International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(9): 165-168
www.biochemjournal.com
Received: 11-06-2025
Accepted: 15-07-2025

Dr. C Lavanya
Assistant Professor, Department of Veterinary Anatomy, Veterinary College and Research Institute, Salem, TANUVAS, Tamil Nadu, India

Dr. SA Sivakumar
Assistant Professor and Head, Department of Veterinary Anatomy, Veterinary College and Research Institute, Salem, TANUVAS, Tamil Nadu, India

Dr. S Tamilselvan
Assistant Professor, Department of Veterinary Anatomy, Veterinary College and Research Institute, Theni, TANUVAS, Tamil Nadu, India

Corresponding Author:
Dr. C Lavanya
Assistant Professor, Department of Veterinary Anatomy, Veterinary College and Research Institute, Salem, TANUVAS, Tamil Nadu, India

Gross morphological study of vertebral column of Indian palm squirrel (*Funambulus palmarum*)

C Lavanya, SA Sivakumar and S Tamilselvan

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i9c.5546

Abstract
The present study was performed in an adult Indian palm squirrel which was found dead in the premises of Veterinary College and Research Institute, Salem. The bones of the animal was recovered by biological maceration technique. The vertebral formula of the Indian palm squirrel was C7, T12, L7, S3. Atlas was a thin ring shaped bone. Axis was very short with blunt odontoid process. Third to fifth cervical vertebrae had bifid transverse process and sixth had trifid process. Seventh cervical vertebra had undivided transverse process and foramen transversarium was absent. First nine thoracic vertebrae showed common features and the tenth thoracic vertebra was the anticlinial vertebra. Last two thoracic vertebrae showed similar features of lumbar vertebrae. Spines and transverse processes of the lumbar vertebrae inclined forward. Sacrum was quadrilateral, composed of three sacral segments and the dorsal spines were not fused. First seven coccygeal vertebrae were typical with well developed processes, thereafter the vertebrae were composed of bodies only. The morphological findings of the vertebral column of Indian palm squirrel expressed both similarities and also variations between different species of the same family.

Keywords: Vertebral column, squirrel, axial skeleton, morphology

Introduction
The study of mammalian vertebral column has been increased the interest among the morphologists emphasizing the importance of correlation between the functional morphology of the vertebral column and the type of locomotion, lifestyle and habitat and also the evolution of different species of same family (Hofmann *et al*., 2021) [3]. The vertebral column of vertebrates were categorized into different regions, i.e. cervical, thoracic, lumbar, sacral and coccygeal vertebrae. Squirrels are the members of the family *Sciuridae* under the order Rodentia, which include tree squirrels, ground squirrels and flying squirrels. There are five species of striped squirrels *viz*., *Funambulus layardi*, *F. palmarum*, *F. pennatii*, *F. sublineatus and F. tristriatus* that are belonging to South Asia. Among these species, *F. palmarum* is considered to be a species of south India (Sharma, 2015) [8].
Based on the habitat and lifestyle, squirrels can be categorized into arboreal, terrestrial, fossorial and gliding squirrels. Indian palm squirrel or the three-striped palm squirrel is native inhabitant to south India and Sri Lanka. They are the size of a large chipmunk, with a bushy tail slightly shorter than the body. The body is grey brown in colour with three white lines on the back and a creamy white belly (Paskins *et al*., 2007) [7].
Indian palm squirrels are terrestrial and arboreal animals. They are very agile, diurnal omnivores very fast for their size and weight. The bones of the particular species were evolved over millions of years, depending on the requirements especially on their walking nature. Tree squirrels which are mostly involved in jumping and leaping from tree to tree, they must have special adaptations in their appendicular bones and vertebral column (Sharma, 2015) [8].
In this article, the gross morphological details of the vertebral column of the Indian palm squirrel was studied. The information available on the vertebral anatomy of the given species was very scarce and this will also pave way for the phylogenic studies of the related ancestral species.

Materials and Methods

An adult male Indian palm squirrel was found dead in the premises of Veterinary College and Research Institute, Salem. The carcass was recovered and processed by biological maceration (Thippan *et al*., 2019) [9] in the Department of Veterinary Anatomy, VCRI, Salem. It was kept submerged in water for three weeks. After completion of maceration, the bones were collected, cleaned and soaked in 3 percent potassium hydroxide for two days. Later the bones were processed in calcium hydroxide for achieving white colour of the bones. The prepared bones were segregated and arranged in order for the study of vertebral column.

Results and Discussion

The vertebral formula of the Indian palm squirrel was C7 (cervical), T12 (thoracic), L7 (lumbar), S3 (sacral). This observation was in accordance with Thippan *et al*. (2019) [9] who observed the vertebral formula of Indian giant flying squirrel as C7, T12, L7, S3, Cy 27. The number of coccygeal vertebrae could not be exactly mentioned in the present study of Indian palm squirrel, due to missing of few very small bones during processing.

Cervical vertebrae (C7)

Atlas (C1) was a ring shaped bone. The dorsal arch was wider than the ventral arch. Dorsal arch possessed a small median tubercle and the alar foramen on either side near the anterior margin. Ventral arch was very narrow and bear a small caudally pointed tubercle on the posterior margin (Fig.1).

Fig 1: Cervical Vertebrae (C7)

Anterior articular facets were concave and oval, kept wide apart which articulates with the occipital condyles. Small round facets present on the posterior surface for the articulation with axis. Wings or alae projected laterally and perpendicularly, and was pierced anteriorly by the alar foramen. Wings represented the transverse process and it was in the form of two divisions, posterior and ventral. The foramen transversarium present between the two divisions of wings. Foramen transversarium, alar foramen and fossa atlantis were significant in the atlas of mole rat (Ozkan *et al*., 2007) [6]. The greatest diameter of the vertebral canal was observed in the atlas as in case of hare and rabbit (Hussein *et al*., 2020) [4].

Axis (C2) of Indian palm squirrel was comparatively shorter, than other mammalian species where the body of the axis was the longest among all vertebrae in cattle, horse, dog (Dyce *et al*., 2010) [1], in bats (Gaudioso *et al*., 2017) [2] and in hare and rabbit (Hussein *et al*., 2020) [4]. Dorsal spine was plate-like, bifurcated in the caudal portion and terminated over the posterior articular processes. Similar observations were noticed in mole rat (Ozkan *et al*., 2007) [6], in hedgehog (Ozkan *et al*. 2005) [5] and in Indian giant flying squirrel (Thippan *et al*., 2019) [9].

Posterior articular processes had downward facing facets. Ventral spine was absent. Transverse process was small, pointed, posteriorly directed and pierced with foramen transversarium. Anterior articular surface was condyloid. Dens or odontoid process was short, blunt and rounded, extended beyond the ventral arch of the atlas during articulation in Indian palm squirrel, but the dens was very long and pointed in Indian giant flying squirrel (Thippan *et al*., 2019) [9].

Third to fifth cervical vertebrae (C3 to C5) had common features, in which dorsal and ventral spines were absent in Indian palm squirrel. Width of the bodies were more or less equal. Upward facing anterior articular processes and downward facing posterior articular processes were noticed. The diameter of the vertebral canal increased from C3 to C5. Transverse processes were bifid with anterior and posterior divisions in Indian palm squirrel, in contrast they were undivided in Indian giant flying squirrel (Thippan *et al*., 2019) [9].

Sixth cervical vertebra (C6) possessed trifid transverse process with anterior, posterior and lateral divisions, similar to that of the horse (Dyce *et al*., 2010) [1].

Seventh cervical vertebra (C7) had a small dorsal spine. Transverse process was undivided and directed laterally.

Foramen transversarium was present in all the cervical vertebrae except seventh cervical vertebra in Indian palm squirrel as reported in hedgehog (Ozkan *et al*. 2005) [5] and Indian giant flying squirrel (Thippan *et al*., 2019) [9]. The width of the neural arches gradually decreased from C3 to C7.

Thoracic vertebrae (T12)

Length of the bodies increased from T1 to T12. Size of the vertebral canal decreased gradually from T1 to T12. Anterior and posterior notches in the pedicles formed large intervertebral foramen with the subsequent vertebrae. Anterior and posterior costal facets were shallow. Small and round facets were noticed in the anterior and posterior articular processes (Fig.2).

Fig 2: Thoracic Vertebrae (T12)

The spine of T1 is short and T2 is the tallest, thereafter the height diminished gradually to T12 in Indian palm squirrel, whereas height of the spines increased upto T3 and then diminished in hare and rabbit (Hussein *et al*., 2020) [4]. Spines of T1 to T9 inclined backward, while those of T11 and T12 inclined slightly forward. Spine of T10 is vertical and was the anticlinial vertebra in Indian palm squirrel while, the last two thoracic spines were vertical in mole rat (Ozkan *et al*., 2007) [6].

Thoracic vertebrae from T1 and T9 showed common morphological features and T11 and T12 possessed features similar to that of lumbar vertebrae. The spines of T1 to T9 were thin and pointed. The dorsal spine of tenth thoracic vertebra (T10) was plate-like resembling that of lumbar vertebrae, which showed the transition between thoracic and lumbar vertebrae. Ventral spines were absent in all the thoracic vertebrae. Mammillary processes were noticed in all thoracic vertebrae while, the accessory processes were evident from T8 onwards. Similar observations were reported in Indian giant flying squirrel by Thippan *et al*. (2019) [9]. Transverse processes were short, vertical and carried the tubercular facets for the tubercle of the ribs. In last two vertebrae, transverse process were very blunt, almost absent and tubercular facets also were absent. T11 and T12 had curved articular processes and well developed mammillary and accessory processes.

Lumbar vertebrae (L7)

The bodies were dorso ventrally compressed and size of the vertebral canal decreased from first to last lumbar vertebrae. Length of the bodies increased from L1 to L6, then decreased in L7. Dorsal spines appeared plate-like, inclined forward, height increased from L1 to L7 in Indian palm squirrel. Similar observations were noted in hare and rabbit, but the spines were vertical (Hussein *et al*., 2020) [4]. Thin ridge like ventral spines noticed in L2 and L3 only in present study, while ventral crest was observed in last two lumbar vertebrae of mole rat (Ozkan *et al*., 2007) [6] (Fig.3).

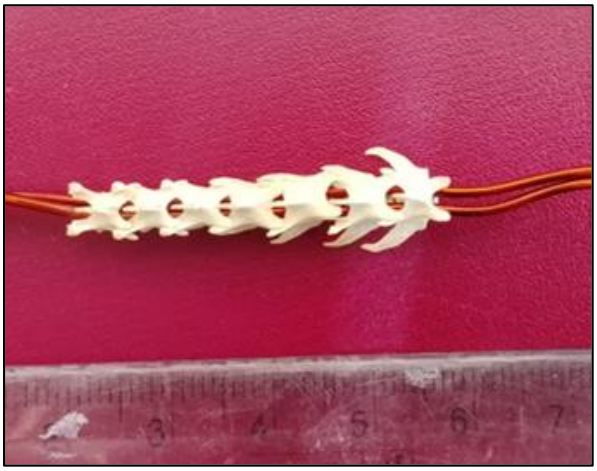

Fig 3: Lumbar Vertebrae (L7)

Transverse processes were very short and blunt in L1 and L2, then the length increased gradually up to L7. The processes were long and directed cranio ventrally from the bodies. Mammillary processes were present as in the hedgehog (Ozkan *et al*., 2005) [5]. The size of the accessory processes decreased from L1 to L6 and disappeared completely in L7.

Sacral vertebrae (S3)

Sacrum was formed by the fusion of three sacral segments in a quadrilateral shape. There were four sacral vertebrae fused in hedgehog (Ozkan *et al*., 2005) [5], rabbit (Hussein *et al*. 2020) [4] and mole rat (Ozkan *et al*., 2007) [6]. Dorsal spines were separate and not fused even at the bases, similar to that of horse (Dyce *et al*., 2010) [1]. Articular processes fused in the form of two pairs of tubercles on either side of dorsal spines. Anterior articular process of first sacral vertebrae was curved with medially facing facets, similar to lumbar vertebrae (Fig.4).

Fig 4: Sacrum (S3) and Coccygeal Vertebrae (Cy)

Transverse process of S1 and S2 fused in the form of wings, which were prismatic and vertical. Wings had posterior rough articular area for articulation with ilium. Posteriorly the wings were continued by the plate like lateral border of sacrum. Two dorsal and two ventral sacral foramina were observed. Pelvic surface was straight with two transverse ridges marking the fusion of sacral segments, as in hedgehog (Ozkan *et al*., 2005) [5], whereas the pelvic face was concave in sacrum of mole rat (Ozkan *et al*., 2007) [6].

Coccygeal vertebrae

The number of coccygeal vertebrae was not mentioned exactly, however, 14 numbers of vertebrae were retrieved and studied. First seven coccygeal vertebrae were typical with well developed dorsal spines, articular processes, plate like wide transverse processes (Thippan *et al*., 2019) [9]. The transverse process of Cy1 and Cy2 were straight, while Cy3 to Cy7 were inclining caudally. The well developed articular processes in the proximal tail region attribute to the functional adaptations to the arboreal locomotion (Hofmann *et al*., 2021) [3]. The transition of the vertebrae was observed from Cy8 where the spines and articular processes were greatly reduced in size. Thereafter, the vertebrae contained only long narrow bodies with expanded extremities. The length and size of the vertebrae reduced gradually towards the tip of the tail.

Conclusion

The vertebral formula of the Indian palm squirrel was C7, T12, L7, S3. Peculiar difference in the cervical vertebrae was presence of short and small axis, in contrast with other mammalian species. Transverse processes of third to fifth cervical vertebrae were bifid, while the sixth was trifid. Tenth thoracic vertebrae was the anticlinial vertebra and last two showed similarities with lumbar vertebrae. The

quadrilateral sacrum with three sacral segments was flat and had a posteriorly overhanging dorsal spine. First seven coccygeal vertebrae were typical, thereafter composed of only bodies. The morphological features of vertebral column of Indian palm squirrel showed several similarities with related species, and also variations within the same family.

References

1. Dyce KM, Sack WO, Wensing CJG. Textbook of veterinary anatomy. 4th ed. St. Louis (MO): Saunders/Elsevier; 2010.
2. Gaudioso PJ, Díaz MM, Barquez RM. Morphology of the axial skeleton of seven bat genera (Chiroptera: Phyllostomidae). An Acad Bras Cienc. 2017;89(3):2341-2358.
3. Hofmann R, Lehmann T, Warren DL, Ruf I. The squirrel is in the detail: anatomy and morphometry of the tail in Sciuromorpha (Rodentia, Mammalia). J Morphol. 2021;282(11):1659-1682.
4. Hussein AA, Nsaif RH, Salih AN. Morphometric comparative study of vertebral column, ribs and sternum between hare and domesticated rabbit. Eurasian J Biosci. 2020;14:6491-6495.
5. Ozkan ZE. Macroanatomy of axial skeleton of hedgehog. Indian Vet J. 2005;82(8):877-880.
6. Ozkan ZE. Macro-anatomical investigations on the skeletons of mole-rat (*Spalax leucodon* Nordmann) III. Skeleton axiale. Vet Arhiv. 2007;77(3):281-288.
7. Paskins KE, Bowyer A, Megill WM, Scheibe JS. Take-off and landing forces and the evolution of controlled gliding in northern flying squirrels (*Glaucomys sabrinus*). J Exp Biol. 2007;210:1413-1423.
8. Sharma SK. Presence of Indian palm squirrel *Funambulus palmarum* Linnaeus in southern Aravallis. Zoos' Print J. 2005;20(6):1908-1909.
9. Thippan M, Lakshmishree KT, Melinamani D, Manjunath SS, Jayaramu GM, Vinay S. Gross morphology and morphometric studies on the vertebral column of Indian giant flying squirrel (*Petaurista philippensis*). Int J Livest Res. 2019;9(2):138-153.