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Osseous pathologic changes in the lumbar region of the equine vertebral column: A descriptive post-mortem study in three breeds

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Abstract

Background: Data on equine lumbar pathology hardly exist in breeds other than Thoroughbreds.

Objectives: To describe pathological changes of the osseous lumbar vertebral column in Warmblood horses, Shetland ponies and Konik horses.

Study design: Descriptive post-mortem study.

Methods: The lumbar vertebral columns of 34 Warmblood horses, 28 Shetland ponies, and 18 Konik horses were examined by computed tomography (CT). Osteoarthritis (OA) of articular processes (APJs), OA of intertransverse joints (ITJs), intervertebral disc (IVD) mineralisation, impingement of spinous (SPs) and transverse (TPs) processes and spondylosis were scored. Breed differences in prevalence and severity of pathologies were analysed by linear regression analysis and by calculating Spearman's rank correlation coefficients (r_s).

Results: In Warmblood horses, the prevalence of OA of APJs, impingement of SPs and TPs was respectively 90%, 36%, and 35%, significantly higher than in the other breeds ($p < 0.001$). In Konik horses, IVD mineralisation (40%) and spondylosis (10%) were more frequent than in Warmbloods and Shetland ponies ($p = 0.03$). Severity score for OA of ITJs was highest in Shetland ponies ($p < 0.001$). For impingement of SPs, severity score was highest in Warmbloods ($p = 0.03$), and of TPs lowest in Shetland ponies ($p = 0.003$). For all parameters, except for spondylosis in Shetland ponies, there was a positive correlation between percentage of vertebrae affected and age, with IVD mineralisation scores increasing faster in Konik horses ($p < 0.001$). In all breeds, there was also a positive relation between scores of severity and age for OA of APJs and ITJs and for IVD mineralisation, with severity scores increasing faster in Shetland ponies ($p = 0.04$). Strong left/right correlations of the severity scores were seen for OA of the APJ, ITJ, impingement of TPs, and paramedian spondylosis ($r_s = 0.74$–0.86, all $p < 0.001$).

Main limitations: Clinical histories were not available.

Conclusions: There are distinct breed differences between prevalence and severity of osseous pathologies of the lumbar spine. Warmblood horses have higher scores for most pathologies with IVD mineralisation being more important in Konik horses and OA of ITJs in Shetland ponies.

KEYWORDS
articular process, disc, horse, impingement, intertransverse, spondylosis

1 | INTRODUCTION

Thoracolumbar pathology has since long been related to poor performance in horses,[1–3] and work on the prevalence has been done mainly in Thoroughbreds,[4,5] French trotters[6] and in populations with a mixture of breeds.[7–13] However, there are hardly any data on the occurrence of thoracolumbar pathology in Warmbloods,[14] the major horse breed used for equestrian sports other than racing. Breed differences in pathological manifestations of thoracolumbar disorders can be expected because of differences in developmental anatomy,[15] genetics[16] and use.

The increasing interest in thoracolumbar pathology coincides with better availability and improved resolution of modalities for diagnostic imaging of the equine axial skeleton. Classic techniques such as radiography[6] and ultrasonography[17] have important limitations for this purpose and are insufficient for accurate detection of a number of typical thoracolumbar pathologies. More advanced imaging modalities like computed tomography (CT) and magnetic resonance imaging (MRI) are difficult to achieve in the live horse due to limitations of the bore size and available magnets for MRI and adequate tissue penetration of CT, together with the need for general anaesthesia. As a consequence, the accurate detection of pathological changes of the equine thoracolumbar vertebral column that may be related to clinical back problems is challenging or even sometimes impossible.[18]

The aim of this descriptive post-mortem study was to make an inventory of the prevalence and severity of osseous pathological changes in the lumbar vertebral column of Warmblood horses and to compare the outcome with two breeds considered closer to the original wild horse: Shetland ponies and semi-feral, free ranging Konik horses. Ex vivo specimens were imaged with CT, which was considered the modality most suited for the comprehensive and accurate detection of most osseous pathologies. Based on clinical experience and their athletic use, and on breeding history, because selection for favourable traits may inadvertently introduce (un)desirable, not immediately clinically visible traits, we hypothesised that Warmblood horses would show more pathological changes. In Shetland ponies, less pathological changes were expected, because they are non-athletic and generally not ridden, and our clinical experience of apparently a low incidence of back problems in this breed. In Konik horses fewer changes were expected because these horses are not ridden, there is no selection for breeding and these horses have shown very little variability in the anatomy of their vertebral column.[15] It was further hypothesised that there would be a positive correlation between the occurrence and severity of pathologies and age, in line with an earlier study about bony changes in the lumbosacroiliac region of the vertebral column in a mixed population of horses.[9]

2 | MATERIALS AND METHODS

2.1 | Collection and preparation of specimens

From 2017 to 2021, 80 equine cadavers from a research herd (terminal work unrelated to the axial musculoskeletal system) or in which permission to use the animals for research had been granted by their owners from three breeds were collected:

1. Warmblood horses ($n = 34$, 32 Dutch Warmbloods, 1 Oldenburger, 1 Westfalen); 17 females, 15 castrated and 2 intact males.
2. Shetland ponies ($n = 28$): 26 females, 2 castrated males.
3. Semi-feral Konik horses ($n = 18$): 10 females and 8 intact males.

The complete lumbar region, between the last thoracic and the first sacral vertebra, was examined. Age, body mass, sex, and number of lumbar vertebrae were noted for all animals (Table 1). Preparation of the specimens was performed as described previously.[15]

2.2 | CT examination

All lumbar vertebral columns were examined within 4 h of euthanasia. Columns of the Shetland ponies were scanned in dorsal recumbency, those of the other breeds in ventral recumbency in a custom designed CT tray. A 64-slice sliding gantry CT (Siemens, Definition AS) was used with settings as follows: 140 kVp, mA varying between 280 and 380 according to focal cadaver size, rotation time 0.7 s, reconstruction in bone algorithm B50 and 1 mm slice thickness (WW/WL 3000/600), reconstruction in soft tissue algorithm B30 and 2 mm slice thickness (WW/WL 300/50), matrix 512 × 512, scan field-of-view variable according to cadaver size.

2.3 | Data evaluation

CT images were stored in DICOM format using the PACS system (Agfa) and evaluated by both a board-certified specialist in veterinary diagnostic imaging (SV) and a board-certified specialist in equine surgery (TS).

TABLE 1 Age (median, range), body mass (mean, SD), sex and number (*N*) of lumbar vertebrae of included Shetland ponies, Konik horses and Warmblood horses.

		Age (years)		Body mass (kg)	Sex		Number of lumbar vertebrae		
Breed	***N***	**Median**	**Range**	**Mean (SD)**	**f**	**m**	**5**	**6**	**7**
Shetland pony	28	7.8	3.5–17.5	182 (22)	26	2	3	22	3
Konik horse	18	6.0	1.0–19.0	261 (50)	10	8	2	16	0
Warmblood horse	34	9.8	0.5–26.5	571 (79)	17	17	6	28	0

Abbreviations: f, female; m, male.

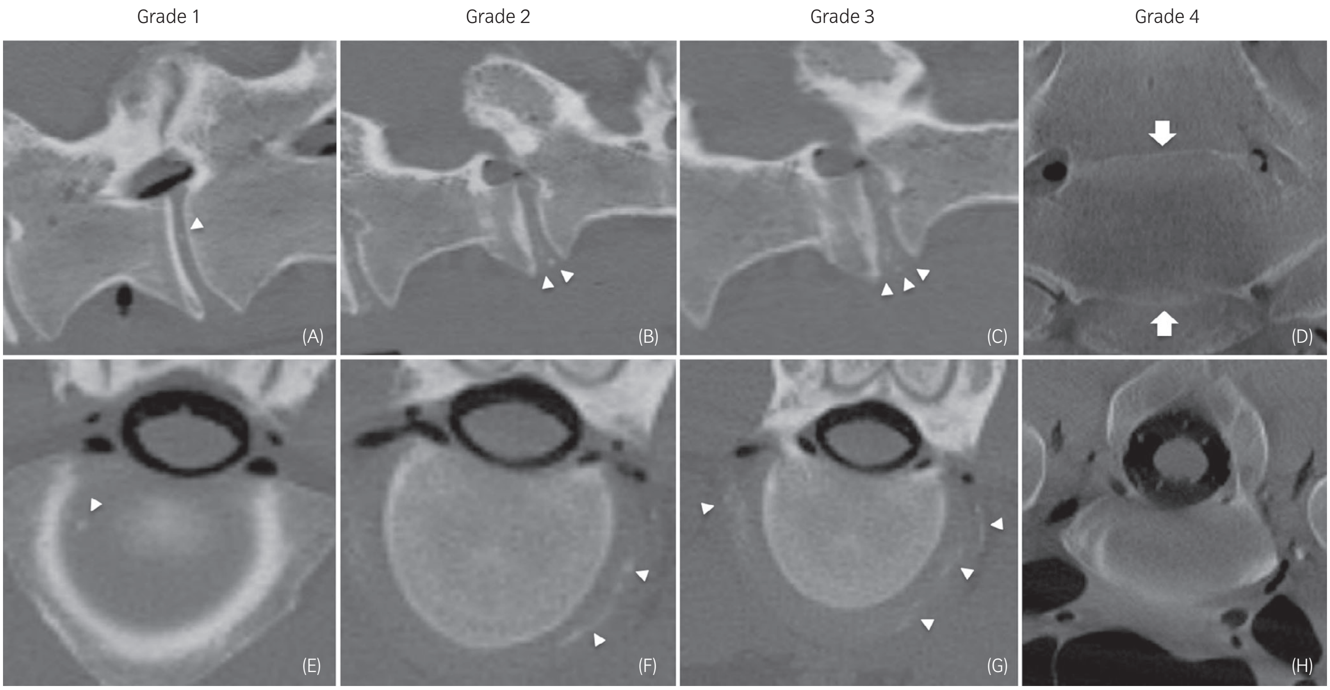

FIGURE 1 Reconstruction images of sagittal (A–C), frontal (D) and transverse planes (E–H) for illustration of different grades of intervertebral disc (IVD) mineralisation (Grade 0: no mineralisation is depicted). Grade 1 (A, E): mild changes, few mineralisations (1, 2), <10% of the disc. Grade 2 (B, F): moderate changes, multiple mineralisations (>2), 10%–50% of the disc. Grade 3 (C, G): severe changes, generalised mineralisation >50% of the disc. White arrowheads highlight mineralisations in different grades. Grade 4 (D, H): no disc(s) discernible/intervertebral space obliterated (between arrows). All images are derived from Warmblood horses.

Differences in interpretation were discussed until consensus was reached. The images were reconstructed in multiplanar 3D format for assessment of the vertebral column using a bone algorithm and window width. A traditional vertebral reference system was used, and vertebrae were conventionally counted from the cranial reference point caudad. Numbers of thoracic, lumbar, and sacral vertebrae were counted and used to define the lumbar vertebral segment for assessment of pathology. The following four types of pathology were assessed and scored, and for all pathologies the most severe score determined the final grade.

2.4 | Osteoarthritis

Lumbar articular process joint (APJ) and intertransverse joint (ITJ) complexes were evaluated for osteoarthritis (OA). Joint complexes were defined as the articular and periarticular surfaces of both cranial and caudal aspects of the articular or transverse processes of the lumbar vertebrae. The grading scheme from VanderBroek et al.[7] was used, which was slightly modified by adding a grade 4 (ankylosis), resulting in five categories (0–4) (Table S1). Left and right joint complexes were graded separately.

2.5 | Intervertebral disc mineralisation

A custom-made scoring system was used to grade intervertebral disc (IVD) mineralisation (Figure 1). In this system, grades were defined from absence (grade 0) towards presence and extension of mineralisation, with a maximum of grade 4 when the disc and intervertebral space were absent (Table S2).

2.6 | Impingement

Impingement of the spinous processes (SPs) and transverse processes (TPs) was graded using a modification of the grading system of Haussler et al.[4] Grades 0 and 1, and grades 4 and 5 of Haussler's system were combined resulting in a total of four grades (0–3) (Table S3). Impingement between left and right TPs was recorded separately.

2.7 | Spondylosis

Spondylosis was classified as the presence of new bone formation involving the vertebral bodies.[4,14,19] Spondylosis of the spinal segment consisting of the last thoracic vertebra, the consecutive lumbar vertebrae and first sacral vertebra, was scored using the radiographic grading system of Meehan et al.[19] (grades 0–5) (Table S4). Spondylosis was not only scored in the median plane, but also in both left and right paramedian plains.

2.8 | Statistical analysis

As scores were not normally distributed, the Spearman rank-order test was used to estimate correlations between the pathophysiological variations. Breed differences in the average scores of the different osseus pathologies were tested with a Kruskal–Wallis test. An intervertebral space was considered having a pathological change if the score was higher than 0. To compare breed differences and differences between intervertebral spaces for the proportion of scores >0, logistic regression analysis was performed. *p*-values were based on the likelihood ratio test.

Per horse, the number of affected vertebrae (i.e., score >0) was counted, and expressed as the percentage of vertebrae with a score >0. Subsequently, per osseous pathological change, general linear regression was performed on the percentages and on the scores of affected vertebrae. Variables in the model were breed (Warmblood, Shetland, Konik), age (in years), the interaction between breed and age, and side (left/right or left/right/middle for spondylosis). Sex was not included in the model because the large differences in sex distribution between the Warmblood horses, Shetland ponies and Konik horses. Model residuals were considered normally distributed if skewness and kurtosis were between −2 and 2. Results are presented as Least Square means with 95% confidence interval (CI). A Tukey's multiple comparison test was performed. All data analyses were performed with SAS software (SAS Institute Inc).

3 | RESULTS

3.1 | Specimens

All cadavers ($n = 80$) that entered the study were analysed and none were excluded. Warmblood horses were oldest (median age of 9.8 years; range 0.5–26.5 years), followed by Shetland ponies (median age of 7.8 years; range 3.5–17.5 years) and Konik horses (median age of 6.0 years; range 1.0–19.0 years) (Table 1). The majority of specimens had 6 lumbar vertebrae: 89%, 82% and 79% of Konik horses, Warmblood horses, and Shetland ponies, respectively. The remaining specimens had five, with the exception of three Shetland ponies with seven lumbar vertebrae (Table 1).

3.2 | Locations

In the 80 specimens a total of 552 intervertebral spaces were assessed for each of the four types of pathological changes with few missing values (Tables S5 and S6). A total number of 387 ITJs were present (196 left-sided, 191 right sided), which were scored for OA (Tables S5 and S6).

3.3 | Osteoarthritis

3.3.1 | Articular process joints

OA affected on average 90% of the APJs of Warmblood horses; 66% in Konik horses and 37% in Shetland ponies ($p < 0.001$) without a significant left/right difference (Figure 2A, Tables S5 and S6; $p = 1.0$). The severity of affected APJs was low (on average <1.5), and not different between breeds (Table S5, Figure 2B; $p = 0.6$). Both prevalence and severity of OA in APJs increased with age similarly in all breeds ($p < 0.001$).

3.3.2 | Intertransverse joints

Intertransverse joints were present in 387 of 1104 potential intervertebral spaces (35.1%; 95% CI: 32.2–37.9). ITJs were absent between T18 and L4 in all breeds, except for one left-sided ITJ between L3–L4 in a Warmblood horse. Per horse, percentages of ITJs affected by OA were 56%, 52% and 43%, in respectively Warmblood horses, Shetland ponies and Konik horses ($p = 0.2$; Figures 2C and 3). There was an increase with age ($p < 0.001$), which was not significantly different between breeds ($p = 0.3$). There was no difference between left and right ($p = 0.7$; Tables S5 and S6). The grade of pathology was more severe ($p < 0.001$) in Shetland ponies (score = 3.3) than in Konik (score = 1.9) and Warmblood horses (score = 2.3) (Figure 2D). The increase of severity with age was similar for Konik and Warmblood horses, but much higher in Shetland ponies (interaction $p = 0.04$).

3.4 | Intervertebral disc mineralisation

The percentage of IVD mineralisation was highest in Konik horses (40%), followed by 12% in Warmblood horses and 3% in Shetland

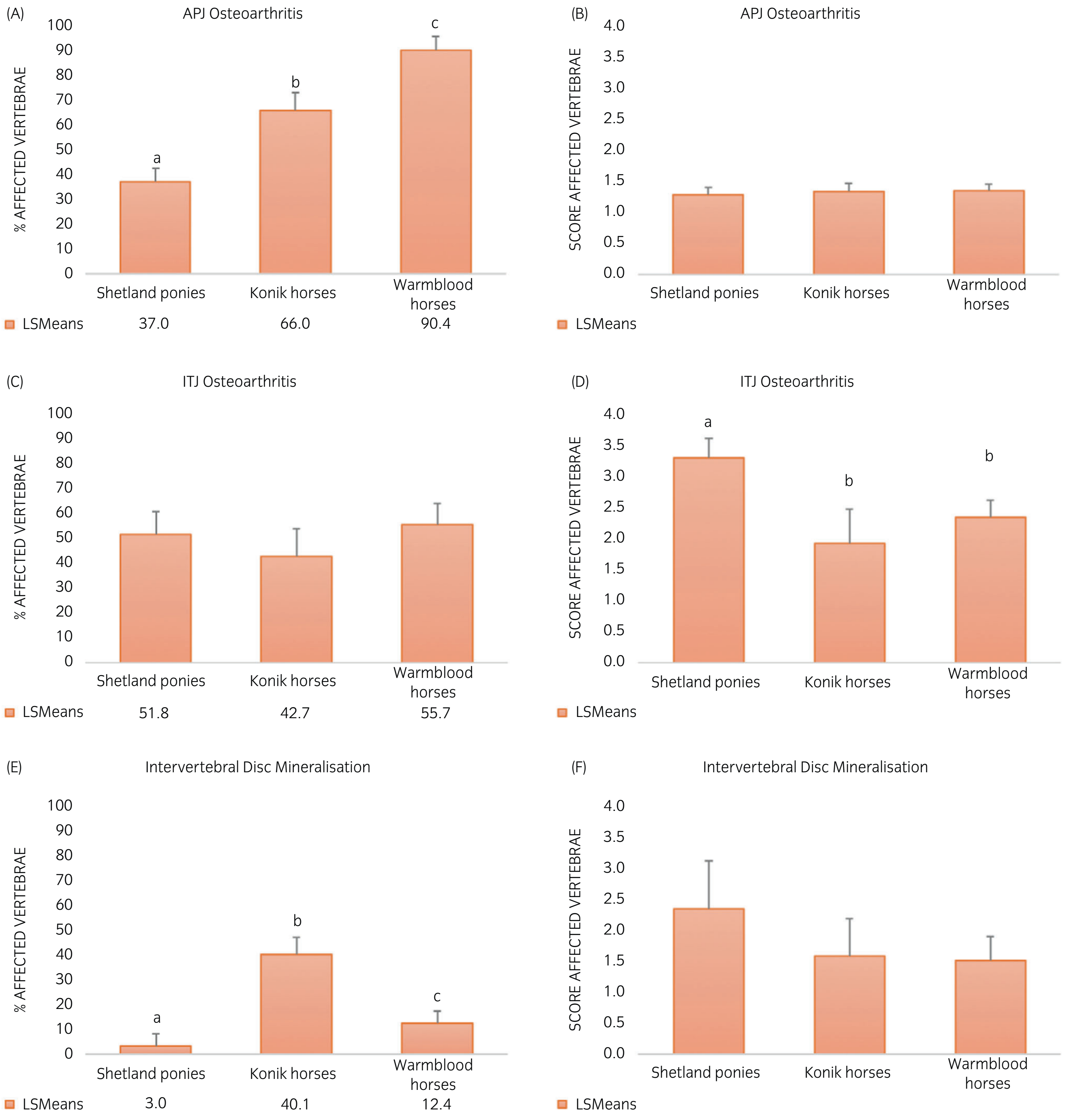

FIGURE 2 Prevalence (%) of the affected vertebrae (score >0) per horse (LSMeans and CI) per breed for osteoarthritis (OA) of articular process joints (APJs) and intertransverse joints (ITJs), mineralisation of intervertebral discs, impingement of spinous processes (SPs) and transverse processes (TPs) and spondylosis in the figures on the left (subpanels A, C, E, G, I, and K). On the right side, per breed the severity scores (LSMeans and CI) of affected vertebrae (subpanels B, D, F, H, J, and L). Different letters within each subpanel denote significant differences ($p < 0.05$).

ponies ($p = 0.03$) (Figure 2E). The increase with age was larger in Konik horses (interaction $p < 0.001$) than in Warmblood horses and Shetland ponies. The severity was higher in Shetland ponies (2.3), but not significantly different ($p = 0.2$) compared to the other breeds (1.5 and 1.6) (Figure 2F). For IVD mineralisation no predilection site could be determined.

3.5 | Impingement

3.5.1 | Spinous processes

Warmblood horses had the highest percentage (36%) of affected intervertebral spaces ($p < 0.001$) and highest severity score (1.9) for

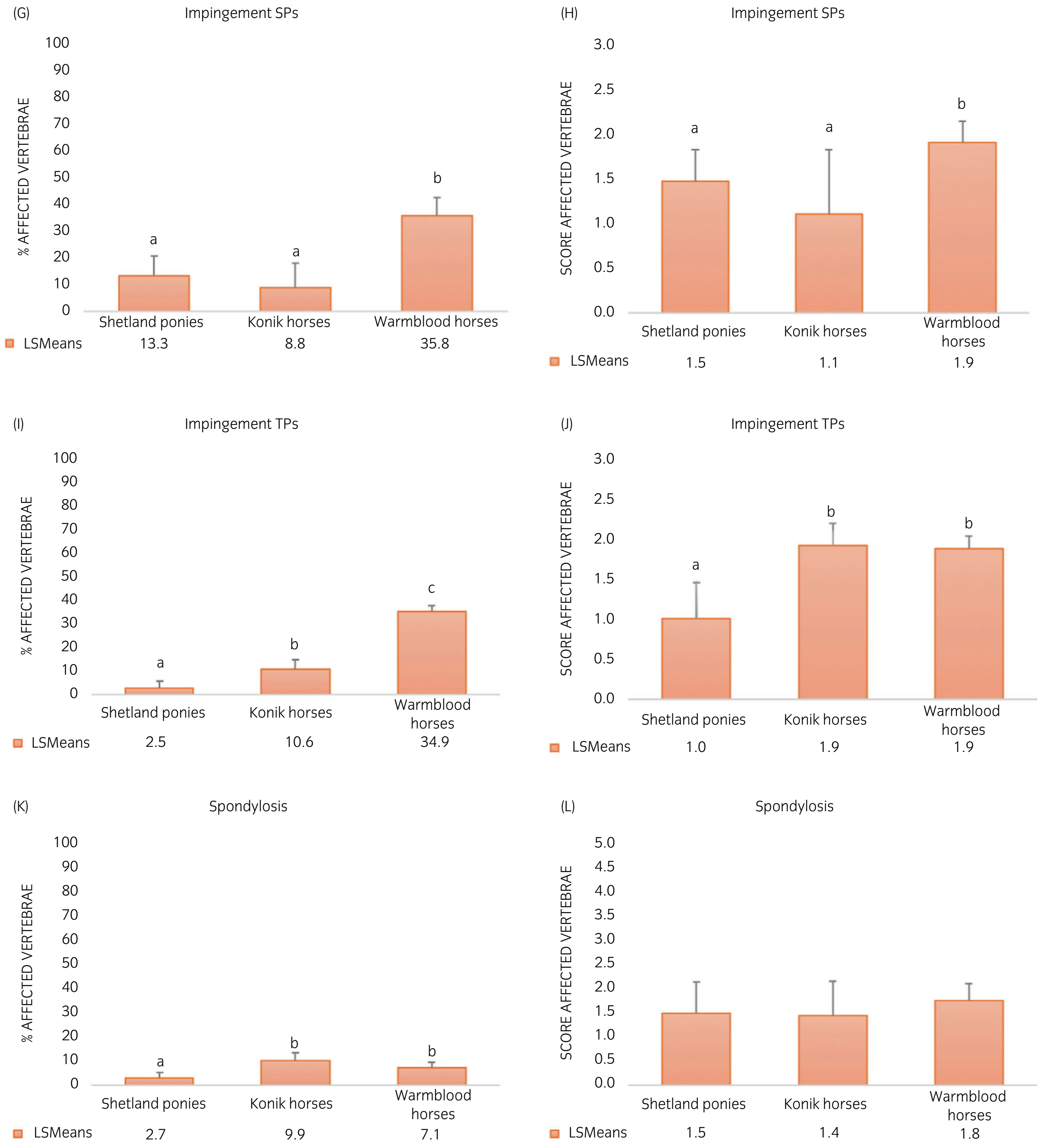

FIGURE 2 (Continued)

impingement of SPs ($p = 0.02$) (Figure 2G). For both the percentage of affected vertebrae and the scores of severity, results were significantly lower in Konik horses and Shetland ponies (Figure 2G ($p = 0.02$) and 2H ($p = 0.03$)). In all breeds, higher prevalence for impingement was noted between caudal lumbar vertebrae, with the exception of L6–S1. Percentages of affected vertebrae increased with age ($p = 0.004$).

3.5.2 | Transverse processes

In Warmbloods more impingement (35%) of TPs was seen than in the other breeds (3% and 11% for Shetland ponies and Konik horses respectively, $p < 0.0001$, Figure 2I, Table S5), with an age effect in all breeds ($p = 0.005$). Examples of specimens with and without impingement of TPs are visible in Figure 3. Severity was less in Shetland

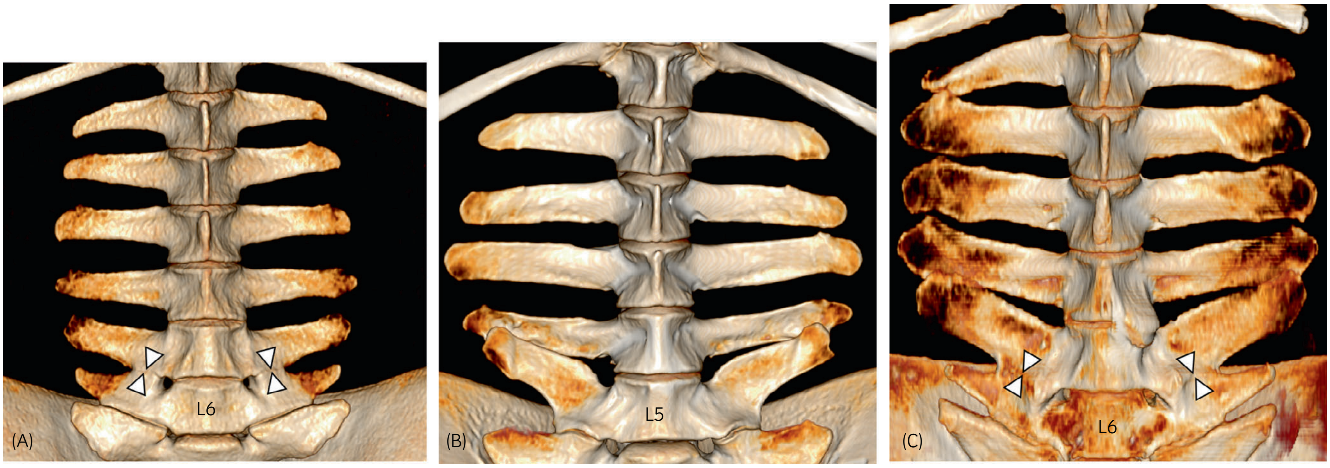

FIGURE 3 Volume rendering (VR) reconstruction of the ventral aspect of the lumbar region of three specimens. (A) 9-year-old Shetland pony, (B) 15-year-old Konik horse, (C) 22-year-old Warmblood horse. Differences in impingement of the transverse processes (TPs) and intertransverse joints (ITJs). (A) impingement absent, bilateral ITJs (between arrowheads) between L5 and L6. (B) bilateral impingement between TPs of L4–L5, ITJs absent. (C) impingement present between several TPs of L1–L5, bilateral ITJs (between arrowheads) between L5 and L6. Specimen B has five lumbar vertebrae.

ponies compared to Warmblood and Konik horses ($p = 0.003$, Figure 2J). In all breeds, impingement occurred most frequently between L4 and L5 ($p < 0.001$), with a breed effect at all positions between L1 and L5, which was the highest for Warmbloods ($p < 0.001$). There was no difference between left and right (Tables S5 and S6).

3.6 | Spondylosis

A low percentage of spondylosis was noted overall. Konik horses had most spondylosis (10%) compared to Warmblood horses (7%; $p = 0.4$) and Shetland ponies (3%) ($p = 0.004$, Figure 2K, Table S5). The significant breed-age interaction ($p = 0.004$) is reflected in a smaller increase with age in Shetland ponies, than in Warmbloods and Konik horses, the latter having the highest increase with age. The severity score was not different between breeds ($p = 0.4$; Figure 2L). There was a side effect in severity scores with the median severity score (1.1) being lower than the left paramedian score (2.1) ($p = 0.02$), but not than the right (1.4) ($p = 0.1$, Figure 4). For left and right paramedian and median spondylosis there was no predilection site in any of the breeds, with the exception of Warmblood horses where the median and right paramedian site a higher prevalence at L3–L4 ($p = 0.02$).

3.7 | Correlation between different pathological findings

Apart from strong left/right correlations (all $p < 0.001$) for most pathologies (OA of the APJ ($r_{s\,(549)} = 0.79$) and ITJ ($r_{s\,(188)} = 0.86$), impingement of the TPs ($r_{s\,(550)} = 0.82$), and paramedian spondylosis ($r_{s\,(550)} = 0.74$)), other correlations were weak with r_s varying between 0.05 and 0.45 (p-values varying between $p = 0.08$ and $p < 0.001$; Table S6).

4 | DISCUSSION

There were distinct differences between the three breeds in the prevalence of the four types of osseous pathology of the lumbar vertebral column, which confirmed our main hypothesis.

Breed differences in the prevalence of various equine orthopaedic diseases are known to exist[20] and were recently also noted in the developmental anatomy and associated phenotypical variations of the equine vertebral column.[15] Thus, the overall outcome of this study was expected. However, the large differences between the breeds identified here make some of the specific outcomes interesting.

The Konik horses used in this study are not direct descendants from wild horses. However, they are generally considered to be close to the now extinct Tarpan or European wild horse. These horses have an average bodyweight similar to wild horses and all individuals came from a semi-feral population in a nature reserve that had enjoyed free exercise in a large enclosure of 2000 hectares. The Konik horses had highest percentages of IVD mineralisation and spondylosis. The Shetland ponies obviously had a much lower bodyweight and had, as animals coming from private owners, a very heterogeneous background. However, the physical workload over life for Shetland ponies in general tends to be low to very low, nevertheless, they had the highest scores for osteoarthritis (OA) of ITJs. Most Warmblood horses are bred for equestrian activities like dressage and show jumping and their average bodyweight and height at the withers has increased considerably over the past decades.[21] Specific information on the exercise history of the individual Warmblood horses in this study was not available, it can be assumed, however, that the Warmblood horses are more likely to have undertaken athletic careers as ridden horses than the other two breeds. Warmblood horses were relatively severely affected and had the highest percentages for OA of APJs and impingement of SPs and TPs, together with the highest severity score for both intervertebral spaces with impingement.

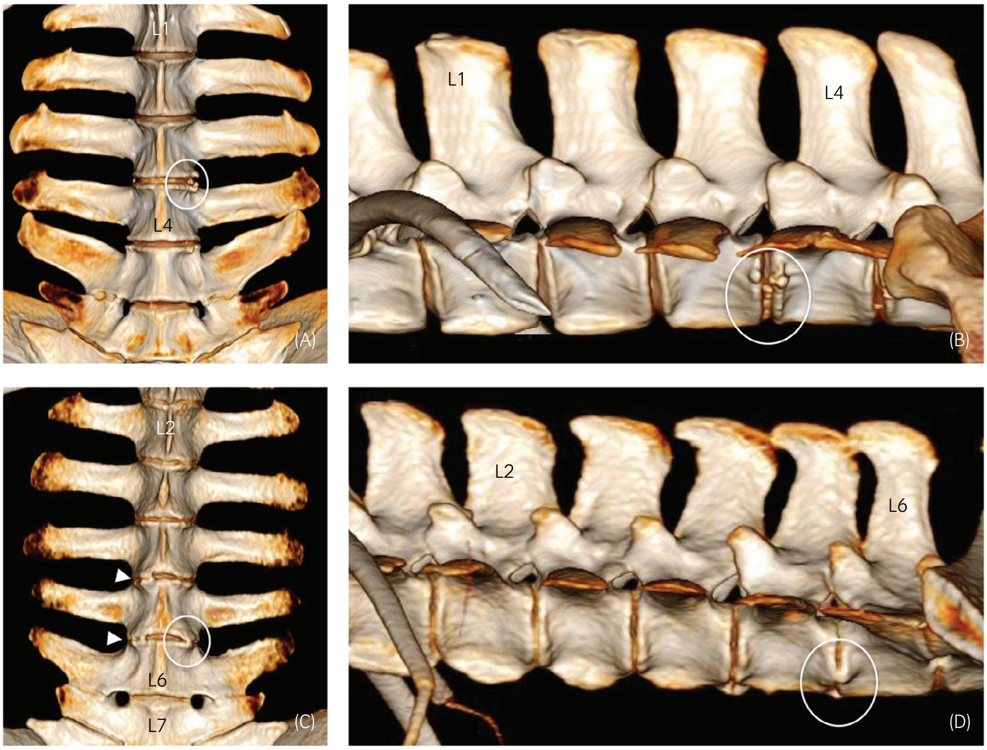

FIGURE 4 Volume rendering (VR) reconstruction of the ventral (A and C) and left lateral (B and D) aspect of the lumbar region of two specimens: 15-year-old Konik horse (A, B) and 11-year-old Shetland pony (C, D). White circles (A, B) indicate left paramedian spondylosis grade 3 between L3 and L4. Arrowheads (C) indicate paramedian spondylosis grade 4 between L4–L5 and L5–L6 on the right side. White circles (C, D) indicate paramedian spondylosis grade 4 between L5 and L6 on the left side. Shetland pony (C, D) has seven lumbar vertebrae.

There was an age effect, also noted by Scilimati et al.,[14] for the prevalence of all disorders in all breeds, but the effect size was different for specific pathologies and breeds. The Konik horses had the lowest median age but the strongest interaction between age and prevalence of IVD mineralisation and spondylosis. In all breeds, age effects for severity of pathological changes of OA of the APJs. OA of the ITJs and IVD mineralisation were seen, with a much earlier increase in Shetland ponies. These age effects were not surprising and are in line with a study[7] where OA in APJs also showed this effect in a mixture of 15 breeds varying from miniature breeds to draught breeds, including racing and non-racing breeds. An increase in prevalence and severity of pathological changes during ageing can of course be explained by age-related degeneration of tissues, However, the present study shows that there are clear breed-related differences, which may warrant further research. Breed is known to be an important determinant of the susceptibility for musculoskeletal diseases.[19] The mechanisms through which these breed effects act can be expected to be complex, with genetics and growth rate as most likely factors, and warrant further research. In the current study, Shetland ponies showed least pathological changes in the lumbar region, followed by the intermediate-sized Konik horses and the tall and heavy Warmblood showed most pathologies. However, the relationship is not straightforward, studies with a mixtures of breeds and sizes did not report a specific correlation between height and OA of APJ,[7,14] and also not for age and OA of the APJs.[14] It is also likely that use and cumulative workload of the animals plays a role too, which factors are indirectly related to breed.

The interesting difference between the low prevalence of OA in APJs and high severity score of OA in ITJs in Shetland ponies can possibly be explained by the difference in function of both joint types. Lumbar APJs facilitate flexion/extension movement. In contrast, ITJs generate lumbar stability by decreasing axial rotation and lateral bending.[22] In case of OA, pathology of the APJs will decrease lumbar movement and hence hamper normal movement. End-stage OA (ankylosis) of ITJs will create even more stability, reducing rotation and lateral bending, which might be beneficial instead of detrimental for the rather stiff, less animated gait pattern of Shetland ponies.

Human intervertebral disc mineralisation is associated with degeneration and can affect disc kinematics. This may lead to pain but can also be asymptomatic.[23] To the authors' knowledge, disc mineralisation in equines has never been reported in the region between Th16 and L5, which led us to design a simple grading system. The mineralisation appeared to be very similar to dystrophic calcification which is part of an early degenerative process and a frequent radiographic finding in chondrodysplastic canine breeds predisposing them to disc herniation.[24–27] Familial occurrence and estimates of high heritability of disc mineralisation have been reported in dogs and it would not be illogical that a familial occurrence could also play a role in Konik horses. Whether IVD mineralisation could predispose equines to some form of disc pathology, with related consequences, needs to be further explored. There is a known predisposition of pathology of the lumbosacral discs in Thoroughbred racehorses probably because of the preferred gait, that is canter and gallop that implies a large flexion-extension motion of the lumbosacral area.[28,29] In the current study, no difference in the prevalence of lumbosacral disc mineralisation and of more cranially located discs could be determined in any breed. This is in line with earlier findings in Warmbloods.[30]

Impingement of the SPs and TPs have both the largest prevalence in Warmblood horses. The prevalence is comparable to that in Thoroughbreds.[4] In all breeds, as in Thoroughbreds, higher numbers for impingement were noted between caudal lumbar vertebrae, with the exception of L6–S1.[4,8,14,28] Impingement of SPs is commonly seen as pathological; however, the condition can be an incidental finding in healthy horses without clinical signs.[31–33] For impingement of TPs the clinical relevance is unknown and needs to be determined. In our study, as well as in a study with Thoroughbreds, Stecher's observation[3] that ankylosis of ITJs occurs before impingement of TPs could not be confirmed.

References for equine spondylosis are limited, but the condition is typically found in the mid-caudal thoracic vertebral column, and very occasionally affecting cervical and lumbar vertebrae.[19,34,35] Spondylosis was not found in relatively young Thoroughbreds (mean age 4.5 ± 1.5 years)[4] in contrast to older horses (mean age 9.2 ± 7.2 years).[14,28] In the current study, low numbers of median spondylosis were encountered in all breeds. Significantly higher numbers for paramedian spondylosis were seen in Konik horses when compared to Shetland ponies, but not to Warmblood horses. However, despite the very low prevalence and low severity scores, for the individual horse the condition still could be of clinical importance. Denoix reported a more common lateral location of lumbar spondylosis compared to the thoracic area.[35] A lateral location is more challenging from the viewpoint of conventional radiographic imaging.[14]

The use of computed tomography made it possible to visualise several typical pathological changes (e.g., OA of the ITJs, disc mineralisation, and paramedian spondylosis), which often remain undetected using radiography and ultrasonography, and equine practitioners should be aware of that. Technically, ultrasonography could be helpful for the determination of impingement of TPs, and maybe for the detection of OA of ITJs, but assessment of the complete extent of lesions and an accurate gradation are difficult if not impossible. Moreover, body and muscle size in Warmblood horses are also limiting factors that will decrease the quality of both radiographic and ultrasonographic imaging of the back. There are ongoing developments of advanced imaging possibilities, such as cone beam CT applied with robotic arms that encircle the equine body. This technique decreases these limitations in imaging the equine spine, but not completely for the lumbar vertebrae, because of the earlier mentioned large size. In-depth knowledge of the osseous pathologies is essential in itself. Determination and validation of the impact on the range of motion and their clinical implication are equally important.

There are a number of limitations of this study. First, only osseous changes, with the exception of disc mineralisation, have been described, and we are aware that soft tissue lesions form a large part of the pathological conditions of the equine musculoskeletal system. Second, the horses from which the specimens originated could not be examined clinically. Clinical examinations could possibly have indicated normal or restricted ranges of motion or even pain and these findings could have been interesting and helpful in determining the clinical relevance of certain findings. Third, the description of IVD mineralisation required the introduction of a novel scoring system to grade changes in the amount of mineralisation. This scoring system is not validated, and further research is needed with respect to the extent and severity of mineralisation and the potential clinical manifestations and their relevance. However, the current study was designed as an inventory of pathological osseous changes of the lumbar vertebral column by the use of an advanced imaging technique in different breeds. For assessing clinical relevance, a different study is necessary.

5 | CONCLUSION

Osseous lumbar pathology is frequent in horses with distinct differences between equine breeds in both prevalence and severity. In general, Warmblood horses are most affected, considerably more than Konik horses and Shetland ponies. Certain pathologies, which are poorly imaged with radiography and ultrasonography, can be better visualised by CT, which may help interpretation. For some of the conditions the clinical relevance has still to be determined.

AUTHOR CONTRIBUTIONS

Tijn J. P. Spoormakers had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of data analysis and with, Stefanie Veraa, P. René van Weeren and Harold Brommer designed the study. Tijn J. P. Spoormakers acquired data. Tijn J. P. Spoormakers and Stefanie Veraa evaluated the CT images. E. A. M. Graat and Tijn J. P. Spoormakers performed statistical analysis. All authors drafted and critically revised the manuscript and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA INTEGRITY STATEMENT

This study surely uses new data but it was not created but examined in different specimen.

ETHICAL ANIMAL RESEARCH

Research ethics committee oversight not currently required by this journal: the study was performed on material collected during post-mortem examinations.

INFORMED CONSENT

Informed consent for inclusion of equine material was granted by the animals' owners.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/evj.14035.

DATA AVAILABILITY STATEMENT

The data that support findings of this study are available from the corresponding author upon reasonable request: Open sharing exemption granted by the editor due to lack of provision in the owner informed consent process.

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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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