Pathological changes involving lumbar and sacral vertebrae and sacroiliac joints (SIJs) have been identified as causes of unilateral hind limb lameness, gait abnormalities, back stiffness, and lack of hind limb impulsion or engagement in horses and chronic poor performance in athletic horses.

The objective assessment of low back and pelvic pain, and a clear identification of the causes, is difficult in horses. Back problems are often unresolved because of a clinical inability to localize abnormalities and due to the limitations of local analgesic techniques and advanced diagnostic modalities.

Lumbosacroiliac abnormalities can be acquired through artropathy of the intertransverse joints (ITJs), articular process joints (APJs), and SIJs and through kissing lesions of the dorsal spinous processes (DSPs). Additionally, known anatomic variations have been described, including fusion of the lumbar transverse processes, fusion of the sacral DSPs, presence of lumbosacral transitional vertebrae, varying number of lumbar and sacral vertebrae, and divergence of the DSPs between the fifth (L5) and sixth lumbar vertebrae (L6). Knowledge of the types and incidence of anatomic variations and abnormal changes of the lumbosacral region can facilitate a better understanding of back pain etiopathogenesis in horses. Some anatomic variations can predispose dogs to vertebral instability, radiculopathy, and hip dysplasia, and radiculopathy at the spinal level has been suggested as a cause of dangerous behavior in horses.

OBJECTIVE
To provide a postmortem description of anatomic variations and changes of the lumbosacroiliac region in horses. The authors hypothesized that lesion severity would increase with age and body weight and correlate to anatomic variations.

SAMPLES
Lumbosacroiliac vertebral specimens from 38 horses (mean age, 16 years; range, 5 to 30 years) that died or were euthanized for reasons unrelated to the study between November 2019 and October 2021.

PROCEDURES
The lumbosacroiliac region of the vertebral column was removed from each cadaver. After dissection, disarticulation, and boiling, the anatomic specimens were examined for anatomic variations and osseous changes of the articular process joints (APJs), intertransverse joints (ITJs), and sacroiliac joints (SIJs). The lengths of L6-S1 intertransverse articular surfaces were measured and their ratios calculated. Descriptive statistics were obtained, and the χ² test was used to assess differences in anatomic variations and abnormal changes of the APJs, ITJs, and SIJs.

RESULTS
The most common anatomic variation was a sacrum-like shape of the transverse processes of L6 (29/38 [76%]) and converging orientation of dorsal spinous process of L6 (33/38 [87%]). The highest prevalence of bony changes was detected at L5-L6 (right, 34/38 [89%]; left, 33/38 [87%]) and L6-S1 APJs (right, 38/38 [100%]; left, 37/38 [97%]) and at SIJs (right, 32/38 [86%]; left, 31/38 [82%]). The shape of L6 transverse processes differed between breed (P = .01) and was associated with presence of L4-L5 ITJs (P < .01).

CLINICAL RELEVANCE
Age and sex were associated with changes of the sacral dorsal spinous processes, ITJs, and APJs. The clinical significance of these findings could not be confirmed based on the study limitations.
horses. Anatomic variations of the cervicothoracic junction can predispose horses to forelimb lameness and cervical pain. In addition, some anatomic variations of the lumbosacral segment may alter the normal biomechanics of the area, predisposing to an early development of abnormal changes or inability to work correctly, resulting in poor performance. While there are some necropsy studies of the thoracolumbar region of the vertebral column in horses, only a few have focused on the lumbosacrococcygeal region and are mostly based on Thoroughbred racehorse specimens.

The aim of the study reported here was to describe the incidence of anatomic variations and abnormal changes of the lumbosacrococcygeal region in a mixed population of horses (ie, variable breeds, ages, and size). The authors hypothesized that lesion severity would increase with age and body weight and correlate to anatomic variations.

Materials and Methods

Specimens and specimen preparation

All horses aged ≥ 4 years that had died or were submitted for euthanasia at the Veterinary Teaching Hospital of the University of Perugia, Italy, between November 2019 and October 2021, for reasons unrelated to this study, were included. After necropsy, the sacrum and a recorded number of lumbar vertebrae were removed intact from each cadaver. The ilial wings were isolated from the pelvis by means of cutting the ilial neck bilaterally with the use of a saw, close to the acetabulum. Once the soft tissues were removed by sharp dissection, the ilumbar vertebrae, sacrum, and SIJs were disarticulated and boiled in water for approximately 12 to 15 hours to remove any remaining soft tissue. They were then soaked and boiled in water (50%) and 20% hydrogen peroxide (50%) to whiten them for approximately 10 to 15 minutes and air-dried before being evaluated.

Categorization of anatomic variations

The bones were arranged in anatomic order, and the sacral vertebral formula was recorded for each specimen. The specimens were examined for the presence of anatomic variations and pathological changes of the lumbosacrococcygeal region as follows.

The transverse processes of L6 were categorized as lumbar-like or sacrum-like depending on their relative shape; they were considered lumbar-like if their shape was similar to the lumbar transverse processes and sacrum-like if their appearance was similar to the sacral wings (Figure 1).

The DSPs of L6 were categorized as converging or diverging on the basis of the orientation of the vertical axis of the relative DSP. A DSP was considered converging when it showed the same orientation as the DSP of the preceding lumbar vertebrae and considered diverging when it showed the opposite orientation (Figure 1). The DSP of the lumbar vertebrae were evaluated for the presence of fusion (Figure 2).

The presence of the ITJs between the transverse processes of the lumbar vertebrae and their location was recorded. When the ITJ was identified, the composite orientation (Figure 1).

Figure 1—Representative dorsal (A and B; cranial is toward the top) and lateral (C through E; cranial is toward the left) images of L5 and L6 vertebrae harvested from cadavers of 38 client-owned horses that died or were euthanized for reasons unrelated to the study between November 2019 and October 2021 and evaluated for anatomic variations and bony changes of the lumbosacrococcygeal region. The L6 transverse process shows a lumbar-like shape (A) and sacral-like shape (B), with difference in length and appearance of the respective transverse processes. The dorsal spinous processes (DSPs) of L6 vertebrae show either a converging orientation toward the DSP of L5 (C), perpendicular to the orientation of that of the vertebral column (D), or diverging orientation away from the DSP of L5 (E), yielding different sizes of the interspinous space between L5 and L6 DSPs.

Figure 2—Representative lateral images of L5 and L6 vertebrae (A and B; cranial is toward the left) and sacrum (C through F; cranial is toward the left) harvested from cadavers as described in Figure 1. The interspinous space of L5–L6 is occluded ventrally by new bone formation (white arrow), the DSP of L6 is perpendicular to the orientation of that of the vertebral column, and there is contact at the dorsal aspect of the DSP between L4 and L5 (A); the left L4–L5 and L5–L6 APJs imaged show severe bony changes and ankyloses, respectively (A). More severe occlusion by new bone formation (asterisk) is shown as well as contact between the dorsal aspects of the DSP of L5 and L6 and ankyloses of the left L5–L6 APJ (B). The DSP of the sacral vertebra imaged shows occlusion by new bone formation of the ventral and the middle parts of S3 and S4 (C); the entire S1 and S2, almost the entire S2 and S3, and the ventral aspects of S3 and S4 (D); and almost the entire S2 and S3 and the ventral aspects of S3 and S4 (E); or decreasing amount of new bone formation occluding the sacral interspinous spaces moving from S1 to S3 (F).
Figure 3—Representative dorsal images of the L5-L6 ITJs (A and B) and dorsal (C) and ventral (D) images of the L6-S1 ITJs (cranial is to the top of the images) harvested from cadavers as described in Figure 1. The left L5-L6 ITJs are ankylosed (A and B), and there is periarticular bone proliferation (white arrow) at the level of L5 (A) and osteophytes (black arrow) at L4-L5 ITJ (B). Incomplete lumbosacral transitional vertebra (incomplete L6 sacralization on the left side) shows the fusion of the left L6-S1 ITJ, severe periarticular bone proliferation of the left L5-L6 ITJs (white arrow), and osteophytes on the ventral aspect of the L6 vertebral head (C). The right L6-S1 intervertebral foramen (black arrow) is enlarged (D).

The sacrum was evaluated for the presence of fused DSPs (Figure 2), number of sacral vertebrae, and the presence of articular processes between the first (S1) and the second (S2) sacral vertebrae. The presence of ≥1 nutrient foramina involving the ventral aspect of the last sacral vertebra or first caudal vertebra was recorded (Supplementary Figure S1).

The L6-S1 intertransverse foramina were classified as open or closed/semiclosed on the basis of the presence and amount of bone encircling the incisura alae sacralis (Figure 4). The sacrum was also evaluated for the presence of left and right accessory dorsal foramina between S1 and S2 and possible fusion between them; the presence of a dichotomous S1-S2 dorsal foramen was recorded.

Fusion of the sacrum with the first coccygeal vertebra was classified as a sacrocaudal transitional vertebra, as previously described (Supplementary Figure S1). The lumbosacral transitional vertebra was defined as sacralization of L6 characterized by the fusion of 1 (incomplete sacralization; Figure 3) or both (complete sacralization) transverse process(es) of L6 and the sacral wing(s), simulating normal ankylosis between the sacral vertebral. The length of the ITJ sacral articular surfaces and that of the sacral wings along the long axis were also measured and their ratio calculated.

Categorization of abnormal changes

The presence and severity of abnormal changes were evaluated at the articular joint margins as evidence of new bone proliferation (ie, osteophytes, enthesiophytes, or both). The presence of bony changes at the level of the ITJs between the fourth (L4) and fifth (L5) lumbar vertebrae and between L5-L6 ITJs was recorded. The lumbosacral ITJs were evaluated for proliferative periarticular osseous lesions.

The presence of unilateral or bilateral bony changes and symmetry of the lesions involving the L4-L5, L5-L6, and L6-S1 APJs and the SIJs was recorded.

The severity of osseous changes as new bone proliferation and change in the size of the APJs, ITJs, and SIJs (Figure 5) was scored using the following grading system adopted by Haussler et al to establish the severity of abnormal bony changes of the joint surface: grade 0 = mild, osseous changes affecting < 25% of the articular or periarticular surfaces; grade 1 = moderate, osseous changes affecting 25% to 50% of the articular or periarticular surfaces; grade 2 = severe, osseous changes affecting > 50% of the articular or periarticular surfaces; and grade 3 = ankylosis, osseous proliferation with partial or complete bridging of the articular processes. Furthermore, the SIJs were evaluated for the presence and localization of periarticular proliferation and for the shape of the iliac joint margins classified as either lipping, flattening, or modeling using a modified classification previously described (Supplementary Figure S2).
Figure 5—Representative ventral images of left L5-L6 ITJs (A through D; cranial is to the top of the images), lateral images of left L5-L6 APJs (E through H; cranial is to the left of the images), and dorsomedial images of ileal articular surfaces (I through K; dorsal is to the left of the images) harvested from cadavers of horses as described in Figure 1. The right L5-L6 ITJs imaged show mild (black arrow; A), moderate (B), and severe (C) bone proliferation with osteophytes and absence of the joint space (D). The ventrolateral aspect of the L5 vertebral head (white arrow) shows mild new bone formation (B and D); severe bone proliferation (arrowhead) is visible on the ventral aspect of the intertransverse articular surface of L6 (D). The left L5-L6 APJs show mild (black arrow; E), moderate (circle; F), and severe (G) bone proliferation on the dorsal and cranial aspects of the L6 articular process. There is also complete obliteration of the L5-L6 APJ joint space (ankylosis) and fusion of the dorsal spinous processes (H). The auricular surface (AS) of the ileum, close to the ileal neck (IN), shows mild (I), moderate (J), and severe (K) periarticular bone proliferations (black arrows) along its ventral aspect.

Statistical analysis

Data were analyzed using commercially available statistical software (JASP version 0.16.1; The JASP Team). For the statistical analysis, males and geldings were pooled together; categorical data included sex (male vs female) and breed (warm-blood, Thoroughbred, Standardbred, Arab, Anglo-Arabian, and other breeds). A descriptive statistic was applied to the specimen data and the anatomic variations and abnormal changes were identified. Continuous data (age and body weight) were tested for normality using the Shapiro-Wilk test and homoscedasticity using the Levene test, and statistical tests were then applied as appropriate.

A Student t test or Mann-Whitney U test were used, as appropriate, to test for differences between anatomic variations of the shape of L6 (lumbar-like vs sacrum-like); fusion of the DSPs of the lumbar vertebra (no vs yes) and sacral vertebra (no vs yes); sacrocaudal transitional vertebra (no vs yes); presence of nutrient foramina on the ventral aspect of the sacrum (no vs yes) and localization (S5 vs others); APJs between S1-S2 (no vs yes); fusion of the ITJs (no vs yes); presence of bony changes at L4-L5, L5-L6, and L6-S1 ITJs and APJs (no vs yes); presence of bony changes at the SIJs (no vs yes); and age and body weight.

Analysis of variance or the Kruskal-Wallis test were used, as appropriate, to test for differences in the shape of the L6-S1 intertransverse foramen (open, closed, or semiclosed), and in the grade of bone changes at L4-L5, L5-L6, and L6-S1 ITJs and APJs and in the SIJs with age and body weight. Post hoc analysis was performed using the Tukey or Dunn test, as appropriate.

χ² or Fisher exact tests were used, as appropriate, for examining differences in the anatomic variations and the presence of abnormal changes at the ITJs, SIJs, and APJs previously reported for sex and breed; a residual analysis was performed to identify the source of any difference. χ² tests and calculation of Φ or Cramer V coefficients were used to determine associations between different anatomic variations and between anatomic variations and abnormal changes.

The lengths of the sacral articular surfaces and the sacral wings and their ratios were tested for differences in sex, breed, and L6 shape using the Student t test or Mann-Whitney U test and analysis of variance or Kruskal-Wallis, as appropriate; post hoc analysis was performed using the Tukey or Dunn test. Pearson correlation coefficient was calculated to examine the correlation between the sacral articular surface and sacral wing lengths, and their ratios, and horse age and body weight. Statistical significance was set at P < .05.

Results

Specimens

In total, 38 specimens were included in this study, similar to previous anatomic studies in this field. The breeds consisted of warmblood (n = 13), Thoroughbred (4), Anglo-Arabian (4), Arab (3), Standardbred (3), and others (11). There were 25 females and 13 males, ranging in age between 5 and 30 years (mean, 16 years; SD, 6.5 years) and weighing between 284 and 620 kg (mean, 489 kg; SD, 65 kg). A variable number of lumbar vertebrae from each specimen were available for evaluation: the last 2 lumbar vertebrae (L5-L6) in 11 specimens, 3 lumbar vertebrae (L4-L6) in 17 specimens, 4 lumbar vertebrae (L3-L6) in 7 specimens, 5 lumbar vertebrae (L2-L6) in 2 specimens, and 6 lumbar vertebrae (L1-L6) in 1 specimen (mean, 3; SD, 1).

Anatomic variations

In the majority of the specimens, L6 had a sacrum-like shaped transverse process (n = 29; 76%), a converging orientation of L6 DSP (33; 87%), S1-S2 APJs (25; 66%), and ventral nutrient foramen/
Table 1—Number and percentages of 38 specimens of lumbosacroiliac vertebral regions harvested from cadavers of 38 client-owned horses that had died or were euthanized for reasons unrelated to the study between November 2019 and October 2021, with key anatomic variations.

<table>
<thead>
<tr>
<th>Anatomic variation</th>
<th>Classification</th>
<th>No. (%) of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse processes of L6</td>
<td>Shape</td>
<td>29 (76)</td>
</tr>
<tr>
<td></td>
<td>Sacrum-like</td>
<td>9 (24)</td>
</tr>
<tr>
<td></td>
<td>Lumbar-like</td>
<td></td>
</tr>
<tr>
<td>Dorsal spinous process of L6</td>
<td>Orientation</td>
<td>3 (8)</td>
</tr>
<tr>
<td></td>
<td>Diverging perpendicular to the orientation of the vertebral column</td>
<td>2 (5)</td>
</tr>
<tr>
<td></td>
<td>Diverging directed caudally</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Converging</td>
<td>33 (87)</td>
</tr>
<tr>
<td></td>
<td>Fusion</td>
<td>6 (16)</td>
</tr>
<tr>
<td></td>
<td>Ventrally L5-L6</td>
<td>3/6 (50)</td>
</tr>
<tr>
<td></td>
<td>Dorsally L4-L5</td>
<td>2/6 (33)</td>
</tr>
<tr>
<td></td>
<td>Ventrally L3-L4</td>
<td>1/6 (17)</td>
</tr>
<tr>
<td>L4-L5 intertransverse joint</td>
<td>Presence</td>
<td>17 (45)</td>
</tr>
<tr>
<td></td>
<td>Right side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>16 (42)</td>
</tr>
<tr>
<td></td>
<td>Fusion</td>
<td>2/17 (12)</td>
</tr>
<tr>
<td></td>
<td>Right side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>1/16 (6)</td>
</tr>
<tr>
<td>L5-L6 intertransverse joint</td>
<td>Presence</td>
<td>38 (100)</td>
</tr>
<tr>
<td></td>
<td>Right side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>38 (100)</td>
</tr>
<tr>
<td></td>
<td>Fusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Right side</td>
<td>9 (13)</td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>8 (11)</td>
</tr>
<tr>
<td>S1-S2 articular process joint</td>
<td>Presence</td>
<td>25 (66)</td>
</tr>
<tr>
<td></td>
<td>Bilaterally</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Ventral nutrient foramen/ina</td>
<td>Presence</td>
<td>32 (84)</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Last sacral vertebra</td>
<td>29 (91)</td>
</tr>
<tr>
<td></td>
<td>Last sacral vertebra and first coccygeal vertebra</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Accessory dorsal foramina S1-S2</td>
<td>Presence</td>
<td>23 (61)</td>
</tr>
<tr>
<td></td>
<td>Right side</td>
<td>21 (55)</td>
</tr>
<tr>
<td>Sacrocaudal transitional vertebra</td>
<td>Presence</td>
<td>13 (34)</td>
</tr>
</tbody>
</table>

There was an association between the presence of fusion of the lumbar DSPs and the fusion of L4-L5 ITJs (P = .02; φ = 0.79).

There was an association between the shape of L6 and the presence of the L4-L5 ITJs (P = .005; φ = 0.53) and the presence of an accessory dorsal foramen (P = .01; φ = .50).

In 6 (16%) specimens the total number of sacral vertebrae was 4, and in the other 32 (84%) cases 5 sacral vertebrae were found. The fusion site of the sacral DSPs was variable (Supplementary Table S1). There was a difference in age between specimens with and without fusion of the DSPs of the sacral vertebra (P = .007); specimens with fusion had a higher median age than those without.

The L6-S1 intertransverse foramen was open in 33 (87%) specimens on the left and 30 (79%) on the right, closed in 3 (8%) on the left and 6 (16%) on the right, and semiclosed in 2 (5%) bilaterally (Figure 4). Symmetry in the shape of the intertransverse foramen was observed in 35 (92%) horses. The presence of a dichotomous S1-S2 dorsal foramen was observed in only 2 specimens; 1 on the left side and 1 on the right. In 2 (5%) specimens, the accessory dorsal foramina were fused between them. There was an association between the shape of the L6-S1 intertransverse foramen and the presence of S1-S2 APJs (P = .03; φ = 0.45). An association between the presence of the sacrocaudal transitional vertebra and the position of the ventral nutrient foramen was found for the last sacral vertebra, first coccygeal vertebra, or both (P = .003; φ = 0.59).

An incomplete lumbosacral transitional vertebra (incomplete L6 sacralization) showing fusion of the left ITJ was encountered in only 1 specimen (Figure 3). For this reason, the measurement of the long axis of both sacral articular surfaces and sacral wings was possible in 37 specimens.

The mean length of the left L6-S1 intertransverse articular surface and sacral wing was 6.7 cm (median, 6.5 cm; range, 5 to 9 cm) and 10.2 cm (median, 10.5 cm; range, 7.7 to 12.4 cm), respectively. Otherwise, the mean length of the right L6-S1 intertransverse articular surface and sacral wing was 6.8 cm (median, 6.5 cm; range, 5.5 to 8.2 cm) and 10.2 cm (median, 10.5 cm; range, 8.4 to 12.5 cm), respectively. There was a difference in the left and right L6-S1 ITJ ratios between sexes (P < .001); the ratios were lower in females compared to males. The lengths of the L6-S1 intertransverse articular surface and sacral wings were significantly (P < .003 and P < .03, respectively) shorter in horses presenting a lumbar-like L6 shape compared to a sacral-like shape, as well as their ratios (P < .05). The lengths of the L6-S1 intertransverse articular surface and sacral wings were highly correlated (r = 0.6; P < .001); but they were not correlated with horse body weight or age.

Abnormal changes

The majority of the specimens showed bony changes of different severity at the level of the ITJs,
APJs, and SJJs; in the majority of specimens the changes were symmetric (Supplementary Table S2).

There were differences in the grade of bony changes at the level of L6-S1 ITJs (P < .008) (Supplementary Figure S3) and L6-S1 APJs (P < .04) with age; the severity of changes increased from mild to severe with increasing age.

There was a difference in the grade of bony changes at L5-L6 ITJs (P < .05) and L6-S1 APJs (P < .04) between sexes; males had a higher number of moderate changes and lower number of mild changes compared to females, only for L6-S1 APJs.

There was a lower number of specimens with bony changes at L4-L5 APJs (P < .03) when L6 had a lumbar-like shape.

Most of the periarticular bone proliferation of the SJJs was located at the dorsocaudal and ventrocaudal aspect of the sacrum and of the ilium (Supplementary Table S3). Left iliac joint margins were defined as modeling in 14 specimens (43%), lipping in 11 (36%), and flattening in 7 (21%). Right iliac joint margins were defined as lipping in 17 specimens (55%), modeling in 10 (33%), and flattening in 4 (12%). Symmetry of the shape of the iliac joint margins was observed in 25 specimens (76%).

Discussion

The results of this observational study revealed many anatomic variations and abnormal changes in the equine lumbosacroiliac region. They partially supported the initial hypotheses because there was only a correlation between the severity of bony changes and horse age; there was no correlation with body weight.

In agreement with previous studies,4,5,13,14 the majority of specimens had 5 sacral vertebrae (84%) and only 16% had 4 sacral vertebrae. The fusion of a variable number of sacral DSPs was recorded in 61% of specimens. According to Barone,6 sacral DSPs are usually fused at their base but are almost completely detached proximally. Because these previous findings were mostly reported in older horses and there was an association with age in the present study, it is supposed that the fusion of the sacral DSPs may be an acquired condition. However, this is probably of low clinical significance. In contrast, fusion of a variable number of lumbar DSPs was less common (16%), in accordance with a previous study.16 However, it is our opinion that this finding can partly be considered in regard to the kissing spine with more substantial clinical repercussions.

Converging DSPs with a wide L6-S1 interspinous space was the most commonly observed conformation (87% [33/38]), in agreement with previous studies.5,14 Some authors have speculated that the diverging DSP of L6 may induce abnormal stresses on the lumbosacral intervertebral joint related to the more acute angle between L6 and S1 DSPs and that this affects the mobility of the lumbosacral region, leading to altered function, performance, and pathology.4,17 The multifidus orientation relative to the angles of the lumbosacral DSPs may alter the function of the multifidus itself.4 In the present study, there were no correlations identified between this anatomic variation and the abnormal changes of the lumbosacroiliac region evaluated. However, the intervertebral joint (ie, the lumbosacral disk) was not evaluated by the current methods, and the possible implications of this anatomic variation on lumbosacral disk injuries requires further investigation.

The anatomic variations of L6-S1 intertransverse foramina, previously named incisura alae sacrales,18 were identified; they were symmetric in 92% of specimens. The borders of the incisura alae sacrales were previously evaluated for the presence of bony changes using a radiographic technique; most horses had a smooth caudal margin, while in a minority the nerve root foramen appeared opacified or with an irregular margin.18 It is supposed that bone formation on the borders of the incisura alae sacrales may not be an acquired condition because it was nearly always symmetric. The possibility of some L6 nerve root impingements in closed/semiclosed intertransverse foramina should be investigated, especially because there was no correlation with other abnormal changes or anatomic variations in this study.

In the current study, the presence of L4-L5 ITJs was detected in approximately half of the specimens and were symmetric in all except one, in agreement with the results of a recent study.19 Of note, there was an association between the presence of the L4-L5 ITJs and shape of L6. The incidence of L4-L5 ITJs was lower in specimens with a L6 lumbar-like shape compared to those with a L6 sacrum-like shape. In the authors’ opinion, the L6 sacrum-like shape could simulate the presence of the sacral ITJs on the lumbar tract, determining the presence of ITJs also on the more cranial part of the lumbar region, as previously suggested for dogs.20

The presence of L5-L6 ITJs was recorded in all specimens, in accordance with recent studies.14,18 In addition, fusion of L5-L6 ITJ (ie, anatomic variation) was observed in a small number of specimens, not always symmetrically, similar to a previous study of Thoroughbreds23; this variation has been reported at a higher prevalence in Shetland ponies and warmbloods.14 However, ITJs were only classified as normal or ankylosed, without distinguishing between fusion as an anatomic variation or an acquired ankylosis.14 According to Stecher,21 fusion of the lumbar ITJs without any visible periarticular signs of degenerative joint disease can occur before vertebral body physeal closure, considering fusion as a developmental variation instead of a pathological change related to sporting activity. Bony changes involving the ITJs were found in a high percentage of specimens, from 55% to 87%, depending on the ITJs evaluated; the symmetry was high at the level of L6-S1 and gradually decreased from L5-L6 to L4-L5, in partial agreement with a previous study2 in which the prevalence was high but gradually decreased moving cranially.

Age and sex influenced the grade of bony changes in some ITJs; older horses and males had a higher degree of bone lesions at L6-S1 ITJs. The length of the L6-S1 ITJs was similar to that reported
previously in warmblood horses of different ages (4 to 20 years) with a history of lameness or poor performance. In the present study, a difference in the L6-S1 ITJ left and right ratios was identified between sexes, but there were no differences according to age or body weight and the ratios were lower in females compared to males. The lower ratio in females could be explained by the fact that in some mammals such as horses there are clear sex differences in pelvis size and conformation due to different anatomic functions. Females have a relatively larger and rounder pelvic cavity caused by adaptation to obstetric demands. Furthermore, the lengths of L6-S1 intertransverse articular surface and sacral wings were shorter in specimens with a lumbar-like L6 shape compared to a sacral-like shape, as well as their ratios, and they were highly correlated. This is considered a morphological modification between adjacent vertebrae in the transitional area; however, shape- and sex-related differences can influence biomechanical stresses in this area.

Bony changes involving the APJs also had a relatively high prevalence ranging from 63% to 97% moving from L4-L5 to L6-S1, although the degree of symmetry concerning the L6-S1 APJ bony changes was lower compared to the more cranial lumbar APJs. A high prevalence of APJ lesions from T15-T16 to L6-S1 was detected in a previous postmortem study in which the prevalence and severity of the lesions increased with the age of the mixed population of horses. This is in accordance with the results of the present study in which the severity of changes from mild to severe was commensurate with horse age. Furthermore, males had a higher number of moderate changes and a lower number of mild changes in L6-S1 APJs compared to females, highlighting the impact of different sex-related L6-S1 on the biomechanical stresses in this area.

In the present study, incomplete or complete sacralization of the last lumbar vertebrae was rarely encountered, while its prevalence has been previously reported to range from 3% to 6%, 4,5,13,14,22 However, of note, L6 sacralization was diagnosed ultrasonographically at a higher prevalence in horses referred for lumbosacral region pain in a recent study. In a previous study, bilateral L5-L6 ITJ ankylosis was identified in 1 specimen with completed L6 sacralization; in the present study, the only specimen with incomplete left L6 sacralization presented severe L5-L6 ITJ arthropathy on the same side and mild L5-L6 ITJ arthropathy on the opposite side. The role of this anatomic variation in the occurrence of back pain requires further investigation.

Bony changes involving the SIJs were common bilaterally with a differing degree of severity. In the current study, the incidence of periarticular bone proliferation was much lower than that reported in a study by Haussler et al investigating only Thoroughbred specimens. Furthermore, bony changes were more commonly observed on the sacral articular surface or on both the sacral and iliac articular surfaces, contrary to previous studies, in which more degenerative changes were noted on the iliac surface rather than the sacral articular surface in horses with no history of back pain. This is probably related to the differences in the breed of the specimens and the discipline for which they were used, suggesting different biomechanical stresses according to the horses’ discipline. In the current study, bony changes of the SIJs were mostly mild and bilateral, while in the study by Haussler et al, moderate degenerative bony changes were more common in Thoroughbreds.

This study had some limitations. The high breed variability limited the possibility to identify breed differences; for this reason, a higher number of specimens would be necessary in future studies. In addition, the lumbar formula could not be recorded because the number of lumbar vertebrae from each specimen could not be standardized. Furthermore, in agreement with previous anatomic studies investigating the lumbosacral region, abnormalities of the soft tissues were not evaluated because of the methodology applied. Finally, the clinical significance of the anatomic findings was not determined due to lack of information on the history of the horses, such as the presence of lameness or back pain, because they were referred for reasons unrelated to this study.

In conclusion, this study presented an expanded and detailed overview of the anatomic variations and acquired bony changes of the lumbosacral region in horses. It reported some variations and abnormal changes that, to the best of the authors’ knowledge, have not been previously described, advancing understanding of the lumbosacral region. Data are scant regarding the correlation between anatomic variations in the vertebral column and changes in back mobility or predisposition to developing acquired back disorders. For this reason, there is the need for further anatomic, clinical, and biomechanical investigations of the lumbosacral region.

Acknowledgments
No third-party funding or support was received in connection with this study or the writing or publication of the manuscript. The authors declare that there were no conflicts of interest.

The authors thank Mariano Rosati and Fabrizio Tenerini for their technical assistance in the preparation of the anatomic specimens.

References

Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org