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ORIGINAL RESEARCH

# Thoracic to lumbar vertebral column length and length ratios in miniature dachshunds with and without thoracolumbar intervertebral disc extrusion

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## Abstract

**Background:** The chondrodystrophic body type predisposes miniature dachshunds to thoracolumbar intervertebral disc extrusion (IVDE). However, the relationship between thoracolumbar IVDE and the relative lengths of the thoracic and lumbar vertebral columns has not yet been evaluated.

**Methods:** This prospective multicentre study included 151 miniature dachshunds with ($n$ = 47) and without ($n$ = 104) thoracolumbar IVDE. All dogs had their thoracic and lumbar vertebral columns measured with a tape measure. Detailed descriptions were provided to facilitate consistent measurement. A thoracic to lumbar vertebral column ratio was calculated. Thoracolumbar IVDE was confirmed by magnetic resonance imaging or computed tomography.

**Results:** The thoracic to lumbar vertebral column length ratio and absolute thoracic vertebral column length were significantly smaller in miniature dachshunds with IVDE than in those without IVDE ($p < 0.0001$ for both). There were no significant differences in lumbar vertebral column length, age, sex or neuter status between the two groups.

**Limitations:** The dogs without IVDE did not undergo a neurological examination and the thoracic and lumbar vertebral column measurements were not validated.

**Conclusions:** The relative lengths of the thoracic and lumbar vertebral column segments could contribute to the development of thoracolumbar IVDE in miniature dachshunds. Further studies are needed to evaluate ideal thoracic to lumbar vertebral column length ratios in miniature dachshunds.

## INTRODUCTION

Intervertebral disc extrusion (IVDE) is the most common spinal condition in dogs.[1] It is characterised by extrusion of calcified and dehydrated nucleus pulposus through the ruptured annulus fibrosus into the vertebral canal.[2–4] Although every dog breed can be affected, dachshunds and miniature dachshunds in particular are overrepresented in several studies.[5–9] It has been suggested that approximately 20%–25% of dachshunds are affected by IVDE during their lifetime.[8–10]

The aetiology of IVDE is considered to be multifactorial, with genetic, anatomical and biomechanical factors involved.[5,8,11,12] The chondrodystrophic body conformation of dachshunds, characterised by a disproportionally long back and short limbs, is considered a major risk factor for development of IVDE.[8,10,13] A previous study evaluating body dimensions of a variety of dog breeds found that a more pronounced chondrodystrophic body type, characterised by a relatively longer vertebral column and shorter height at the withers, was associated with an increased risk of thoracolumbar IVDE.[8] It has been suggested that a

single inserted retrogene, causing the protein FGF4 to be overproduced, is associated with chondrodysplasia in dachshunds and other dog breeds.[4,8,14–16]

Previous studies evaluating specific body dimensions in dachshunds with IVDE have provided somewhat conflicting results. Levine et al.[13] suggested that dachshunds with a shorter distance between their T1 and S1 vertebrae and a shorter distance between their tuber calcaneus and the midpoint of the patella tendon were more likely to be affected by intervertebral disc disease. However, they also noted that, although less likely to be affected by intervertebral disc disease, dachshunds with a longer distance between T1 and S1 experienced more severe spinal cord injury. Jensen and Ersboll,[17] however, did not identify an association between radiographically visible intervertebral disc calcification and body conformation.

The possible relationship between thoracolumbar IVDE and the relative lengths of the thoracic and lumbar vertebral segments has not been specifically evaluated. This ratio is of potential interest because most IVDEs in chondrodystrophic dogs occur around the thoracolumbar junction between T11 and L2.[5] This suggests that the biomechanical properties of this junction might contribute to the development of IVDE.[2] The thoracic vertebral column is a rigid structure compared to the more mobile lumbar vertebral column, and intervertebral discs play an important role in maintaining thoracic spinal stability.[18]

The aim of this prospective study was to investigate whether the ratio between thoracic and lumbar vertebral column lengths is associated with the presence of thoracolumbar IVDE in miniature dachshunds. It was hypothesised that there would be a difference in thoracic to lumbar vertebral column length ratios between miniature dachshunds with and without thoracolumbar IVDE.

## MATERIALS AND METHODS

Between March 2020 and October 2021, miniature dachshunds with thoracolumbar IVDE were prospectively enrolled from the neurology services at the Royal Veterinary College (RVC), Anderson Moores Veterinary Specialists (AMVS) and the University of Hannover Faculty of Veterinary Medicine. For all cases, clients received an information leaflet about the study aims and methods before providing written consent to allow their dog to participate. To be included, miniature dachshunds had to have clinical signs and imaging findings compatible with thoracolumbar IVDE. Standard dachshunds were not included due to the substantial size differences between the two breeds and the overrepresentation of the miniature dachshund in the participating hospital populations.

Each affected dog underwent a general physical and neurological examination by a board-certified neurologist or resident in neurology and neurosurgery. A diagnosis was obtained by computed tomography (CT) or magnetic resonance imaging (MRI) under general anaesthesia. CT was performed with a 320-slice scanner and MRI was performed with a high-field scanner (1.5 T, Intera; Philips Medical Systems for RVC and AMVS; 3.0 T, Achieva dStream; Phillips Medical Systems for University of Hannover; 1.5 T, Achieva [until August 2020]). Although imaging protocols could vary between cases, each MRI study included a minimum of T2-weighted and T1-weighted sagittal and transverse sequences. After a diagnosis of thoracolumbar IVDE was confirmed, the following measurements were performed. First, for the thoracic vertebral column, using a ruler or tape measure, starting at the base of the neck, the vertebral column was measured to the end of the rib cage in millimetres (Figure 1). The end point of the measurement was identified by palpating the last rib and following it vertically to where it meets the vertebral column. Second, for the lumbar vertebral column, using a ruler or tape measure, starting at the end point of the thoracic measurement, the vertebral column was measured to the lumbosacral junction in millimetres (Figure 1). This point was identified by placing a hand on the cranial aspect of the thigh with the little finger on the patella and placing the thumb vertically on the back of the dog. The point at which the thumb rests was estimated to be the lumbosacral junction. The measurements were obtained by the attending veterinary surgeon or veterinary nurse. Measurements were performed with the dog in a standing position if possible. For dogs that were unable to support their weight, manual support was used to maintain a similar position. To aid in correct and consistent measurements, written instructions with photographs were provided (Supporting Information). To compensate for size differences between individual dogs, a ratio was calculated by dividing the thoracic vertebral column length by the lumbar vertebral column length. A value of 1 indicates that the thoracic and lumbar vertebral segments have the same length, a value of less than 1 indicates that the thoracic vertebral column is shorter than the lumber vertebral column and a value greater than 1 indicates that the thoracic vertebral column is longer than the lumbar vertebral column.

A control group of neurologically normal miniature dachshunds was recruited using a Google Forms questionnaire distributed to members of the public via Facebook, the Dachshund Breed Council newsletter and the Dachshund Health UK blog between March 2020 and October 2021. Additionally, control group data were collated by the first author using her own miniature dachshunds (nine dogs), those belonging to friends (four dogs) and those that attended a Southern Dachshund Association summer fun show in July 2021 (22 dogs). All dogs in this group had to be skeletally mature (more than 12 months of age) to be included in this study. None of the control dogs underwent a general physical and neurological examination at the time of measurement, but owners were asked to confirm that their dogs did not


**FIGURE 1** Photographs illustrating how measurement of thoracic vertebral column length (a) and lumbar vertebral column length (b) was performed

have a history of spinal disease or injury. The written and photographic instructions provided and the measurements performed were identical to those used to measure the group of miniature dachshunds affected by thoracolumbar IVDE.

Statistical analysis was performed on all data sets using SPSS (V.28.0.0.0; IBM). A Mann–Whitney *U*-test was used to analyse the difference between the thoracic and lumbar vertebral column length ratios of the control group and the affected group, and to analyse the difference in the distribution of age between the clinical status categories. A Student's *t*-test was used to analyse absolute thoracic and lumbar vertebral column lengths between the control and affected groups. A chi-square test was used to analyse the difference in sex and neuter status. A *p*-value less than 0.05 was considered statistically significant. Graphs were generated on GraphPad Prism and Microsoft Excel.

# RESULTS

## Included dogs

A total of 151 miniature dachshunds with ($n = 47$) or without ($n = 104$) thoracolumbar IVDE were included in this study.

The affected group consisted of 23 males (14 neutered) and 24 females (15 neutered), aged between 2 and 10 years (mean 5.3 years; median 5 years). Presenting clinical signs included spinal hyperaesthesia without neurological deficits (one dog), spinal hyperaesthesia with tail plegia (one dog), ambulatory paraparesis with pelvic limb ataxia (18 dogs), non-ambulatory paraparesis (12 dogs), paraplegia with intact nociception (seven dogs), paraplegia with absent superficial nociception (one dog) and paraplegia with absent deep nociception (seven dogs). The duration of clinical signs varied between 1 and 304 days (median 1 day). The mean thoracic vertebral column length was 149.9 mm (standard deviation [SD] 20.2), and the mean lumbar vertebral column length was 137.4 mm (SD 23.0). In total, 29 (60.4%) affected miniature dachshunds had a longer thoracic than lumbar vertebral column, 12 (25%) had a longer lumbar than thoracic vertebral column and seven (14.6%) dogs had equal thoracic and lumbar vertebral column lengths. The thoracic to lumbar vertebral column length ratio ranged from 0.70 to 2.00 (median 1.12).

The control group consisted of 50 males (30 neutered) and 54 females (34 neutered), aged between 1 and 15 years (mean 5.3 years; median 5 years). The mean length of the thoracic vertebral column was 180.05 mm (SD 42.7), and the mean length of lumbar vertebral column was 136.65 mm (SD 41.9). In total, 83 (79.8%) miniature dachshunds in this group had a longer thoracic than lumbar vertebral column, 18 (17.3%) had a longer lumbar than thoracic vertebral column and three (2.9%) dogs had equal thoracic and lumbar vertebral column lengths. The thoracic to lumbar vertebral column length ratio ranged from 0.58 to 3.86 (median 1.33).

## Comparison between miniature dachshunds with and without thoracolumbar IVDE

There were no significant differences in mean absolute lumbar vertebral column length ($p = 0.994$) (Figure 2c), age ($p = 0.348$), sex ($p = 0.927$) or neuter status ($p = 0.821$) between the two groups. The median thoracic to lumbar vertebral column length ratio was significantly lower in miniature dachshunds with thoracolumbar IVDE than in those without IVDE ($p < 0.001$) (Figure 2a). The mean absolute thoracic vertebral column length was significantly shorter in miniature dachshunds with IVDE than in those without thoracolumbar IVDE ($p < 0.001$) (Figure 2b). For comparative reasons, the analysis was repeated including only control dogs that were 8 years or older ($n = 25$). Miniature dachshunds without IVDE that were 8 years or older had a mean thoracic vertebral column length of 188.32 mm, a mean lumbar vertebral column length of 136.4 mm and a median thoracic to lumbar vertebral column length ratio of 1.33. The mean absolute thoracic vertebral column length and median thoracic to lumbar vertebral column length ratio were significantly lower in miniature dachshunds with thoracolumbar IVDE than in those without IVDE and aged 8 years or older ($p < 0.0001$ for both variables). The mean absolute lumbar vertebral column lengths were not significantly different ($p = 0.875$). None of the performed measurements was significantly different between younger control dogs and those at least 8 years of age ($p > 0.05$).

# DISCUSSION

This prospective study evaluated the association between the relative thoracic and lumbar vertebral column lengths in miniature dachshunds and the presence of thoracolumbar IVDE. Our results suggest that miniature dachshunds with thoracolumbar IVDE have a lower thoracic to lumbar vertebral column length ratio compared to miniature dachshunds without IVDE. Furthermore, this difference seems to be caused by a shorter thoracic vertebral column in the group of miniature dachshunds with IVDE. This finding could be in accordance with a previous study that identified that dachshunds with intervertebral disc disease have a shorter T1–S1 distance than unaffected dachshunds.[13] However, it is unclear whether the shorter T1–S1 distance in the study by Levine et al.[13] could be attributed to a shorter thoracic or a shorter lumbar vertebral segment.

Thoracolumbar IVDE occurs more commonly in high-stress regions along the vertebral column, such as the thoracolumbar junction. It has therefore been suggested that the biomechanical forces acting on the caudal thoracic and cranial lumbar intervertebral discs contribute to the high prevalence of IVDE in this anatomical region.[2,5,13,19] It seems reasonable to expect that the biomechanical properties of the thoracolumbar junction are influenced by the length of the rigid thoracic vertebral column relative to the length of the more mobile lumbar vertebral column. Although it is currently unclear precisely how the length of vertebral column segments would influence biomechanical loading of the intervertebral discs, increased compressive and torsional loading have been implicated in intervertebral disc injury.[20,21] Furthermore, it has been suggested that the intervertebral discs of chondrodystrophic dogs, such as miniature dachshunds, are more sensitive to mechanical stress.[17]

Dogs with thoracolumbar IVDE had a significantly shorter thoracic vertebral column than unaffected control dogs. However, most miniature dachshunds in both groups had a longer thoracic compared to lumbar vertebral column. This is possibly related to the Kennel Club breed standard for miniature

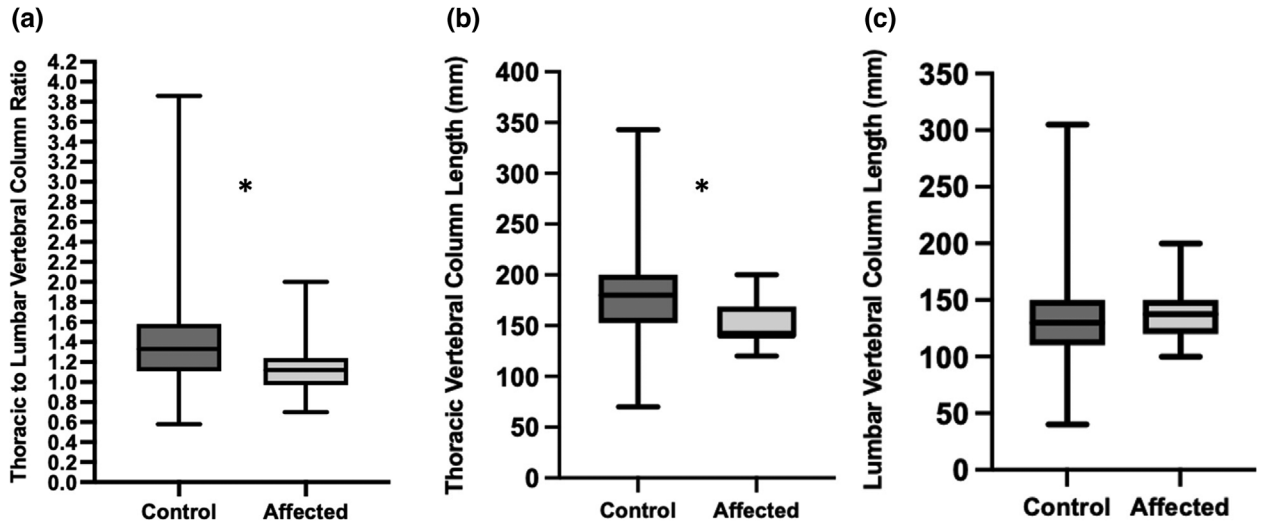


**FIGURE 2** Comparison of (a) thoracic to lumbar vertebral column length ratios, (b) thoracic vertebral column length and (c) lumbar vertebral column length between 47 miniature dachshunds with thoracolumbar intervertebral disc extrusion (IVDE) and 104 miniature dachshunds without thoracolumbar IVDE. The asterisk (*) indicates a significant difference between the affected and unaffected groups

dachshunds. The Kennel Club[22] specifies that the ribs of a miniature dachshund should extend 'well back with a good length of sternum'. It is therefore possible that the breed standard asking for a longer thoracic vertebral column may help in reducing the prevalence of thoracolumbar IVDE in the miniature dachshund. When combined with previous findings in radiographic screening schemes and diet and lifestyle management,[10,23,24] our results have the potential to be incorporated into a breeding strategy to reduce the risk of thoracolumbar IVDE in miniature dachshunds. However, this study did not evaluate or identify the ideal length or proportion of the thoracic compared to the lumbar vertebral column. Therefore, it remains difficult to translate the results of our study into specific breeding guidelines for the relevant dachshund associations. It should further be emphasised that there was substantial overlap and considerable variation in absolute thoracic vertebral column measurements and thoracic to lumbar vertebral column length ratios between miniature dachshunds with and without thoracolumbar IVDE. Variation in vertebral column measurements was especially obvious in the group of miniature dachshunds without IVDE. This could reflect the heterogenous character of this group of dogs or reflect the difficulty in obtaining reliable vertebral column measurements for non-veterinary professionals. The considerable and, potentially variable, curvature of the last rib can make it challenging to reliably identify the caudal border of the thorax. These findings further complicate the development of specific recommendations pertaining to ideal thoracic vertebral column dimensions.

Although the results of this study suggest that a relatively shorter thoracic vertebral column could be considered an anatomical risk factor for thoracolumbar IVDE in miniature dachshunds, a shorter thoracic vertebral column may represent an expression of an increased degree of chondrodystrophy.[13] Chondrodystrophy has been associated with a reduced length of the distal portions of the limbs, shortening of vertebrae and differences in the anatomy and biochemical structure of the intervertebral disk.[12,25,26] Although chondrodystrophy could therefore theoretically result in a shorter vertebral column, it is unclear how this would more selectively affect the thoracic vertebral column in particular. Therefore, further studies that consider other body measurements, such as limb length, combined with thoracic to lumbar vertebral column length would be beneficial.

This prospective study has several limitations. Most dogs in the control group were not assessed and measured by a veterinary professional and did not undergo a general physical and neurological examination. Therefore, it cannot be excluded that some dogs in the control group displayed mild clinical signs of thoracolumbar IVDE. It can further not be excluded that some dogs in the control group will develop clinical signs of IVDE later in life. Ideally, only dogs older than the median age of dogs in the IVDE-affected population would have been included in the control group of miniature dachshunds. For this reason, statistical analysis was repeated including only control dogs that were 8 years or older. This additional analysis revealed identical results compared to the initial analysis; miniature dachshunds with IVDE had a significantly shorter thoracic vertebral column and thoracic to lumbar vertebral column length ratios compared to miniature dachshunds without IVDE that were at least 8 years old. Although detailed instructions with photographs were provided to facilitate consistent measurements, it is unclear if these measurements accurately predict the anatomical length of the thoracic and lumbar vertebral columns. It remains further unclear how patient-specific factors, such as body condition score, would affect the accuracy of measurements. Ideally, vertebral column measurements would have been performed on diagnostic

imaging studies, such as CT or MRI. The necessity for sedation or anaesthesia, in combination with radiation exposure, especially in clinically unaffected dogs, would, however, be difficult to ethically justify. Furthermore, most imaging studies of dogs with IVDE did not include the entire thoracic vertebral column. The specific methodology of this study was aimed at including a large number of cases without the need for expensive diagnostic imaging or general anaesthesia. Further studies are therefore necessary to evaluate the accuracy and reliability of these measurements.

In conclusion, our results suggest that smaller thoracic to lumbar vertebral column length ratios caused by a shorter thoracic vertebral column could potentially be considered an anatomical risk factor for thoracolumbar IVDE in miniature dachshunds. Further research is necessary to validate the accuracy and reliability of the suggested measurements. Future studies should identify the ideal thoracic to lumbar vertebral column length ratios before our findings can be translated into breeding recommendations.

## AUTHOR CONTRIBUTIONS

*Study idea*: Charlotte D.A. Fletcher, Holger A. Volk, Ian Seath and Steven De Decker. *Study design*: Charlotte D.A. Fletcher, Edward J. Ives, Ian Seath, Holger A. Volk and Steven De Decker. *Data collection*: All authors. *Data analysis*: Charlotte D.A. Fletcher and Nicholas J. Grapes. *Data interpretation*: All authors. *Preparation of the first draft*: Charlotte D.A. Fletcher and Steven De Decker. All authors have read and approved the final draft of the manuscript.

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## CONFLICT OF INTEREST STATEMENT

At the time of the study, Ian Seath was chairman of the Dachshund Breed Council and the Southern Dachshund Association, and secretary of Dachshund Health UK (a registered charity).

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The authors received no specific funding for this study.

## DATA AVAILABILITY STATEMENT

Data are available upon reasonable request.

## ETHICS STATEMENT

This prospective study was approved by the Royal Veterinary College Clinical Research Ethical Review Board (URN 2021 2030-3).

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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