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Sridevi P
Department of Veterinary Anatomy and Histology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry, India

Rajalakshmi K
Department of Veterinary Anatomy and Histology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry, India

SivaKumar M
Department of Veterinary Anatomy and Histology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry, India

Corresponding Author:
Sridevi P
Department of Veterinary Anatomy and Histology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry, India

Gross morphological and morphometrical studies on the pelvic girdle of emu (*Dromaius novaehollandiae*)

Sridevi P, Rajalakshmi K and SivaKumar M

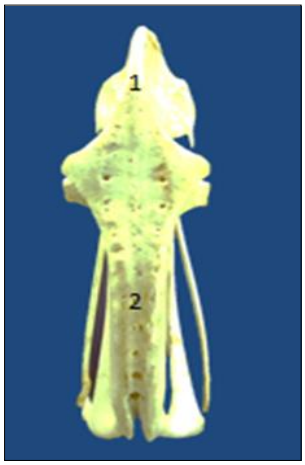
Abstract
The os-coxae consisted of ilium, ischium and pubis which were all parallel to the longitudinal axis of the vertebral column and were fused one above the other. All the three bones participated in the formation of the perforated acetabulum. The acetabulum presented on its caudo dorsal aspect with a large anti-trochanter for trochanter major of the femur. Ilium had a pre acetabular, acetabular part and post acetabular part which were joined with the spines of lumbo-sacral mass. Ischium was semi cylindrical comprised of cranial and caudal part. The dorsal border of the ischium and ventral border of ilium enclosed within a long incisura ilioischiadica. Pubis a long, slender bone was ventral to ischium and cranially joined to the pre acetabular part of the ilium. In between the pubis and ischium separated by incisura puboischiadica. The caudal extremity was expanded and did not project beyond the ischium. The obturator foramen was incomplete oval shaped and it was formed by the union of ventral border of the ischium and the cranial part of dorsal border of the pubis.

Keywords: pelvic girdle, ilium, ischium, pubis, obturator foramen, emu

Introduction
Emu (*Dromaius novaehollandiae*) are large flightless birds originated from arid regions of australia and is the second largest bird in height, after the Ostrich. As large bipeds, emu are attractive bio-model for studying weight bearing mechanism in heavy terrestrial birds. Their ability to run at high speed is due to their highly specialized pelvic limb musculature. Emu has four bellies of gastrocnemius muscle [11] in their hind limb. The pelvic girdle consisted of ilium, ischium and pubis. Pelvic bones of birds have an arched shape and are fused with the synsacrum of the vertebral column. Emu are more susceptible for fractures in pelvic limb due to their heavy weight, running and kicking habits [17]. The present study was conducted to elucidate the morphological and morphometric parameters on the pelvic girdle of emu was carried out due to the scarce information available on this species pertaining to the pelvic girdle.

Materials and Methods
The materials for the study were collected from three adult emu birds of either sex brought for post mortem examination to the Department of Veterinary Pathology, Rajiv Gandhi Institute of Veterinary Education and Research, Puducherry. The pelvic girdle was collected by the regular process of maceration, cleaned, dried and the various gross anatomical features were recorded.

Results and Discussion
The pelvic girdle of emu was long massive bone consisted of right and left hip bones (os-coxae) with the synsacrum, which was also reported in ostrich [19]. The pelvic girdle of peahen was extremely light [18]. The pelvic girdle had immovable articulation between vertebral column and pelvic bone. The pelvic girdle provided maximum area for the attachment of the heavy hind limb muscles. The arch-shaped right and left bones carrying the weight of the body are also reported in emu [1] [12]. The pelvic girdle dorsally (Fig.1) formed pelvic roof by larger caudal part of ilium and lateral wall by ilium and ventrally (Fig.2) bones remains unfused with each other. In ostrich the ventral bones were found fused [2]. The ventrally open structure provides the structural protection to the underlying viscera and the eggs formed in the female emu birds [17] and in bar-headed goose [11].



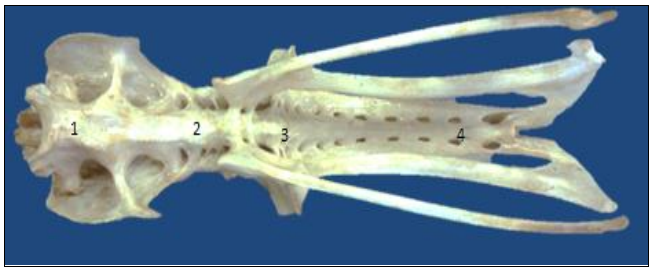
1. Pre-acetabular part of ilium
2. Dorsal sacral foramina of Acetabular part of ilium
3. Dorsal sacral foramina of post - acetabular part of ilium

Fig 1: Dorsal view of pelvic girdle

The os-coxae of emu consisted of ilium, ischium and pubis similar finding reported in ostrich [19] and peacock and peahen [3], and barn owl [6]. These bones were vertical to the long axis of the body and were placed one above the other.

Ilium

Ilium was large, broad, contributed the major part **(**34.3cm**)** among the three bones. It was placed downward and backward direction. Ilium had a pre acetabular, acetabular part and post acetabular part which were joined with the spines of lumbo-sacral mass (Fig.2). This was in accordance with the similar research findings in emu [2]. Pre-acetabular and post-acetabular part was reported in Japanese quail [9], in ostrich [19], in Indian eagle owl [14], in guinea fowl and pigeon [7]. In domestic fowl and duck, fusion of lumbosacral mass in the pre-acetabular part and transverse process in the post-acetabular region was reported [2].

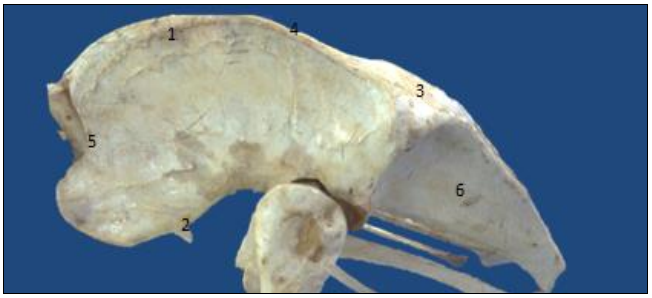


1. Last thoracic vertebrae 2. Lumber vertebrae 3. Sacral vertebrae sacral foramin:

Fig 2: Ventral view of pelvic girdle with fused lumbosaceum

The pre-acetabular part of ilium measured 10.8 cm in length and 2.5cm in width and acetabular part measured 5.3 cm in length and 20 cm in width, while post-acetabular part 18.2 cm in length, 5cm in width. Pre-acetabular part (10.8 cm) was smaller than the post-acetabular part **(**18.2 cm**)** as also reported in goose and duck, while in case of fowl it was reverse [10] and the pre-acetabular part was longer than the post acetabular part in peahen [18].

The pre-acetabular consisted of two surfaces and four borders. The gluteal surface of pre-acetabular part was broad, concave and roughly quadrilateral in shape and compressed laterally on either side, it had numerous ridges for the attachment of muscles as reported in ostrich [19]. In domestic birds, the dorsal surface presented a deep depression [10] and the medial surface was fused with the transverse process of the lumbosacral mass. The dorsal borders of both sides were united with dorsal spinous processes of last thoracic and lumbar vertebrae to form a dorsal iliac crest.



1. Pre-acetabular part of ilium 2. Triangular process 3. Acetabular part of ilium 4. Dorsal iliac crest 5. Notch 6. Post-acetabular part of ilium

Fig 3: Lateral view of ilium

The ventral border was 'S' shaped and forms the iliac crest. It was thin directed outward and backward, concave in front and convex caudally and presented a short triangular process about its middle which was directed downwards as described in similar studies in emu [5]. The cranial border at the middle projected laterally forming a notch, which was also reported in ostrich [2]. The posterior border joined with the post-acetabular part, enclosed a wider area with its counterpart for the sacral vertebrae below.

Acetabular part (Fig.3) was found in middle between pre and post acetabular part, it was smooth and wider than pre and post-acetabular part.

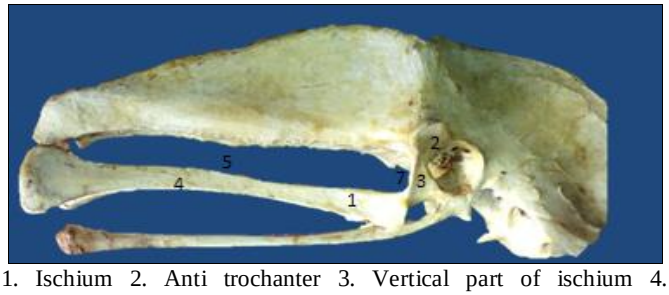
Post-acetabular part (Fig.3) was roughly triangular and was contrary to the findings in duck, fowl, and turkey, where it was quadrilateral in shape [10]. The Gluteal surface of post-acetabular part was concave and presented above a large bony prominence anti-trochanter on the caudodorsal part of acetabulum. The medial surface was fused with sacral vertebrae and absence of iliac fossa as also reported in emu and ostrich [2]. In emu the attachment of bodies of vertebrae project more ventrally leading to the absence of a renal fossa [5]. In emu the kidneys were located just below the lumbo-sacral mass, which makes them more vulnerable to accidental injury during fighting [21]. In domestic birds presence of iliac fossa lodges the kidney [10]. The dorsal borders sloped backward and downward, were separated from each other along the midline by the dorsal spinous processes of sacral vertebrae. The base showed the union between acetabular and post-acetabular part. The caudal extremity of apex was blunt, tuberous, triangular shape and directed downward. However, in duck and domestic fowl caudal extremity of ilium has one or two processes [2]. The ventral border was thick, serrated and had an outward inclination and this border associated with bodies of sacral vertebrae bears the iliac crest. The caudal extremity of ilium was fused with ischium by a cartilage in emu [21].

Ischium

Ischium (23cm) was large broad rod like (Fig.4) as also reported in ostrich and emu. However, in duck and domestic fowl it was triangular plate like [2]. Ischium was almost parallel to the ventral border of ilium. It had a cranially directed vertical, horizontal part and caudally elongated part. The vertical part was triangular and consisted of two

processes a large process below anti trochanter and a small process which was ossified with pubis. The ilium and vertical part of ischium formed the Ilio-ishiatic notch which was reported in emu by other studies [2].

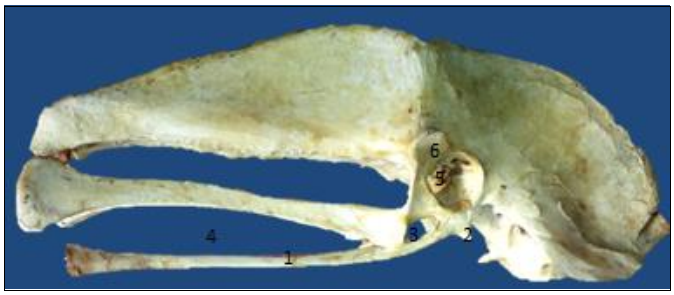
Dorsal surface was flat and cranial extremity was slightly wider, while the body was narrow and the caudal extremity of the elongated part was expanded like a thin spatula shaped. On the ventral surface, it was rounded and at the junction between vertical and horizontal was a small tubercle. The dorsal border of the ischium and ventral border of ilium enclosed a long incisura ilioischiadica. A similar incisura was reported in emu [5] [1], ischiatic foramen observed in domestic fowl [10], in Indian eagle [14], in guinea fowl and pigeon [7]. The caudal extremity of ilium was fused with ischium by a cartilage. The ventral border of ischium didn't extend beyond its caudal, whereas in domestic birds the ventral border of the ischium was seen projected beyond its caudal [10].



1. Ischium 2. Anti trochanter 3. Vertical part of ischium 4. Horizontal part of ischium 5. Incisura ilioischiadica 6. Eongated part of ischium 7. Ilio-ishiatic notch

Fig 4: Lateral view of ischium

The pubis is a long, slender bone (24cm) (Fig.5) located ventral to ischium and cranially joined the preacetabular part of the ilium. In domestic birds were reported that pubis was thin, rib-like bone [5]. The cranial extremity bearded the short, blunt downward directed pectineal process below the acetabulum as described in Indian eagle owl [14], in guinea fowl [7], in pigeon [7], in eagle and brown wood owl [4]. The caudal extremity was expanded and did not project beyond the ischium. The pubis was fused with ischium near its cranial extremity but caudal extremity it not fused with ischium. In between the pubis and ischium separated by an incisura puboischiadica. In peahen that ischiopubic fenestra was wider [18] and in serpent eagle reported that pubis was completely fused with ischium [4]. Large incisura puboischiadica cranially had an incomplete oval shaped obturator foramen. Pubis did not project beyond the ilium and ischium and similar findings reported in emu [9]. However, in bar-headed goose [15], in Indian eagle [14] stated that pubis extended beyond the level of the ilium and ischium.



1. Pubis 2. Pectineal Process of Pubis 3. Obturator Foramen 4. Puboischiadica 5. Perforated acetabulum 6. Antitrochanter

Fig 5: Lateral view of pubis

The ischium and pubis were not completely fused to form pelvic symphysis as observed in emu [5] [17]. However, in ostrich the pubic symphysis was a characteristic feature [2] [19]. The muscular process present in pubis was well developed in case of domestic fowl and pigeon that gave the attachment to the pectineus muscle [10], which was very rudimentary in emu. The obturator foramen were incomplete oval in shaped and it formed by the union of the ventral border of the ischium and the cranial part of pubis of the dorsal border these findings are in accordance with the reports from other avian species like guinea fowl [7], Indian eagle owl [14], eagle and brown wood owl [4]. In ostrich, between obturator foramen and anti-trochanter [20].

Acetabulum

All the three bones participated in the formation of the central perforated acetabulum. It was wide, deep cranial articular part formed by the ilium, the narrow thin caudal part by the ischium and pubis. Whereas, in fowl and duck, pubis was not involved in the formation of the acetabulum [10]. The acetabulum was circular in outline, similar features reported in peafowl [3]. It presented the facet on its caudo dorsal aspect a large anti-trochanter for the trochanter major of femur. These finding agrees with spot-billed pelicans [16], in cattle egret [13], in guinea fowl and pigeon [7]. The area which surrounded the anti trochanter had a several pneumatic foramina.

Conclusion

Gross morphological features of the pelvic girdle of emu birds were studied. The pelvic girdle was formed by ilium, ischium and pubis. The ilium was the largest component and provided wide area for the attachment of the heavy hind limb muscles. The iliac fossa, pubic and ischial symphysis was absent. All the three bones were involved in the formation of the acetabulum. The caudal end of the ischium fused with the ilium and not with the pubis. Pectinal process was present and absence of muscular process. The massive size of the pelvic girdle of emu was related to bipedal posture which aided its hind limb in walking and running.

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