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Original Research

Osseous Pathology of the Synovial Intervertebral Articulations in the Equine Thoracolumbar Spine

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ABSTRACT

The objectives were to investigate the location and severity of osseous lesions of the synovial intervertebral articulations (SIAs) in the equine spine from the cervicothoracic junction to the lumbosacral junction. It was hypothesized that lesion number and severity would increase with horse age and height and that severe lesions would be more prevalent caudal to T16. The vertebrae from C7 to S1 were removed from 56 horses by dissection, disarticulation, and boiling out. Each SIA was evaluated for the presence and severity of osseous lesions which were scored using two methods: numerical grading of lesion severity on a scale of 0–3 and using a visual analog scale (VAS). Descriptive statistics were calculated, and the VAS data were analyzed using a split-plot analysis of variance (ANOVA) to determine the effects of horse age, height, and vertebral level. Periarticular osseous lesions were observed at every intervertebral level from C7-T1 to L6-S1 with 91% of horses having at least one lesion of grade 2 or higher. Split-plot ANOVA indicated significant effects of age ($P = .014$), with older horses having more severe lesions, and vertebral level ($P < .0001$), with more severe lesions occurring in the cranial thoracic (C7-T1 to T2-T3) and caudal thoracic to lumbosacral (T15-T16 to L6-S1) regions. There was no effect of the horse's height on SIA osseous lesions. Regional differences in severity of osseous lesions of the SIA in the thoracolumbosacral spine are likely related to changes in shape and orientation of the articular surfaces which affect the forces and motion patterns during locomotion.

1. Introduction

The synovial intervertebral articulations (SIAs), located between the caudal and cranial articular processes of successive vertebrae, are the typical synovial joints; they have hyaline cartilage covering the subchondral bone of the articular processes, a synovial membrane, and a joint capsule. Similar to other synovial joints, they undergo degenerative changes [1,2] that are a potential source of performance-limiting back pain [3–7]. Clinical signs associated with SIA osteoarthritis include back pain, reduced range of spinal intersegmental motion, and decreased athletic ability [3,8]. This study addresses osseous pathologic changes of the SIA and the prevalence in different regions of the thoracolumbar spine in a diverse equine population and differs from previous studies by including all the intervertebral joints from the cervicothoracic junction to the lumbosacral junction. None of the previous studies has evaluated the cranial thoracic region, and some did not include the entire lumbar region.

Previous necropsy studies of the prevalence of osseous lesions in the equine SIA have focused on Thoroughbred

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racehorses [1,2] in which training and racing at high-speed imposes repetitive cyclical loading to end range of motion. The high forces associated with this type of loading have been suggested to predispose to a higher rate of occurrence of osseous lesions in the SIA of racehorses than in the general equine population [2]. As a result, osseous lesions of the SIA may be overrepresented in the current literature. There is relatively little information describing osseous SIA lesions in horses used in activities other than racing. Therefore, the aim of this study was to describe the distribution and severity of SIA osseous lesions in the equine thoracolumbar spine from the cervicothoracic joint to the lumbosacral joint and to evaluate the effects of the horse's age and height and the vertebral level. It was hypothesized that the number and severity of lesions would increase with age and height of the horse and that severe lesions would be more prevalent caudal to T16.

2. Materials and Methods

2.1. Subjects

Fifty-six thoracolumbar spines were dissected from horses that had been euthanized for reasons unrelated to back pain. The subjects were divided according to age (29 horses <15 years old; 27 horses ≥15 years old) and height at the withers (26 horses <150 cm; 30 horses ≥150 cm). Fifteen breeds were represented ranging in size from miniature horses to draft horses, including both racing and nonracing breeds.

Table 1
Mean and (SD) visual analog scores for osseous lesions of the synovial intervertebral articulations across four groups of horses: young (<15 years), old (≥15 years), short (<150 cm), and tall (≥150 cm).

Level	Age		Height	
	Young	Old	Short	Tall
C7-T1	8.11 (3.64)	10.86 (3.54)	9.28 (3.80)	9.57 (3.41)
T1-T2	6.7 (2.75)	8.40 (2.85)	7.68 (2.92)	7.38 (2.69)
T2-T3	5.18 (2.14)	7.20 (2.95)	6.07 (2.91)	6.22 (2.22)
T3-T4	4.16 (1.78)	6.09 (2.48)	5.15 (2.37)	5.04 (1.94)
T4-T5	3.93 (0.98)	5.23 (2.15)	4.45 (2.10)	4.64 (1.13)
T5-T6	4.29 (1.52)	5.36 (2.28)	4.67 (1.97)	4.93 (1.88)
T6-T7	4.47 (1.18)	5.42 (2.32)	5.04 (2.27)	4.83 (1.31)
T7-T8	4.65 (1.41)	5.19 (1.78)	4.84 (1.69)	4.97 (1.51)
T8-T9	4.99 (1.46)	5.12 (1.51)	5.25 (1.80)	4.88 (1.14)
T9-T10	5.03 (1.76)	5.19 (1.81)	5.14 (1.91)	5.08 (1.67)
T10-T11	4.65 (1.44)	5.59 (2.16)	5.25 (2.17)	4.98 (1.45)
T11-T12	5.26 (1.71)	5.61 (2.06)	5.18 (2.07)	5.64 (1.72)
T12-T13	5.56 (1.82)	6.89 (3.27)	5.96 (2.92)	6.42 (2.32)
T13-T14	5.57 (2.14)	7.31 (3.57)	6.00 (3.14)	6.76 (2.71)
T14-T15	6.27 (1.83)	7.76 (3.59)	6.57 (3.21)	7.36 (2.44)
T15-T16	7.10 (2.30)	8.96 (4.01)	7.28 (3.48)	8.62 (3.01)
T16-T17	8.10 (3.06)	9.96 (3.98)	8.59 (4.10)	9.35 (2.96)
T17-T18	8.65 (3.43)	10.92 (3.64)	8.90 (3.15)	10.47 (3.83)
T18-L1	9.03 (3.28)	11.85 (4.21)	8.77 (4.13)	11.79 (3.41)
L1-L2	8.57 (3.17)	11.36 (4.31)	8.45 (3.80)	11.19 (3.73)
L2-L3	9.14 (3.22)	11.19 (3.65)	8.93 (3.45)	11.16 (3.42)
L3-L4	8.56 (3.23)	10.69 (4.06)	9.05 (3.73)	10.05 (3.59)
L4-L5	9.00 (3.04)	8.75 (3.12)	8.44 (2.81)	9.26 (3.29)
L5-L6	8.54 (3.1)	7.69 (3.03)	7.85 (2.49)	8.61 (3.49)
L6-S1	7.94 (3.1)	9.68 (3.50)	8.69 (3.09)	8.85 (3.48)

Abbreviation: SD, standard deviation.

The vertebrae from C7 to the sacrum were obtained by gross dissection and removal of all soft tissues. The intervertebral joints were disarticulated, and the bones were boiled to remove any remaining soft tissue. After boiling, each vertebra was soaked in a solution of isopropyl alcohol (34.5%), hydrogen peroxide (1.7%), ammonium hydroxide (0.6%), and water (63.2%) for a minimum of 2 days and then air dried. The vertebrae were arranged in anatomic order, and the vertebral formula for each horse was recorded. When there were only five lumbar vertebrae, the joint between L5 and the sacrum was treated as the lumbosacral joint for statistical purposes.

Based on the methodology used in a previous study of SIA lesions [2], the SIA at each spinal level was evaluated for the presence of proliferative or lytic degenerative intra-articular and periarticular osseous lesions at each spinal level using two methods: grade assignment and a visual analog scale (VAS).

2.2. Grade Assignment

The entire intracapsular area of each SIA, which included both articular and periarticular surfaces of the caudal and cranial articular processes, was evaluated. Osseous lesions were graded on a numerical scale according to the following characteristics [9]: grade 0: smooth periosteum and uniform joint surfaces; grade 1: mild degenerative changes (<2 mm in length, involving <25% of the articular and periarticular surface); grade 2: moderate degenerative changes (2–4 mm in length, involving 25%–50% of the articular and periarticular surface); and grade 3: severe degenerative changes (>4 mm in length, involving >50% of the articular and periarticular surface) or active bone remodeling [9]. When an articular process had more than one lesion, the grade corresponded with that of the most severe lesion. At each intervertebral level, the caudal and cranial articular processes were graded separately and, if the grades differed, the higher grade was assigned to the entire complex. The left and right SIA were graded separately.

2.3. Visual Analog Scale

The osseous lesions at each SIA were also graded using a VAS to obtain continuous numerical data. The two evaluations were performed at least a month apart by the same evaluator, who was blinded to the previously assigned numerical grade. For each joint complex, a mark was made along a 20-cm line with the left edge representing no osseous pathology and the right being extremely severe osseous pathology. Distances of these marks from the left edge of the line were subsequently measured and recorded in centimeters. Visual analog scale scores were assigned separately to the left and right SIA.

2.4. Statistical Analysis

All analyses were performed using SAS PROC MIXED (SAS version 3.8, Cary, NC). The grades assigned to each SIA were summarized using descriptive statistics and associations between the prevalence and severity of lesions at different vertebral levels were examined. Since histograms and probability plots for the errors of the VAS data were normal (Gaussian distribution and positive linear relationship, respectively), parametric statistics were used for further analysis of these data. A split-plot analysis of variance with two grouping factors (age and height) and one repeat factor (vertebral level) was used. Age, height, side (left and right), and vertebral level were fixed factors, and horse was a random factor, nested within age $\times$ height. The variance–covariance matrix was modeled by compound symmetry, autoregressive, and unstructured models. The unstructured model had the best fit according to Akaike's information criteria and was used in the evaluation. Linear regression was used to seek an association between the grades assigned and VAS scores.

3. Results

The most common vertebral formula in the horse is C7, T18, L6, S5, and Ca ~ 20. Variations from this vertebral formula in the thoracolumbar region were found in 14 (25%) of horses in this study; 7 horses (12%) had only 17 thoracic vertebrae, 1 horse (2%) had 19 thoracic vertebrae, 3 horses (5%) had 5 lumbar vertebrae, and 5 horses (9%) had a transitional vertebra which involved sacralization of L6 (3 horses) or the presence of ribs attached to L1 (2 horses).

An association between grade assignments and the VAS was established through linear regression. The correlation coefficient was 0.88, which was indicative of a strong positive association. The effect of side (left and right) was determined not to be significant in the analysis of variance and was removed from the model.

3.1. Grade Assignment

Fig. 1 shows examples of osseous lesions of grades 0, 1, 2, and 3. Across the entire group of horses, every spinal level showed osseous lesions in one or more horses. Within individual animals, every horse had at least one mild lesion of grade 1 or higher. Lesions of moderate severity $\geq$ grade 2 were present in 91% of horses (83% of young horses, 100% of old horses). At least one severe grade 3 lesion was found in 48% of horses (34% of young horses, 78% of old horses). There was a higher prevalence of lesions at the joints from C7-T1 to T2-T3 and from T15-T16 to L6-S1, with fewer lesions being present in the mid thoracic region at the joints from T3-T4 to T14-T15 (Fig. 2).

3.2. Visual Analog Scale

Vertebral level had the largest effect on the SIA osseous lesions, regardless of age or height of the horse (Table 1, Fig. 3) ($P < .0001$), with more severe lesions being present from C7-T1 to T2-T3 and from T15-T16 to L6-S1. Across all horses and levels, age had a significant effect on severity of SIA osseous lesions ($P = .014$) with older horses having more severe lesions. The horse's height did not affect severity of SIA osseous lesions ($P = .372$). There were interactions between age and level ($P < .0001$) and height and level ($P = .0003$). Lesion severity across spinal levels followed the same pattern within the different height and age groups (Fig. 4).

4. Discussion

The findings reported here differ from previous studies by evaluating SIA lesions along the entire length of the thoracolumbar spine, particularly by evaluating the SIA at the cervicothoracic and first two interthoracic levels which are sites of severe osseous lesions. The experimental hypothesis that osseous lesions of the SIA would be more severe in the caudal thoracic and lumbosacral regions was supported, but the high prevalence and severity of lesions in the cranial thoracic region had not been predicted.

Variations from the typical equine vertebral formula in the thoracolumbar region are not uncommon [5,7,9,10]. In our study, 25% of horses showed an atypical formula with the most common aberration being one fewer (12%) or one extra (2%) thoracic vertebrae. Stetcher [11] concurred that the most common variation involved having 17 or 19 thoracic vertebrae. The other common variations in this study involved having only five lumbar vertebrae (5%) or a sacralized L6 (9%). In the survey performed by Stubbs et al [2], all 120 horses had 7 cervical and 18 thoracic vertebrae, but 8% had 5 lumbar vertebrae and 25% had a sacralized L6. However, that study also showed some breed differences; notably, all 27 Standardbreds had the typical vertebral formula. Another study [5] of 36 racing Thoroughbreds reported that 39% had an atypical number of vertebrae.

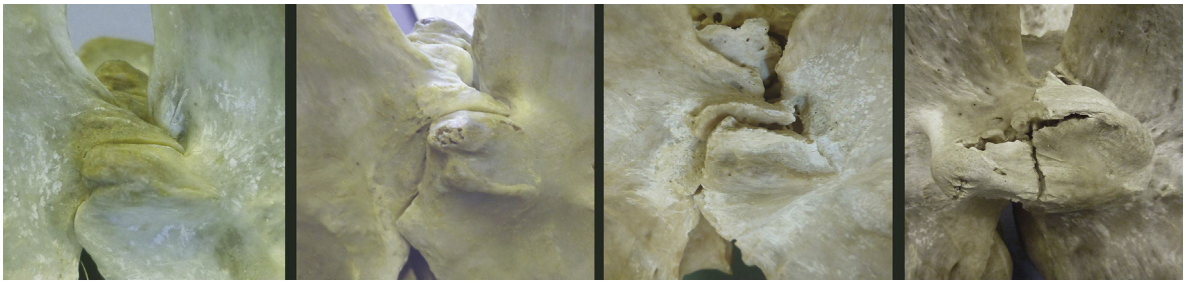

Fig. 1. Examples of periarticular osseous lesions of the synovial intervertebral articulations. Left to right: grade 0 lesion characterized by smooth periosteum and uniform joint surfaces; grade 1 lesion showing mild periarticular changes; grade 2 lesion with moderate periosteal proliferation; and grade 3 lesion demonstrating severe periosteal proliferation and active bone remodeling.

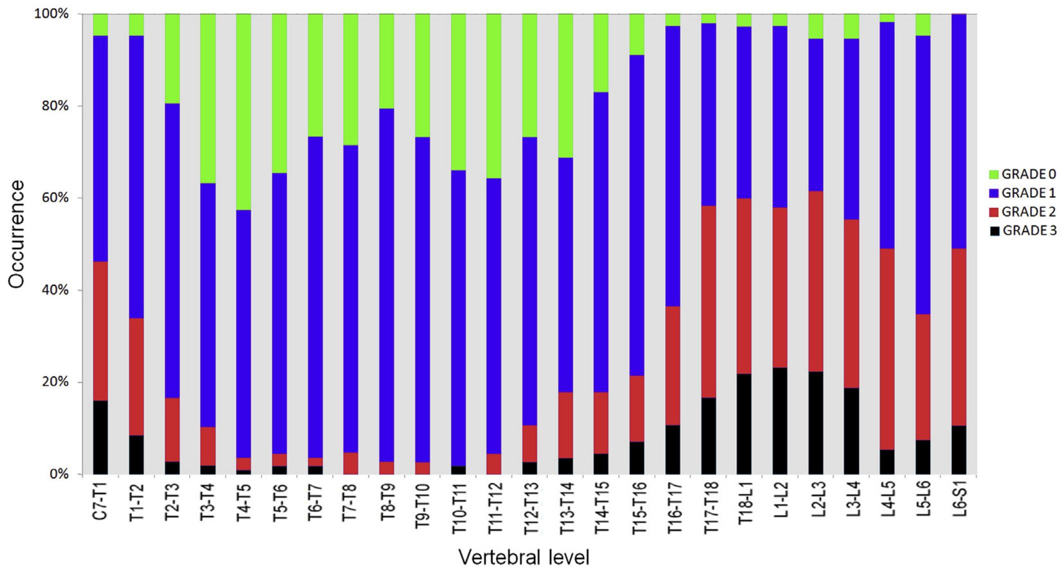

Fig. 2. Graph showing the percentage of horses (n = 56) with grade 0, 1, 2, and 3 osseous lesions of the synovial intervertebral articulations at each intervertebral level from the cervicothoracic junction to the lumbosacral junction across all horses.

The VAS is a measurement instrument that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured [12]. It is frequently applied to evaluate a patient's pain which ranges over a continuum from none to extreme pain [12].

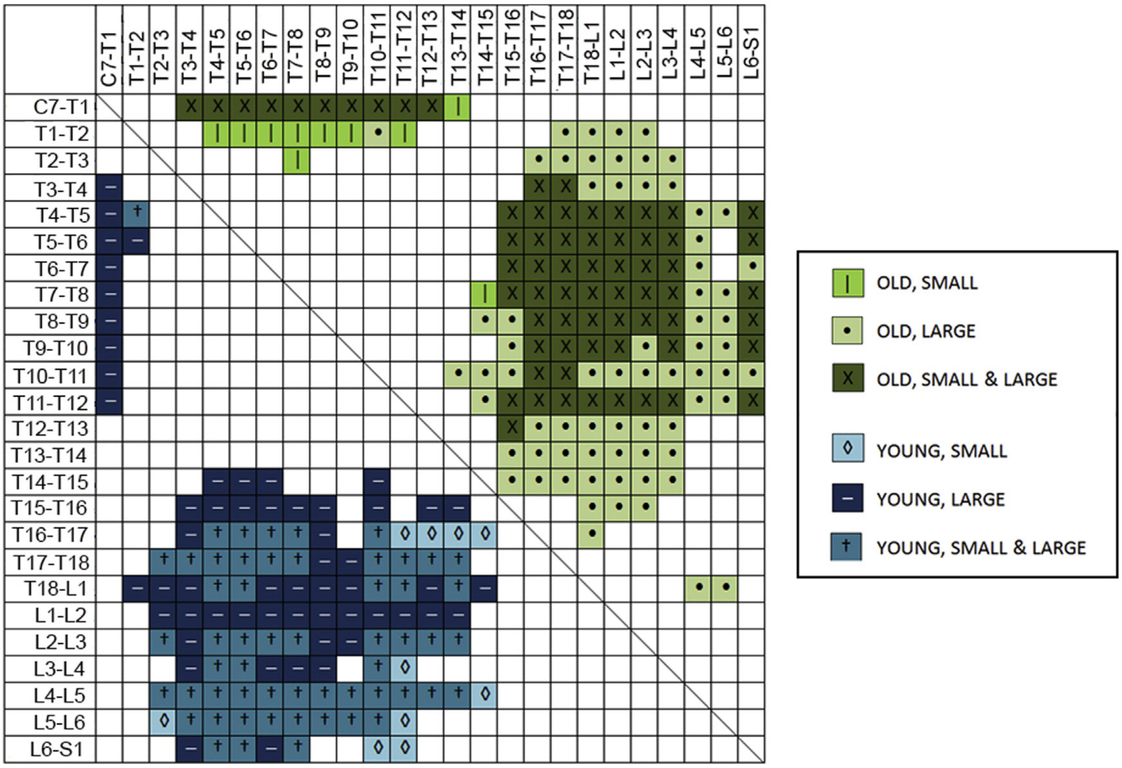

Fig. 3. Significant differences between vertebral levels in the severity of osseous lesions of the synovial intervertebral articulations due to age and height of the horse and interactions between the effects of age and height at the individual intervertebral levels from the cervicothoracic junction to the lumbosacral junction. The lower left half of the graph represents young horses (<15 years), and the upper right half of the graph represents old horses (≥15 years). Shaded boxes indicate significant differences between the intervertebral levels which are indicated on the x and y axes. Differences are coded by color and symbol.

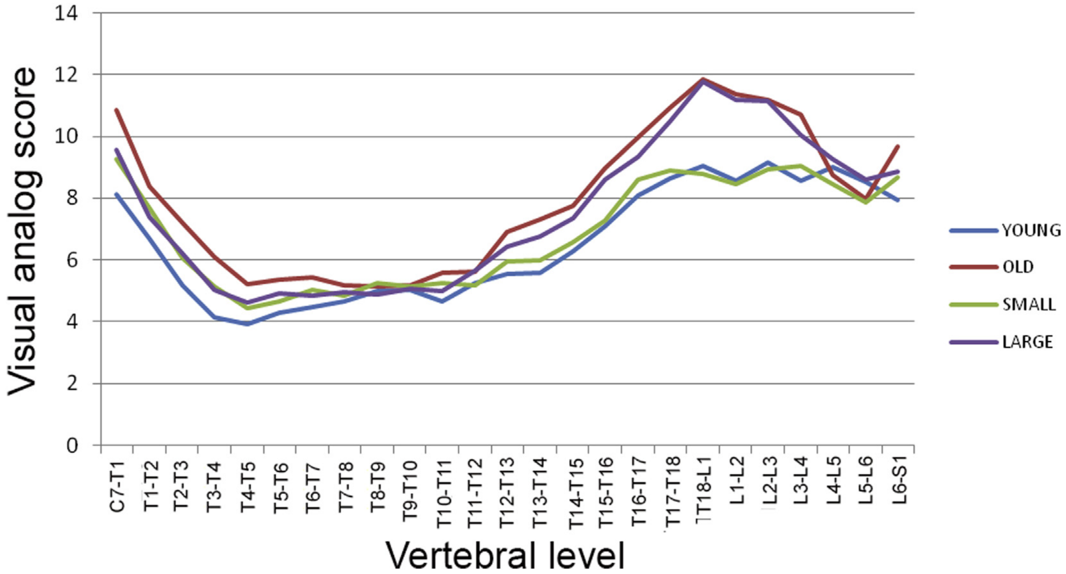

Fig. 4. Mean visual analog score for osseous lesions of the synovial intervertebral articulations from the cervicothoracic junction to the lumbosacral junction in horses according to age (young: 29 horses <15 years old; old: 27 horses ≥15 years old) and size (small: 26 horses <150 cm; large: 30 horses ≥150 cm).

In this study, a VAS was applied to quantify visual pathologic lesions of the SIA as a continuous rather than a categorical (ordinal) measurement. The linear relationship between the categorical grading scores and the continuous VAS scores ($r = 0.88$) suggests that either grading system can be used to evaluate osseous lesions of the equine SIA. Both scales are qualitative and subjective, but an advantage to using the VAS is that a larger number of pathologic changes can be assessed and factored into the final score. Furthermore, the continuous nature of the VAS is perhaps better suited to the spectrum of the pathologic findings than a categorical grading system that implies discrete jumps in severity between each grade.

In a 1980 survey of 443 horses presenting with a history of a thoracolumbar complaint [13], vertebral lesions were diagnosed in 202 horses (38.6%), but there was no mention of SIA lesions. This likely reflects the diagnostic capabilities at that time; specifically, high output x-ray generators were not available. Even with the benefit of powerful imaging techniques, clinical diagnosis of SIA lesions is not as sensitive as post mortem evaluation of subtle bony lesions. Lesions of the SIA have been detected at many vertebral levels in both clinical [6,14] and necropsy [1,2,15] studies. We found SIA osseous lesions at all intervertebral levels from the cervicothoracic junction to the lumbosacral junction, but with regional differences in severity. There were 29 grade 3 lesions at three intervertebral levels in the cranial thoracic spine (C7-T1 to T2-T3), 157 grade 3 lesions across 10 intervertebral levels in the caudal thoracic and lumbosacral spine (T15-T16 to L6-S1), but only 21 grade 3 lesions at the other 12 intervertebral levels (T3-T4 to T14-T15). The greater severity of SIA osseous lesions in the caudal thoracic and lumbar regions concurs with other studies [3,4,9], though this is believed to be the first report describing the presence of severe lesions in the cervicothoracic and cranial thoracic SIAs.

The regional variations in severity of SIA osseous lesions may relate to anatomic differences in the orientation of the articular surfaces. In people, lumbar facet joints that have a more sagittal orientation show more degenerative changes [16]. Townsend and Leach [17] divided the equine thoracolumbar intervertebral joints into four regions based on SIA orientation and morphology: T1-T2, T2-T16, T16-L6, and L6-S1. The size, shape, and orientation of the articular surfaces affect SIA mobility and may have the effect of stabilizing the spine by imposing limitations on the direction or amount of movement [18,19]. Movement restrictions imposed by the SIA may contribute to the fact that the horse's back has considerably greater mechanical stiffness in lateral bending than in dorsoventral flexion–extension [20]. At T1-T2, the large, radially oriented facets allow considerable flexion–extension but caudal to this level the tangentially oriented facets allow more bending and axial rotation. Changes in the shape and orientation of the facets at the cervicothoracic junction are likely to contribute to the severity of SIA lesions in this region.

From T2 to T16, the cranial facets are small and flat with a tangential orientation that allows more lateral bending and axial rotation. These movements are greatest around T12 [17]. In the vertebrae caudal to T16, the articular surfaces become radially oriented with interlocking facets that preclude lateral bending and axial rotation [17]. T16 has tangential cranial facets and radial caudal facets; it is called the diaphragmatic vertebra indicating that it is a transitional vertebra between the more cranial vertebrae with a thoracic type of SIA and the more caudal vertebrae with a lumbar type of SIA [19]. The change in articular morphology at T16 corresponds with the level at which SIA lesions become significantly more severe. It appears that morphology of the articular facets and their effect on SIA motion may be important in relation to the development of arthritic changes.

Dorsoventral flexion and extension in the lumbar region contribute to stride length especially in the asymmetrical gaits [21]. Repeated loading by propulsive forces generated from the hind limbs during locomotion may play a role in the increased pathology observed from T15-T16 to L6-S1. The caudal cervical spine and the cervicothoracic junction are highly mobile both in flexion–extension [22] and lateral bending [23]. At T1-T2, considerable flexion–extension is possible, but there is little lateral bending or axial rotation [24]. Caudal to T2, stability for attachment of the thoracic synsarcosis is provided by strong soft tissues, many of which exert considerable leverage through their attachments to the long dorsal spinous processes of the withers. Contributing to the severity of lesions in the cranial thoracic region is the fact that the first two thoracic spines are short and do not have strong ligamentous attachments [19], and the intervertebral discs between T1-T2 and T2-T3 are thicker than those of the other thoracic intervertebral joints. These factors may contribute to a lack of joint stability that increases the susceptibility to SIA lesions.

The ground reaction forces generated by the limbs apply rotational and torsional forces to the vertebrae, and if there is dynamic joint instability (micromotion) during loading, it predisposes to the development of arthritic changes. The activity of the deep spinal stabilizing musculature, primarily m. multifidi in the thoracolumbar region, is important for preventing micromotion of the SIA during loading. Defective neuromotor control of these muscles has been associated with the presence of back pain in people [25], and the muscles are likely to remain dysfunctional even after the back pain resolves [26]. In horses, a relationship between back pain and dysfunction of the deep spinal stabilizer muscles has not been definitively proven. However, severe osseous spinal pathology has been associated with ipsilateral atrophy of m. multifidi at the same spinal level [2], and regular performance of rehabilitative exercises has been shown to induce hypertrophy of these muscles in riding school horses [27], racehorses [28], and therapy horses [29].

The prevalence and severity of SIA osseous lesions increased with the horse's age, which supports the experimental hypothesis. Girondroux et al [4] did not find a difference in age between horses with SIA arthritis and their general clinic population. However, it is difficult to make comparisons because the horses in that study were relatively young with mean age <9 years, whereas in the present study, the older horses were all considerably older with a minimum age of 15 years. In people, the prevalence of osteoarthritic facet joints increases with age. Before 45 years of age, only minor cartilaginous changes occur, but after that age advanced cartilage changes, subchondral sclerosis, and osteophytes become more common [16]. It is possible that arthritic lesions are more common in horses over a certain age. If osseous SIA lesions are, indeed, more common in older horses, it suggests a degenerative etiology as a consequence of repeated stresses imposed over several years [7].

The horse's height is closely correlated with body weight [30] and was used in this study as a proxy for horse size. The findings did not support our hypothesis that taller horses would have a higher prevalence and severity of SIA osseous lesions which might be expected as a consequence of experiencing larger forces due to a greater body mass.

The presence of osseous spinal pathologies is not necessarily associated with back pain. However, it has been suggested that SIA lesions are more consistently associated with back pain than impinging spinous processes [3]. The articular surfaces of the SIA and the joint capsules are richly innervated. In the lumbar region, the articular facets at each spinal level are innervated by the medial branch of the dorsal ramus exiting at the intervertebral foramen at the same level and also by a branch of the dorsal ramus cranial to it [31]. It seems likely that some of the more severe lesions reported here would have been painful, especially those with active bone pathology. In support of this, 12 horses with radiographic evidence of osteoarthritis of the SIA, but no other detectable osseous abnormalities, all showed improvement after periarticular injection of local anesthetic solution. This suggests that the SIA lesions were probably responsible for the clinical signs of pain and poor performance. In another study [14], nuclear scintigraphic images of the SIA from T13 to L1 showed increased radiopharmaceutical uptake in 25.8% of 31 clinically normal horses and in 61.5% of 65 horses with clinical evidence of thoracolumbar pain and SIA osteoarthritis. Thus, horses with back pain are more likely to show increased radiopharmaceutical uptake in the SIA than clinically normal horses. Severe osseous lesions of the SIA may be associated with atrophy of m. multifidi at the same or adjacent spinal levels, though this has yet to be proven in horses. We hypothesize that if m. multifidi are indeed inactivated, then m. longissimus goes into spasm in an attempt to stiffen the intervertebral joints and compensate for the loss of function of m. multifidi. This is an inefficient strategy, however, since the long back muscles have a global effect on the thoracolumbar spine rather than acting in a localized region. Tension in m. longissimus may, in turn, be associated with the reduced spinal flexion–extension observed at or close to the thoracolumbar junction in horses with back pain [32].

In conclusion, dissection of 56 thoracolumbar spines from a diverse group of horses showed that osseous lesions are commonly present in the equine SIA with more severe lesions being found in the joints close to the cervicothoracic, thoracolumbar, and lumbosacral junctions. The novel finding that severe lesions were common at the cervicothoracic junction and in the cranial thoracic intervertebral joints poses a diagnostic and therapeutic challenge due to the relative inaccessibility of these vertebrae. The severity of SIA osseous lesions increased with age, suggesting a degenerative component, but not with size of the horses.

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