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Comparative Computed Tomographic Measurements of the Synsacrum in Some Birds

Mediciones Tomográficas Computarizadas Comparativas del Sinsacro en Algunas Aves

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SUMMARY: The Synsacrum is constructed of pelvic bones, sacral, lumbar vertebrae and some thoracic vertebrae, and it takes the form of a thin sheet of bone which is curled downwards at the sides. This study is designed to assess the morphometric specialization of the lumbosacral portion of the vertebral section in flying and non-flying winged creatures. Several parameters (ratio of cranial/caudal parts and diameter/length) of the lumbosacral vertebral column were calculated in computed tomography (CT). The ratio of diameter/length of the synsacrum was the narrowest in ostrich while the widest was in pigeon. While the cranial/caudal ratio was the smallest in ostrich and the largest in pigeon. The parameters of penguin were closed to that of pigeon. It is supposed that this ratio is related to the bird locomotion, flying, swimming or/and strolling.

KEY WORDS: Birds; Computed Tomography; Synsacrum.

INTRODUCTION

Birds have two sorts of locomotion. One is flying utilizing their forelimbs and the other is bipedal strolling utilizing their hind limbs. Non-avian long tailed theropod dinosaurs use their tail as a counterbalance (Gatesy, 1990). The weight of a standing or running bird body is supported at the hip joint, but as there is no balancing tail, the body's center of mass is well ahead of the hip. The bird has to hold the front end of the body up by pulling downwards on the rear end of the synsacrum (Pennycuick, 2008). The synsacrum is consisted of pelvic bones, sacral, lumbar vertebrae and some thoracic vertebrae, and it takes the form of a thin sheet of bone that is curled downwards at the sides, which is very resistant to longitudinal bending and acts as a pelvic lever and shock absorber (Baumel & Witmer, 1993; Pennycuick, 2008). It has been proposed some time ago that an exceptional balance detecting organ of the body is necessary during walking, in light of the fact that their rear appendages are situated at the back of the gravity center, and some confirmation upheld this thought (Biederman-Thorson & Thorson, 1973; Delius & Vollrath, 1973). At Present, the proposed area of such an organ is the lumbosacral segment of the vertebrae (Necker, 2006). In this study, the synsacrum of turkey, ostrich, chicken, duck, geese, pigeon and penguin, were inspected morphometrically by Computed tomography.

MATERIAL AND METHOD

Animals. Cadavers of mature chicken (*Gallus gallus domesticus*, 2 kg), turkeys (*Meleagris gallopavo*, 13 kg), pigeons (*Columba livia*, 0.5 kg) ducks (*Cairina moschata*, 5 kg), geese (*Anser anser*, 4 kg) ostriches (*Struthio camelus*, 135 kg) were obtained from Beheira and Menufiya governorates, Egypt and a cadaver of one cape or African penguin (*Spheniscus demersus*, 3kg) supplied by veterinary hospital, Tottori University, Japan were used in this study.

3D reconstruction, Synsacrum measurements and statistical analysis. The cadavers were scanned using CT scanner (Toshiba Tokyo, Japan) at 120 kV and 50 mA current and 2.00 mm thickness. All CT images of the synsacrum were processed using an imaging workstation (Virtual place Fujin AZE. Tokyo, Japan).

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Synsacrum Parameters

WL. The whole length of the Synsacrum.
CSL. Length of the synsacrum cranial to the hip joint.
TD. Transverse diameter of the vertebral canal at the level of the glycogen body.
VD. Vertical diameter of the vertebral canal at the glycogen body.

The whole length (Fig. 1, A-B: WL) and cranial length (Fig. 1, A-C: CSL) were measured. The transverse and vertical diameters of the most stretched the vertebral canal were measured (Fig. 1TD). CSL/WL and TD/WL ratios were calculated (Table I).

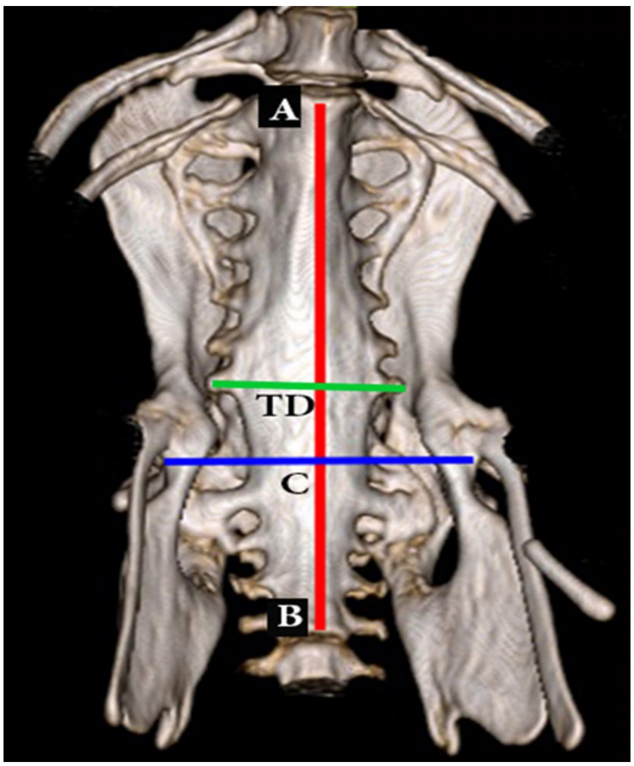

Fig. 1. 3D CT images of the synsacrum of penguin. Red line: The whole length of the synsacrum. Blue line: Determine the level of the hip joints. Green line: the widest part of synsacrum. TD: Transverse diameter. A: The cranial end of synsacrum. B: The caudal end of synsacrum. C: The level of the hip joint.

RESULTS

Mid sagittal slices of all specimens were shown in Figure 2. Ostrich had small glycogen body and the expansiveness of the canal was relatively little with its length (Fig. 2). The vertebral canal on cross section was also rounded (Fig. 3). It was clear that the pigeon has a wide vertebral canal at the level of the glycogen body, nonetheless, the ostrich had the narrowest vertebral canal (Table I). Penguin's vertebral canal was similar to chicken. In penguin, the cranial length rate was the longest in all specimens of this experiment. Penguin was only one specimen, we have to mention the birds other than penguin and the parameters of penguin were compared with the other bird data.

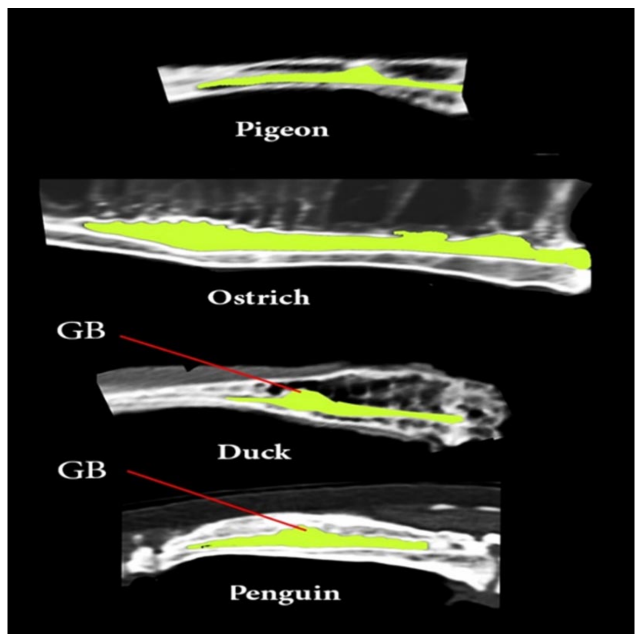

Fig. 2. CT Sagittal section, showing the spinal cord and the vertebral canal of the synsacrum and its content at the level of glycogen body (Red arrow).

Table I. Total measurements of WL, CSL, TD and VD in different birds.

Species	Ostrich	Turkey	Geese	Duck	Chicken	Pigeon	Penguin
WL (cm)	50.7 ± 1.5	14.1 ± 0.36	9.5 ± 0.5	8.97 ± 0.15	7± 0.04	3.25 ± 0.35	7
CSL (cm)	12 ± 0.25	7 ± 0.25	3.57 ± 0.4	3.55 ± 0.07	3.8 ± 0.3	1.95 ± 0.07	5
TD (cm)	2 ± 0.15	1.1 ± 0.1	0.79 ± 0.04	0.7v 0.04	0.7 ± 0.01	0.52 ± 0.03	0.75
VD (cm)	1.55 ± 0.07	0.87 ± 0.07	0.68 ± 0.03	0.69 ± 0.02	0.6 ± 0.02	0.4 ± 0.02	0.4
TD/WL (%)	4	7	8	8	10	15	10
CSL/WL (%)	24	50	38	40	54	60	71

WL. The whole length of the synsacrum. CSL. Length of the synsacrum cranial to the hip joint.TD. Transverse diameter of the vertebral canal at the level of the glycogen body. VD. Vertical diameter of the vertebral canal at the glycogen body. The results presented as an average ± SD (Standard Deviation)

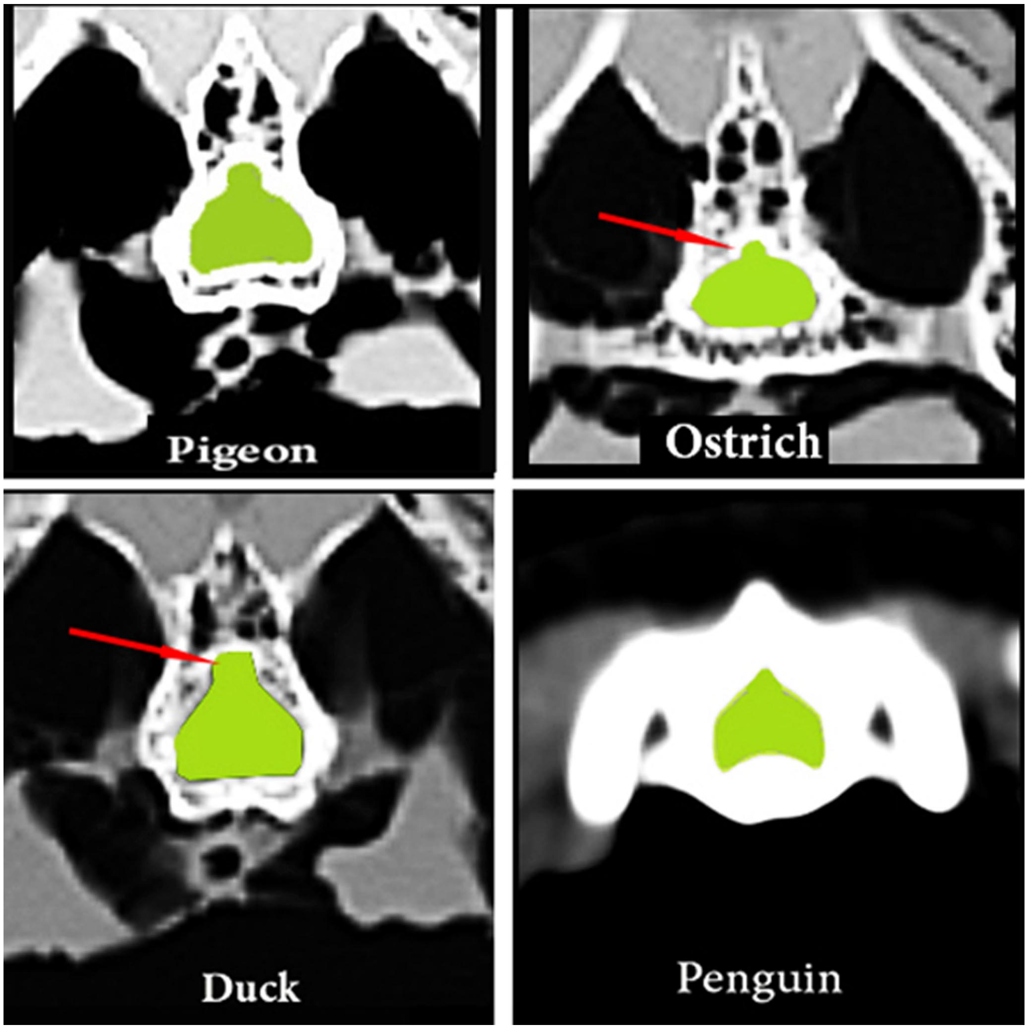

Fig. 3. CT images of the synsacrum. Cross section, showing the vertebral canal at the level of the glycogen body (green area). Red arrows showed the well-developed glycogen body in duck and a relatively small glycogen body in ostrich.

DISCUSSION

At the point when advanced feathered creature tails are contrasted and those of their more primitive fowl or non-avian theropod progenitors, there are three essential contrasts: Lessening in the quantity of caudal vertebrae, shortening of the caudal vertebral bodies, and combination of the most distal caudal vertebrae into the pygostyle (Gatesy & Dial, 1996; Rashid *et al*., 2014). During development the diminishment of the birds' tail is joined by a liquefying of lumbosacral vertebrae named synsacrum (Norell & Clarke, 2001; Zhou, 2004). In modern birds, the synsacrum have specializations which appear to work as a sense organ of equilibrium (Necker, 2006). These specializations incorporate an extended vertebral canal with vast liquid spaces, a split spinal cord which houses a glycogen body (Necker *et al*., 2000; Necker, 2005). In this study the augmenting of the vertebral canal at the level of the glycogen body in flying and swimming birds was larger than non-flying birds. In this study flying birds like pigeon or chicken showed high TD/WL (relative size) and CSL/WL (Balance) ratios. While non-flying birds like ostrich showed low TD/WL and CSL/WL ratios. Surprisingly, penguin (as a non-flying bird) ratios were similar to pigeon. Extreme kinds of locomotion the flightless ostrich and the common swift, have well developed accessory lobes but differ in the shape of the dorsal canals (Necker, 1999). The dorsal canals appear as deep evaginations in the ostrich but rather shallow grooves in the swift, pigeons, chickens, geese, swans, songbirds showed normal canals (Necker, 2006).

CONCLUSION

In conclusion, our study safeguards the fact that flying and swimming birds has an extra-labyrinth organ of equilibrium. Non flying birds although they do not have a tail might adopt a physical body balance that works with the equilibrium centers in the brain. This mechanical balance includes the cranial displacement of the center of gravity. The information of this study may be useful to estimate the flying ability of the fossil vertebrates like pterosaur.

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RESUMEN: El sinsacro está formado por huesos pélvicos, sacros, vértebras lumbares y algunas vértebras torácicas, y toma la forma de una fina lámina de hueso curvada a los lados hacia abajo. Este estudio está diseñado para evaluar la especialización morfométrica de la porción lumbosacra de la sección vertebral en criaturas aladas voladoras y no voladoras. Se calcularon varios parámetros (relación de partes craneal/caudal y diámetro/longitud) de la columna vertebral lumbosacra en tomografía computarizada (TC). La relación diámetro/longitud del sinsacro fue la más estrecha en avestruz mientras que la más ancha fue en paloma. Mientras que la relación craneal/caudal fue la más pequeña en avestruz y la más grande en la paloma. Los parámetros del pingüino estaban cerrados en relación a los de la paloma. Se supone que esta relación está relacionada con la locomoción de las aves, volando, nadando y/o caminando.

PALABRAS CLAVE: Aves; Tomografía computarizada; Sinsacro.

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