

Sex differences in the bony pelvis of the fruit-eating bat, *Eidolon helvum*

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Investigation into the bony pelvis of the fruit-eating bat, Eidolon helvum, revealed differences in the pelvic dimensions. The pubic joint of the female consists of interpubic ligament that increased in length until puberty. In the juvenile male Eidolon the pubic joint consists of ligament. Ossification of the interpubic ligament in the male is not an adult phenomenon but begins at the juvenile stage. In the adult the distance from the ischial tuberosity to the iliac crest, from the ischial tuberosity to the medial end of the pubis, and the outlet anteroposterior diameter of the pelvis, were significantly higher in the male than in the female. This indicates that the hip bone in the male is longer in both the vertical (height) and transverse (width) measurements than in the female. The dimensions of the adult pelvic inlet and outlet transverse diameters were significantly higher in the female than in the male. This indicates that the female pelvic canal is wider than the male and this is a consequence of the female interpubic ligament.

key words: interpubic ligament, juvenile, adult, bat

INTRODUCTION

Differentiating the sex of skeletons has been a very useful tool in anthropology, in anatomy and in forensic medicine. In order to assess excavated skeletons, sexual dimorphism is the only clue [20]. The study of sexual dimorphism of the bony pelvis has attracted the attention of several authors studying various animal species including man [2,6,9,11,14,15], great ape [9], monkey [1,8,17,23,24] loris [12], water vole [28] and mouse [3,25–27]. The bony pelvis of several species of bats has also attracted some authors [4,7,10,13,21,29]. Though extensive work has been done on several bat species, mostly temperate and non-fruit eating, information is lacking about *Eidolon helvum*. *Eidolon helvum* is a tropical chiropteran, fruit-eating, and widely distributed all over Africa and some other tropical regions of the world. It is also important to know whether the joint is ankylosed right from post-natal life. The present work studied the nature of the interpubic ligament in the juvenile and the adult,

and differences in the dimensions of the bony pelvis of the male and female adult *Eidolon helvum*. Rawlings [18] in the *Macaca Mulatta* maintained that the ankylosis of the symphysis pubis in the male is a function of age. Does this opinion hold for other species of the mammalian order such as the chiroptera?

MATERIAL AND METHODS

A large number of *Eidolon helvum* was shot down during the month of November in their roosting colony on the campus of the Obafemi Awolowo University, Ile-Ife, Nigeria. Thirty-seven adult bats (average body weight 160 g), made up of 20 male and 17 female, and nine juvenile (average body weight 40 g), made up of 5 male and 4 female, were used. After decapitation flesh was removed from the body, pelvic skeletons were dissected out and properly cleaned and dried. Non-metric observations included the shape of the inferior ischiopubic ramus, the shape of the pelvic outlet, the presence or absence

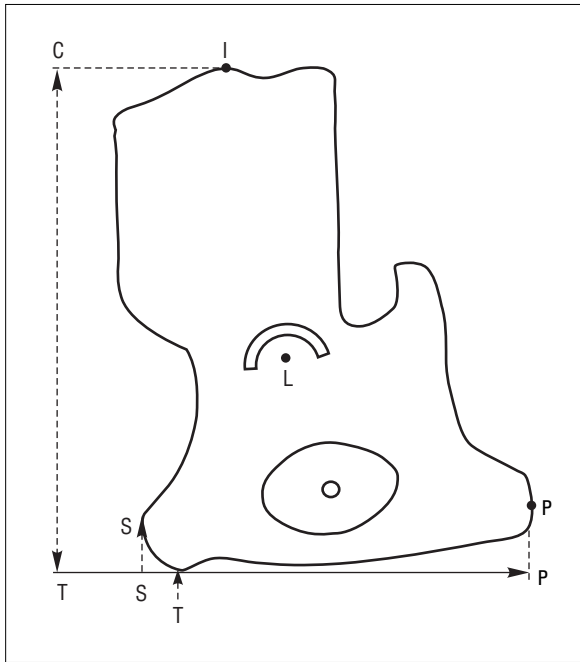


Figure 1. A schematic illustration of the lateral view of the pelvis of *Eidolon helvum*. P — medial end of pubis, T — inferior end of ischial tuberosity, I — crest of ilium, S — posterior end of ischium (ischial tuberosity). Scale: 3 cm to 1 cm.

of true symphysis and the presence of interpubic ligament. Metric recordings were done with *Vernier callipers* as follows:

LI (length of ilium) was measured from the point of fusion of the hip bones at the acetabular notch to the uppermost point on the iliac crest (Fig. 1). LP (length of pubis) was measured from the acetabular notch to the medial end of the pubis (Fig. 1). LT (length of ischium) was measured from the acetabular notch to the lowest point of the ischial tuberosity (Fig. 1). WSPR (width of superior pubic ramus) was measured at its widest extent (zz, Fig. 2). BCD was measured as the distance between the iliac crests at their lateral most points (yy, Fig. 2). CT was measured as the distance between the uppermost point on the iliac crest and the lowest point on the ischial tuberosity. This also represents the vertical height of the hip bone (Fig. 1). SP was measured from the lateralmost point of the ischial tuberosity to the medial end of the pubis. This is also the transverse length of the hip bone (Fig. 1). IE was measured as the distance between the two iliopubic eminences (ee, Fig. 2). This measures the oblique diameter of the pelvic inlet. IAD was measured as the distance between the middle of the anterior sacral promontory and the middle of the upper aspect of the pubic joint or interpubic ligament. This measured the anteropos-

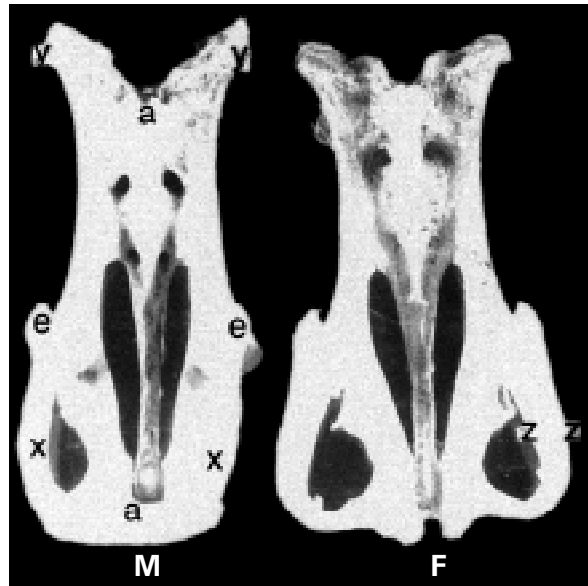


Figure 2. The anterior view of macerated pelvic skeleton of adult male (M) and female (F) *Eidolon helvum*. Interpubic bone is present in the male but absent in the female. yy — bicristal diameter, ee — diagonal diameter of outlet, aa: anteroposterior diameter of inlet, xx — inlet transverse diameter, zz — width of superior ramus of pubis.

terior diameter of the pelvic inlet (aa, Fig. 2). ITD. was measured as the widest transverse diameter of the inlet. This measured the pelvic inlet (xx, Fig. 2).

OAD was measured as the outlet anteroposterior diameter, from the inferior border of the pubic joint to the tip of the coccyx (CP, Fig. 3). OTD was measured as the widest diameter of the outlet between the ischial tuberosities. This measured the outlet transverse diameter (OO, Fig. 3).

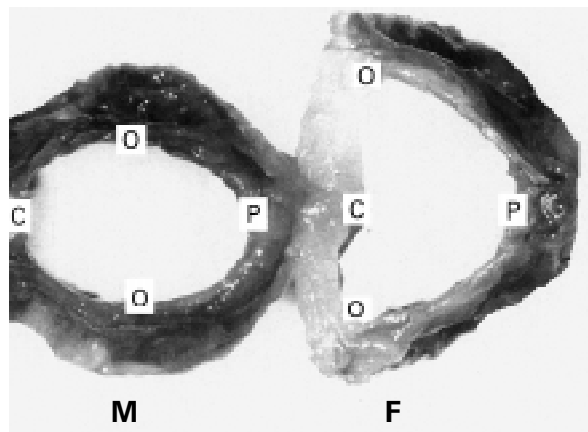


Figure 3. Skeleton of adult male and female pelvises of *Eidolon helvum* stained with Alizarin red S. Interpubic bone (P) in the male is stained. Interpubic ligament (C) in the female is unstained. Pelvic inlet of male is oblong, of female is triangular in shape.

The length of the interpubic ligament in the juvenile and adult female pelvis was measured as the distance between the medial ends of the pubic bones.

Alizarin red S staining: The pelvic skeletons of some of the male and female were processed for Alizarin red S staining. The dye stained only bone tissue.

Photographs were taken of the skeleton of the juvenile and adult bat pelvis. The metric values obtained for the male and female were compared statistically using a two-tailed Student t-test.

RESULTS

Qualitative (non-metric): In the adult female there was absence of true pubic symphysis. The medial ends of the pubic bones were joined by ligament (Fig. 3). The outlet of the female pelvis is triangular in shape, with the base as the interpubic ligament and the apex as the tip of the coccyx. The inferior border of the ischiopubic ramus is convex (Fig. 4). In the adult male, the pubic joint is not a symphysis but a synostosis in which complete fusion of the medial ends of the pubic bones had taken place (Fig. 3).

Alizarin red S staining: The component bones of the pelvis in the juvenile and adult were stained red. The interpubic ligaments were present in the juvenile and the adult female pelvis and were not stained. In the male all bones of the pelvis were stained and there was no interpubic ligament. In the juvenile male there was interpubic ligament but the midportion was stained (Fig. 3).

Quantitative (metric): Table 1 shows the t-test of the adult pelvis. The length of the pubis (LP), the width of the superior pubic ramus (WPR), the height of the hip bone (CT), the width of the hip bone (TP),

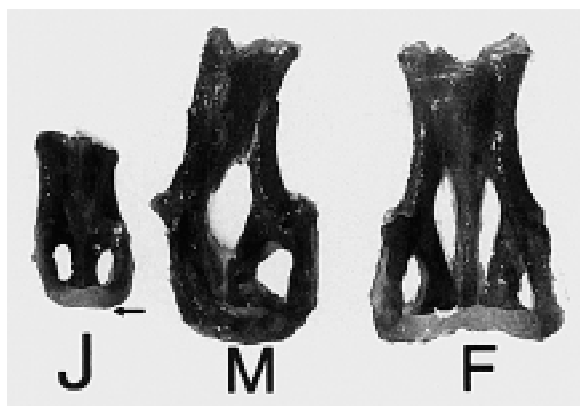


Figure 4. Juvenile (J), male (M) and female (F) pelvises of *Eidolon helvum* stained with Alizarin red S. Interpubic ligaments (arrow) in juvenile and adult female pelvises were unstained. Interpubic bone in adult male (arrow head) was stained.

the diagonal diameter of the inlet of the pelvis (IE), and the anteroposterior diameter of the inlet (IAD) of the pelvis were significantly higher in the male than in the female. The LP ($P < 0.001$), TP ($P < 0.001$), OAD ($P < 0.001$) and IE ($P < 0.01$) showed stronger indices for sex differences than WPR ($P < 0.05$) and CT ($P < 0.05$). The inlet transverse diameter (ITD) and outlet transverse diameter (OTD) in the female were significantly higher than in the male ($P < 0.001$ and 0.001 respectively). The length of the ilium, the length of the ischium, the bicristal diameter and the inlet anteroposterior diameter showed no significant difference between the sexes ($P < 0.05$).

The mean length of the interpubic ligament in the adult female was 1.38 cm while that of the juvenile female was 0.65 cm.

DISCUSSION

Eidolon helvum is a megachiropteran bat [16]. Marked qualitative and quantitative differences were observed in the bony pelvis of the male and female. The pubic joint of the female is not a true symphysis but is replaced by interpubic ligament. The ligament increased in length from the juvenile to the adult. It averaged 0.65 cm in the juvenile (average body weight 40 g) and 1.38 cm in the adult (average body weight 160 g). Crelin in his work on the free-tailed bat also observed that the pubic joint in the female *Tadarida brasiliensis* is also made of interpubic ligament. Crelin and Newton [5] analysed the nature of the interpubic ligament and noted it contained predominantly elastic fibres. The increase in length observed in the interpubic ligament of the female *Eidolon* from the juvenile to the adult age, coupled with the elasticity of this ligament as described by Crelin and Newton [5], is to provide the expansion needed during pregnancy and parturition. Crelin [4] explained that the elastic nature of the interpubic ligament in the adult female *Tadarida brasiliensis* makes it possible for this ligament to stretch to more than 15 times its original length during pregnancy in order for the pelvic canal to cope with the size of the full term bat foetus. The pubic joint of the juvenile is like that of the female. The ligament, however, becomes progressively ossified as the bat matures and the ossification process starts at the middle of the ligament because only the middle portion stained with Alizarin red S, a stain indicative of the presence of bone. Perhaps the ossification process spread to both ends of the maturing adult bone. Rawlings [18], who reported ankylosis of the symphysis pubis in the male *Macaca mulatta*, indicated it was a func-

Table 1. 2-tailed Student t-test of measurements (cm) of adult male and female pelvis of *Eidolon helvum*

Variable	Sex	Cases	Mean	SD	SEM	T-value	P Level
Length of ilium LI	Male	20	2.1345	0.061	0.014	-0.44	NS
	Female	17	2.1453	0.087	0.021		
Length of pubis LP	Male	20	1.5025	0.033	0.007	25.88	***
	Female	17	1.1135	0.057	0.014		
Length of ischium LT	Male	20	0.8695	0.031	0.007	0.74	NS
	Female	17	0.8600	0.047	0.011		
Width of superior ramus pubis WSPR	Male	20	0.1690	0.014	0.003	1.93	*
	Female	17	0.1582	0.020	0.005		
Bicristal diameter BCD	Male	20	1.2125	0.093	0.021	-0.67	NS
	Female	17	1.2294	0.050	0.012		
Height of hip bone CT	Male	20	3.0620	0.077	0.017	1.78	*
	Female	17	3.0159	0.081	0.020		
Width of hip bone SP	Male	20	1.6000	0.061	0.0014	12.97	***
	Female	17	1.3382	0.061	0.015		
Diagonal inlet diameter IE	Male	20	1.5090	0.094	0.021	3.63	**
	Female	17	1.4041	0.080	0.019		
A-P inlet diameter IAD	Male	20	2.4190	0.075	0.017	-0.14	NS
	Female	17	2.4229	0.092	0.022		
Transverse inlet diameter ITD	Male	20	1.3875	0.133	0.030	-3.74	**
	Female	17	1.5194	0.064	0.016		
A-P outlet diameter OAD	Male	20	1.3520	0.066	0.015	9.93	***
	Female	17	1.1294	0.070	0.017		
Transverse outlet diameter OTD	Male	20	0.8915	0.044	0.011	-15.87	***
	Female	17	1.2271	0.082	0.020		

* Significant $P < 0.05$, ** significant $P < 0.01$, *** significant $P < 0.001$; NS not significant

tion of age and that the development of the female pelvis paralleled that of the male until puberty. The present finding in the megachiropteran, *Eidolon helvum*, suggests differently. Ossification was present even in the male juvenile *Eidolon* (body weight 40 g), indicating that development of the male is different from the female even before puberty. A definite statement cannot be made about symphysis pubis of the mammalian orders because even in the same order species have different morphology. In the adult male microchiropteran, *Tadarida brasiliensis*, the pubic joint is a true symphysis [4]. This is in contrast to the finding in adult male *Eidolon helvum* in which it is a synostosis. *Tadarida brasiliensis* is insectivorous [19,22]. The megachiropteran, *Eidolon helvum* is fruit-eating [16]. The dissimilarities in the pubic joints of adult male *Tadarida brasiliensis* and *Eidolon helvum* may be very useful in differentiating the species of these bats, thus emphasising the use of pel-

vic sexual dimorphism in subdividing the bat mammalian order into subfamilies as was done in phyllostomidae by Walton and Walton [29]. The significantly higher value of LP (distance from the acetabular notch to the ischial tuberosity) and SP (distance from the medial end of the pubis to the lateralmost point of the ischial tuberosity) in the male than in the female ($P < 0.001$) suggests that the pubis is clearly longer in the male than in the female. This may be contributive to the oblong shape of the inlet in the male. The significantly higher values of the inlet transverse diameter (ITD) and outlet transverse diameter (OTD) in the female than in the male ($P < 0.0001$) shows that the pelvic cavity in the female is much wider than in the male. Gingerich [8] and Leutenegger [12] in their separate studies on non-human primate bony pelvis explained that the presence of sexual dimorphism was due to alteration of the female pelvis at puberty, presumably to cope with the de-

mands of pregnancy and parturition. This opinion is supported in the present work where the interpubic ligament increased in length from 0.65 cm in the juvenile female (average body weight 40 g) to 1.38 cm in the adult female (average body weight 160 g). There was no significant difference observed in the length of ilium, bicristal diameter and inlet anteroposterior diameter between the male and the female. This indicates that these parameters contribute little to sexual dimorphism in the *Eidolon helvum*. Uesugi et al. [25–27] in mice, rats, Chinese hamsters and frogs, and Tague [23] in *Macaca mulatta* have observed that the pubis contributes to the sexual dimorphism of the pelvis more than the ilium or the ischium. A similar observation is recorded here in the *Eidolon helvum*.

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