraglenoid groove (T2), piriform tubercule (T3), proportion of the length of the sciatic chords (T4), symmetry or asymmetry of the notch chords (T5), course of the contour of posterior notch cord relative to a line drawn parallel to notch depth (T6), composite arch (T7), eversion of the inferior border of the pelvis (Ischiopubis ramus) (T8), absence or presence of phallic ridge (T9), ishiopubic ramus aspect (T10) and the proportion of pubis length to ischium length (T11)

The Suchey and Brooks method[11] was used for age estimation. The method assesses the degree of degeneration of symphyseal surface by evaluating the presence of furrows, ridges, ossific nodule, lipping or ridging. It has been proven that these features vary with age as degenerative changes increases with age. To ascertain the age of our samples, visual comparisons were made with standard Suchey and Brooks casts purchased from France casting Colorado USA. The matching phases were recorded and a corresponding age range and mean age was assigned to each hip bone (see table 1). The College Research Ethics Committee approved the study.

Table 1. Suchey-Brooks age estimation.

Phase	Male age range & mean age	Female age range & mean age	Phase description	Pictorial representation
Phase 1	15-23 (18.5)	15-24 (19.4)	There is lack of delimitation of superior / inferior extremity, ridges and furrows	
Phase 2	19-34 (23.4)	19-40 (25.0)	The Symphyseal surface may still show ridge development. Lower and Billowing surface, ossific nodule may occur at upper extremity.	
Phase 3	21-46 (28.7)	21-53 (25.0)	There is Ventral rampant in beginning stages and absence of lipping of dorsal margin.	
Phase 4	23-57 (35.2)	26-70 (38.2)	The symphyseal surface is finegrained and hiatus can occur in upper ventral rim	
Phase 5	27-66 (45.6)	25-83 (48.1)	The symphyseal face completely rimmed, some depression on the face itself	

Phase 6	34-86 (61.2)	42-87 (60.0)	The symphyseal face shows depression, rim erosion, marked ventral ligamentous attachments.	 None of our samples corresponded to the Suchey and Brooks phase 6.

Results

Table 2 shows the results of applying the Phenice and Bruzek methods to estimate sex of the harvested bones with known sex. The Phenice methods classified 81.82% of the bones accurately while the Bruzek had 100% accuracy. Two of the bones with known sex were wrongly classed by the Phenice method. Tables 3 and 5 showed the percentages of the sampled hip bones that were classified as either males or females using the Phenice method only, the sex of 14.82% of the sampled bones could not be determined. The Bruzek method estimated sex for 93.30% of the sampled hipbones (see table 5 ad 6). The visual assessment of the developmental stages of the symphyseal surfaces and the result of age estimation are shown in tables 1 and 6. Age could not be estimated for eight of the samples because the symphysis surfaces were partially eroded.

Discussion

The Phenice, Bruzek and Suchey-Brooks methods used in this study were employed to assign sex and age to hip bones of Anatomy Museum in the Department of Anatomy, University of Port Harcourt as a way of enhancing the forensic values of the bones as well as developing teaching models that could be

Table 2. Validation test for Phenice and Bruzek Methods

Bone tag	Known sex	Sex estimated by phenice method	Sex estimated by Bruzek method
UP-2	Female	Female	Female
UP-18	Female	Female	Female
UP-19	Male	Male	Male
UP-20	Female	Female	Female
UP-21	Female	Female	Female
UP-22	Female	Male	Female
UP-23	Male	Male	Male
UP-24	Female	Male**	Female
UP-25	Female	Female	Female
UP-26	Female	Female	Female
UP-27	Male	Male	Male
Accuracy		9/11 = 81.82%	11/11 = 100%

** Subject is below 20years.

Table 3. Result of sex estimation by Phenice method.

Sample	Ventral arch	Subpubic concavity	Ischio pubic ramus	Inference
Up-1	A	A	A	Male
Up2	P	P	P	Female
Up-3	I	A	P	Indeterminate
Up-4	P	P	P	Female
Up-5	A	A	A	Male
Up-6	A	A	A	Male
Up-7	P	I	P	Female
Up-8	I	A	P	Indeterminate
Up-9	A	A	A	Male
Up-10	I	A	A	Male
Up-11	P	P	P	Female
Up-12	I	A	P	Indeterminate
Up-13	A	A	P	Male
Up-14	A	A	A	Male
Up-15	I	A	A	Male
Up-16	I	A	P	Indeterminate
Up-17	A	A	A	Male
Up-18	P	P	P	Female
Up-19	A	A	A	Male
Up-20	P	P	P	Female
Up-21	I	P	P	Female
Up-22	A	P	A	Male*
Up-23	A	A	A	Male
Up-24	A	P	A	Male*
Up-25	I	P	P	Female
Up-26	P	P	P	Female
Up-27	A	A	P	Male

* Wrongly classified; P = present; A = absent; I = indeterminate

Table 4. Result of sex estimation by Bruzek method.

Bone tag	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Infere nce
Up-1	M	M	M	M	M	M	M	M	M	F	M	Male
Up-2	F	F	F	F	F	F	F	F	F	F	F	Female
Up-3	F	M	M	M	M	M	F	M	M	F	M	Male
Up-4	M	F	F	F	F	F	M	M	F	F	F	Female
Up-5	M	M	M	M	M	M	M	M	I	F	F	Male
UP-6	M	I	M	M	M	I	F	M	I	M	F	Male
Up-7	I	F	M	F	F	F	F	F	F	M	F	Female
Up-8	M	I	F	M	M	M	M	F	F	F	F	Indeterminate
Up-9	M	M	M	M	M	M	M	I	M	M	F	Male
Up-10	I	M	M	M	M	M	M	F	M	M	F	Male
Up-11	I	F	F	F	F	F	F	F	M	M	F	Female
Up-12	M	M	M	M	M	M	M	M	M	F	F	Male
Up-13	M	M	M	M	M	M	M	M	M	M	F	Male
Up-14	M	I	M	M	M	M	M	M	M	M	F	Male
Up-15	M	M	M	M	M	I	M	F	M	M	F	Male
Up-16	M	M	M	M	M	M	M	M	M	M	F	Male
Up-17	M	M	M	M	M	I	M	M	M	M	F	Male
Up-18	F	I	F	F	F	F	F	F	F	F	F	Female
Up-19	M	F	M	M	M	M	M	F	M	M	M	Male
Up-20	F	F	F	F	F	F	F	F	F	F	F	Female
Up-21	F	I	F	F	F	F	F	F	F	F	F	Female
Up-22	I	F	F	F	F	F	F	F	F	F	F	Female
Up-23	M	F	M	M	M	I	M	F	M	M	F	Male
Up-24	I	F	F	F	F	F	F	F	F	F	F	Female
Up-25	F	F	F	F	F	F	F	F	F	F	F	Female
Up-26	I	I	F	I	F	F	F	F	F	F	F	Female
Up-27	M	M	M	M	M	M	M	M	M	M	M	Male

M = male; F = female; I = indeterminate

Table 5. Summary of results for both Phenice and Bruzek method.

Methods	Male	Female	Indeterminate
Phenice	14 (51.85%)	9 (33.33%)	4(14.82%)
Bruzek	15(55.56%)	11(47.74%)	1(3.70)

used by students for hands-on-skills in sex and age estimations. The aim is not to make comparison of these methods but to apply multiple morphoscopic approaches to ascertain the certainty of sex and age assign to the unidentified bones as application of several identification methods enhances the level of accuracy.

However, there are some observations we would like to share in this article from our experience. As shown in table 2, the Phenice method estimated the sexes of 9 out of the 11 samples of known sex. The mean estimated age for one of the bones that the sex could not be accurately estimated was 19.2 years (range 15-24). It appears strong expression of sexually dimorphic characteristics of the pubis begins at puberty and progressively into adulthood, thus the effect of age, gene and other environmental factors that influences the development of the hip bone could significantly affect the accuracy of Phenice method in age estimation.

Our findings revealed that the ventral arc in isolation estimated sex of 19 hipbones representing 70.4% of total sample when compared to other Phenice's traits. This is considerably lower compared to previous studies where the ventral arc was rated as the best indicator for sex[20,21,22,23]. In a study by Johnson-Beldford[24], the ventral arc had lower sexing accuracy rate for females and higher accuracy for males. The low sexing

Table 6. Result of age estimation using Suchey-Brooks method.

Bone tag	Sex	Suchey and Brooks phases	age range and mean age
Up-3	Male	3rd phase	21-46 (28.7)
Up-4	Female	2nd phase	19-40 (25.0)
Up-5	Male	1st phase	15-23 (18.5)
Up-6	Male	4th phase	23-57 (35.2)
Up-7	Female	5th phase	25-83 (48.1)
Up-9	Male	4th phase	23-57 (35.2)
Up-10	Male	4th phase	23-57 (35.2)
Up-12	Male	4th phase	23-57 (35.2)
Up-13	Male	5th phase	27-66 (45.6)
Up-14	Male	4th phase	23-57 (35.2)
Up-15	Male	4th phase	23-57 (35.2)
Up-16	Male	4th phase	23-57 (35.2)
Up-17	Male	3rd phase	21-46 (28.7)
Up-18	Female	2nd phase	19-40 (25.0)
Up-19	Male	4th phase	23-57 (35.2)
Up-21	Female	1st phase	15-24 (19.4)
Up-22	Female	2nd phase	19-40 (25.0)
Up-23	Male	4th phase	23-57 (35.2)
Up-24	Female	1st phase	15-24 (19.4)

accuracy rate of the ventral arc in this study could be due to geographic and temporal difference in sample population, as several researches have shown sexual dimorphism differ in expression in populations[25,26,27]. In addition, it has been observed the ventral arch is not visible until the mid-twenties[11-28,29]. It could be conveniently concluded from this study that the ventral arc in isolation is not suitable for estimating sex in sub adults as it could result in possible misclassification.

The sub pubic concavity in isolation accurately estimated the sex for 26 bones making up 96.30% of the study sample. This trait was found reliable as all blindly sexed samples were accurately classified. This finding agrees with the report of Maclaughlin and Bruce[30]. Among the studied samples with known sex, female samples with mean age of 19.4 years had flat ischio-pubic ramus, while male samples above age 25 had pinched ischio-pubic ramus. A similar observation was made by Johnson-Beldford[24].

The Bruzek method estimated sex for 26 of the samples in the present study (96.30%). This accuracy level is close to statistical range recorded by Bruzek[9] and comparable to other studies[14, 31]. All the hipbones had minimum of three out of five group features except for a sample, which had only two and hence the sex could not be estimated. Our findings are in agreement with those of Debono and Mafart[31] who concluded that sex could be satisfactorily assigned to unknown samples using the Bruzek method.

The evaluation of the preauricular surface was assessed for the presence of preauricular grooves, paraglenoid groove and piriform tubercle. The male morphology of the preauricular groove was seen in 55.56% of the male samples, one male specimen had typical female feature with depressions that are well delimited. However, the paraglenoid grooves and piriform tubercle was typical male. The piriform tubercle is the most consistent sexually dimorphic feature in the preauricular surface in our samples as 72.73% of the estimated female samples had preauricular sur morphology that is female. Our result is similar to those obtained for French (76%)[9], Portuguese (70%)[9], Czech-German (71%)[31], populations. The f-f-f combination occurred in 27.27% of the female samples. In similar studies, the f-f-f combination was observed in 23% of females from Paris[9], 28% of females from Coimbra[9] and 31% for females from Czech-German population[32]. Most female cadavers bequeathed to the gross anatomy laboratory are likely nulliparous; this may be the reason for the low f-f-f combination in the preauricular surface in our samples. Dorsal pubic pitting, preauricular grooves, interosseous grooves are well correlated with parity status and the combination of these traits could give the most significant indication for parturition; however, some studies have noted these evidences could also disappear with time[33, 34].

The morphological traits of the greater sciatic notch proved to be excellent parameters for sex estimation as 80% of the male samples had m-m-m combinations for proportion of the length of the sciatic chords (T4), asymmetry of the notch chords (T5), course of the contour of posterior notch cord relative to a line drawn parallel to notch depth (T6). Most insightful is that all samples with known sex were accurately classified. Our results are similar to studies of Portuguese males (80%), but significantly higher than those reported for French (68%) and the population studied by Novotny[9,33]. It should be noted that discriminant function for sex estimation using sciatic notch parameters were generally reported to be high, although there have been few cases of misclassification[9-32-36].

Ludovic and Betrand (2006) that carried out their study using an archeological sample from historic necropolis in Provence, France. They reported highest diagnostic accuracy using greater sciatic notch dimensions

The percentage of samples rightly classified by composite arc was 66.67 for males and 91 for females, similar results was obtained in French population[9]. In Portuguese samples, it was 78% for males and 87% for females;[9] English population had 80% for males and 87% for females[39]. The percentage reported for Czech population was considerably lower as males had 67% and females 58%[32]. Previous studies suggested the differences in the composite arc should not be attributed solely to sexual dimorphism as other environmental factors could play a major role[32-37]. Our result agreed with those from other studies that the composite give higher accuracy when estimating sex for females compare to males[9,32–37].

In the ischiopubic ramus, male morphology was found in 93.33% of the male samples and female morphology was found in 90.90% of female samples. The percentage of f-f-f and m-m-m combinations were 72.73 and 33.33 respectively indicating the traits is better in sex estimation for females. Male morphology was reported in 70% of males from Paris and 51% of males from Coimbra, while the female form was seen in 78% of French females and 85% of Portuguese females. This is in concordance with our study that showed the percentages of typical female forms were higher[9, 32].

The ratio of pubic length to ischium length (T11) have been studied extensively and regarded as sexually dimorphic. In most studies the pubis is longer in females while the ischium is longer in males[38–40,41,42,43]. Curiously, our study do not agree with this reports as 23 bone samples had longer pubis than ischium; it appears also to be the most unreliable trait for sex estimation. The method of determination of the length of the pubis and ischium appear to be a major factor as most studies estimate the length using radiograph. 71% of French and Portuguese males had the male morphology, while 87% and 78% French and Coimbra females had the female forms. The reliability of this trait in sex estimation was also reported to be high in these populations[9,32].

The Suchey and Brooks method estimated the age of 19 samples. This method is sex specific and could not be used for samples whose sexes were not estimated. Majority of the male samples are in the fourth phase. Every intact symphyseal surface was assigned age using the Suchey-Brook method in conjunction with observations made by Wink[12] and Sakue[44]. The first phase of the Suchey-brooks ageing system begins at 18 years and presents with ridges and furrows, lack of delimitation of superior and inferior extremities. The second phase begins at 23 years, it shows lower billowing surface, ridges may still occur and ossific noodle may appear on the upper extremity. The third phase which begins at age 30 showed appearance of ventral rampart and absence of lipping of dorsal margin. The fourth phase that begins at 35 years showed fine grained symphyseal surface; hiatus can occur in upper ventral rim. Phase 5 begins at age 46 and it presents a completely rimmed symphyseal face and some depression on the face itself. (See tables 2 and 6)

Conclusion

This research showed the application of multiple morphoscopic methods could be used to estimate sex and age of unprofiled hipbones. The Phenice method estimated the sex of 85.18% of the samples while the Bruzek method estimated the sex of 96.30% of the studied samples. The age of 19 of the samples were estimated with the Suchey-Brook method. It is important to note that combination of variables should be used in sex and age estimation for accuracy optimization and correct classification as no single variable or trait of any bone is 100% accurate in itself in an identification procedure. The profile created for hipbones in Anatomy museum of University of Port Harcourt has increased their value in forensic anthropology studies as students interested in furthering their knowledge in the identification of unknown skeletal remains could now have teaching models.

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Mini Curriculum and Author's Contribution

1. Loveday Ese Oghenemavwe - PhD: Contribution: He is an effective scientific and intellectual lead researcher for the study, designed the study protocol, data collection method and interpretation. He prepared and drafted the manuscript and was actively involved in the critical review process and final approval. ORCID 0000-0002-3575-9987

2. Augustina Nkem Oludininwa - Msc: Student: Contribution: She is an effective scientific and intellectual participant in the study. She was involved in data acquisition and interpretation, preparation of the initial draft of the manuscript, critical review process and final approval.

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Corresponding author
Loveday Ese Oghenemavwe
E-mail: Loveday.oghenemavwe@uniport.edu.ng