# Pathologic changes in the lumbosacral vertebrae and pelvis in Thoroughbred racehorses

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# Pathologic changes in the lumbosacral vertebrae and pelvis in Thoroughbred racehorses

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**Objective**—To describe the prevalence, characteristics, and severity of soft-tissue and osseous lesions in the caudal portion of the thoracic and lumbosacral vertebral column and pelvis in Thoroughbred racehorses.

**Animals**—36 Thoroughbred racehorses that died or were euthanatized at California racetracks between October 1993 and July 1994.

**Procedure**—Lumbosacral and pelvic specimens were collected and visually examined for soft-tissue and osseous lesions.

**Results**—Acute sacroiliac joint injury was observed in 2 specimens. Signs of chronic laxity or subluxation of the sacroiliac joint were not observed in any specimens. Impingement of the dorsal spinous processes and transverse processes was observed in 92 and 97% of specimens, respectively. Thoracolumbar articular processes had variable degrees of degenerative change in 97% of specimens. Degenerative changes were observed at lumbar intertransverse joints and sacroiliac articulations in all specimens. Some degenerative changes were widespread and severe.

**Conclusions**—Numerous degenerative changes affected vertebral processes, intervertebral articulations, and sacroiliac joints in these Thoroughbred racehorses.

**Clinical Relevance**—Various types of vertebral and pelvic lesions need to be considered during clinical evaluation of the back and pelvis in horses. Undiagnosed vertebral or pelvic lesions could be an important contributor to poor performance and lameness in athletic horses. (*Am J Vet Res* 1999;60:143–153).

Vertebral disorders and injuries of the sacroiliac joint have been identified as substantial causes of chronic poor performance in horses.[1-3] Soft-tissue injuries of the back and pelvis include subluxation of the sacroiliac joint,[4-6] injuries to muscles or ligaments,[1] and degeneration of intervertebral disks.[7,8] Osseous lesions known to develop in the axial skeleton include impingement of dorsal spinous processes,[1,7,9] degenerative joint disease,[3,10,11] ankylosis,[7,8,12] and vertebral fractures.[1,13] However, back problems are still frustrating clinically because of our inability to routinely localize the inciting abnormality or factor(s) contributing to soreness. This inability to accurately diagnose back pain and pelvic lameness in horses limits treatment effectiveness. Additionally, recommendations for management of affected horses are often directed at symptomatic relief and do not address the primary cause of back soreness or lameness.

Knowledge of pathologic changes in the vertebral column and pelvis and their prevalence is important to better understand the etiopathogenesis of vertebral column disorders and back pain in horses. Increased knowledge of vertebral column disorders inherent in athletic horses will enhance our ability to interpret results of advanced diagnostic techniques (eg, scintigraphy) and to offer specific diagnoses.[14] The high prevalence of back pain and lumbosacral vertebral lesions in performance horses[1,7,15] led us to evaluate vertebral and pelvic lesions in Thoroughbred racehorses. The purpose of the study reported here was to describe the prevalence and severity of soft-tissue injuries and osseous lesions of the caudal thoracic and lumbosacral vertebrae and pelvis in a sample of Thoroughbred racehorses.

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## Materials and Methods

**Specimens**—A sample of Thoroughbred racehorses that died at a California racetrack and that were necropsied through the Davis branch of the **California Veterinary Diagnostic Laboratory System (CVDLS)** for the California Horse Racing Board Postmortem Program were studied. Developmental variations in the lumbosacral vertebrae of these horses have been described.[16] Age, sex, and reason for euthanasia were recorded for each horse. Horses were examined at necropsy for gross evidence of acute or chronic injuries (eg, hemorrhage, tissue disruption, inflammation, fibrosis, luxation) in the caudal portion of the thoracic vertebral column, the lumbosacral vertebrae, and pelvis. Soft tissues were removed by manual dissection and chemical dissolution by immersion in 0.5% potassium hydroxide solution at 43 C for 4 to 7 days. Osseous specimens were examined for evidence of acute or chronic pathologic changes.

Modified vertebral reference systems,[16] which use caudad reference points whereby the vertebrae are numbered cranially with the segment number designated within parentheses (eg, L[1], L[2], L[3]), were used to describe the prevalence, characteristics, distribution, and severity of osseous lesions.

**Impingement of vertebral processes**—Impingement was defined as the abnormal physical apposition (ie, encroachment) of 2 vertebral processes. Vertebral process overlap was characterized by malaligned and overriding vertebral processes. Prevalence and location of impingement or overlap of dorsal spinous processes and lumbar transverse processes were recorded and graded according to the apparently progressive features of impingement, arthrosis, and ankylosis (**Appendix**).

**Degenerative joint disease**—Characteristics of degenerative joint disease included (in apparent order of increasing severity) lipping of the articular surface, cortical buttressing, indentation of the articular surface, osteophytes, periarticular and intra-articular erosions, and ankylosis. Prevalence and severity of degenerative changes of vertebral bodies and end plates, articular processes and facets of the caudal thoracic and lumbosacral vertebrae, lumbar intertransverse joints, lumbosacral joint, and sacral and ilial articular surfaces of the sacroiliac joint were recorded. Articular surfaces of the sacroiliac joint were also evaluated for altered morphologic features, articular crevices, and focal indentations.[11,17]

Lipping of the articular surface is peripheral expansion of articular cartilage and subchondral bone into a thin protruding lip at the articular margins.[18] Articular lipping is continuous with the contour of the articular surface and covered with normal-appearing articular cartilage. Cortical buttressing is generalized cortical expansion (ie, modeling) of periarticular bone and is often associated with an increased articular surface area. Indentation of the articular surface is an area of articular surface that is recessed, compared with the adjacent periarticular cortical surface. Osteophytes are irregularly shaped osseous proliferations within the joint margins (ie, intrasynovial) that do not expand the contour of the articular surface.[18-20] Periarticular erosions are superficial lytic or cystic lesions of intrasynovial, nonarticular bone. Intra-articular erosions are degenerative changes and irregular surfaces in articular cartilage. Ankylosis is fusion of 2 vertebral articular surfaces with osseous replacement and union of previously articulating structures.

Degenerative changes were considered mild if < 2 mm in height or depth and if < 25% of the articular surface or joint margin was affected; moderate if 2 to 4 mm in height or depth and if 25 to 50% of the articular surface or joint margin was affected; and severe if > 4 mm in height or depth and if > 50% of the articular surface or joint margin was affected.

**Enthesophytes**—The vertebral or pelvic location, height, and width of enthesophytes at joint capsules and ligamentous (periarticular) or musculotendinous (extra-articular) insertions were recorded.[18-20] These proliferative osseous changes were categorized as mild if < 0.5 $cm^3$ in volume, moderate if 0.5 to 1 $cm^3$, and severe if > 1 $cm^3$.

**Statistical analysis**—A two-tailed Fisher's exact test was used to evaluate the interrelation of categorical variables[a] in all 2 X 2 contingency tables, owing to expected values ≤ 5 within at least 1 cell. $\chi^2$ Analysis was used with all 2 X 3 and larger contingency tables. Contingency tables were also used to examine associations among pathologic variables and developmental variables[16,a] in the same specimens. The level for significance was set at $P < 0.05$.

## Results

**Sample population**—Intact lumbosacral and pelvic specimens were acquired from 36 Thoroughbred racehorses (12 females, 5 sexually intact males, and 19 geldings) that were 2 to 9 years old (mean ± SD, 4.5 ± 1.5 years). Injuries related to the musculoskeletal system were the reason for euthanasia in 29 (81%) horses and included spontaneous fractures or tendon or ligament injury in 21 (58%).[a] Spontaneous musculoskeletal injuries occurred in the left (36%) or right (25%) forelimb. Primary hind limb or vertebral injuries were not found in any specimen.

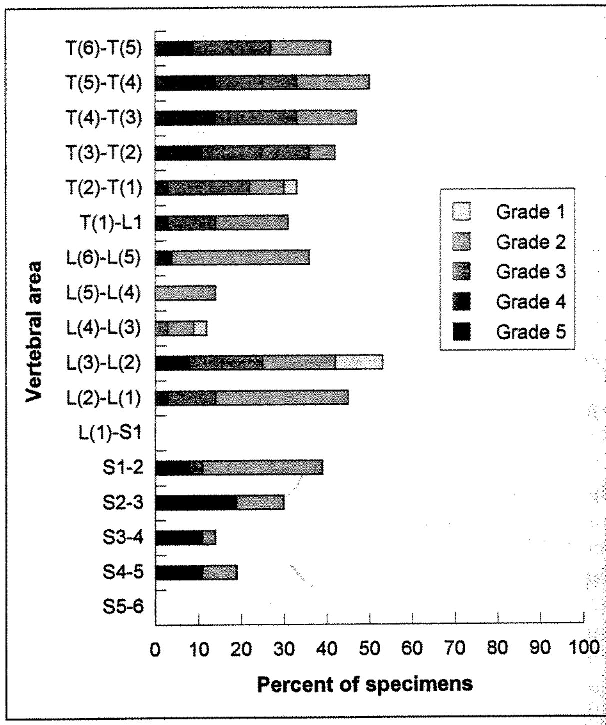


Figure 1—Distribution and severity by grade of impingement of the dorsal spinous process in the caudal portion of the thoracic vertebral column and lumbosacral vertebrae from 36 Thoroughbred racehorses. T(6) was available for evaluation in 22 horses. Six lumbar vertebrae were found in 25 horses, and 6 sacral vertebrae were found in 13 horses. *See* text for grading system used.

**Soft-tissue injuries**—Two horses had evidence of acute subluxation of the sacroiliac joint associated with disruption of the sacroiliac ligament and joint capsule. These horses included a 3-year-old that flipped over backwards and sustained a skull fracture and a 4-year-old that sustained an acute laceration of the flexor tendon of the left hind limb when clipped by another horse during a race. The 3-year-old had unilateral laxity and an acute avulsion fracture of the S1-S4 lateral sacral crest at the insertion site of the dorsal sacroiliac ligament and the 4-year-old had noticeable laxity of the sacroiliac joint bilaterally (left side more severe than right). In both horses, the ventral sacroiliac ligament was intact, whereas the dorsal sacroiliac ligament had substantial disruption near its attachment to the medial portion of the sacroiliac joint. Evidence of chronic subluxation of the sacroiliac joint (ie, joint laxity or fibrosis) was not observed in any specimen.

**Impingement of vertebral processes**—Impingement or overlap of the dorsal spinous processes in the thoracolumbar vertebrae was found in 92% of specimens and involved 36% (135/370) of spinous processes. Impingement was localized to the dorsal half or summit (apex) of the thoracolumbar and sacral dorsal spinous processes. The number of interspinous spaces affected were 1 (n = 8 specimens; 22%), 2 (3; 8%), 3 (7; 19%), 4 (1; 3%), 5 (4; 11%), 6 (2; 6%), 7 (2; 6%), 8 (4; 11%), or 9 (2; 6%). Mean number of impinged dorsal spinous

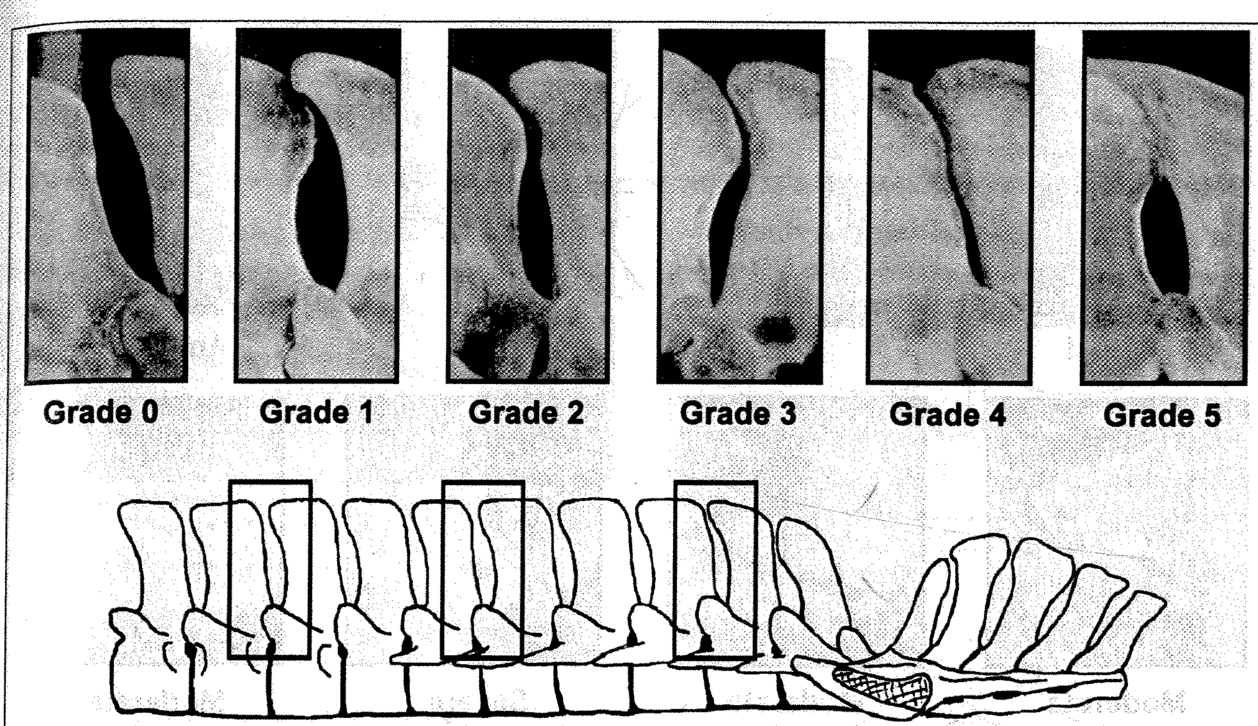


Figure 2—Photographs illustrating grades for impingement of dorsal spinous process in the caudal portion of the thoracic and lumbar vertebral column. Boxes on the drawing of the lateral view represent regions illustrated in photographs.

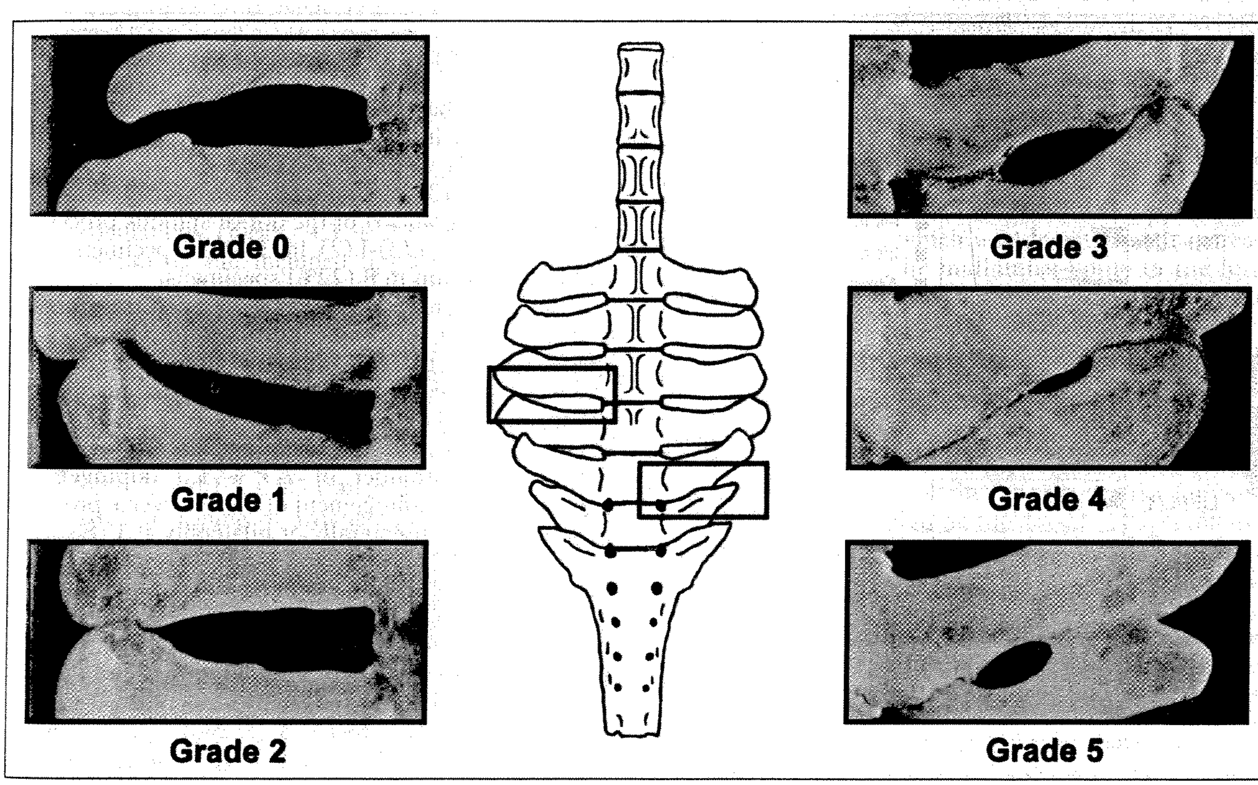


Figure 3—Photographs illustrating grades for impingement of transverse process in the lumbar portion of the vertebral column. Boxes on the drawing of the ventral view represent regions illustrated in photographs. Notice that photographs of grades 3 to 5 include inter-transverse joints medial to sites of impingement of the transverse process.

processes per 11 interspinous spaces evaluated per thoracolumbar specimen was 3.8 ± 2.8 (range, 0 to 9).

Impingement or ankylosis of the dorsal spinous processes of the sacral region was detected in 53% of specimens and affected 19% (36/193) of spinous processes. The number of interspinous spaces affected were 1 (n = 9 specimens; 25%), 2 (5; 14%), 3 (3; 8%), or 4 (2; 6%). Mean number of dorsal spinous process

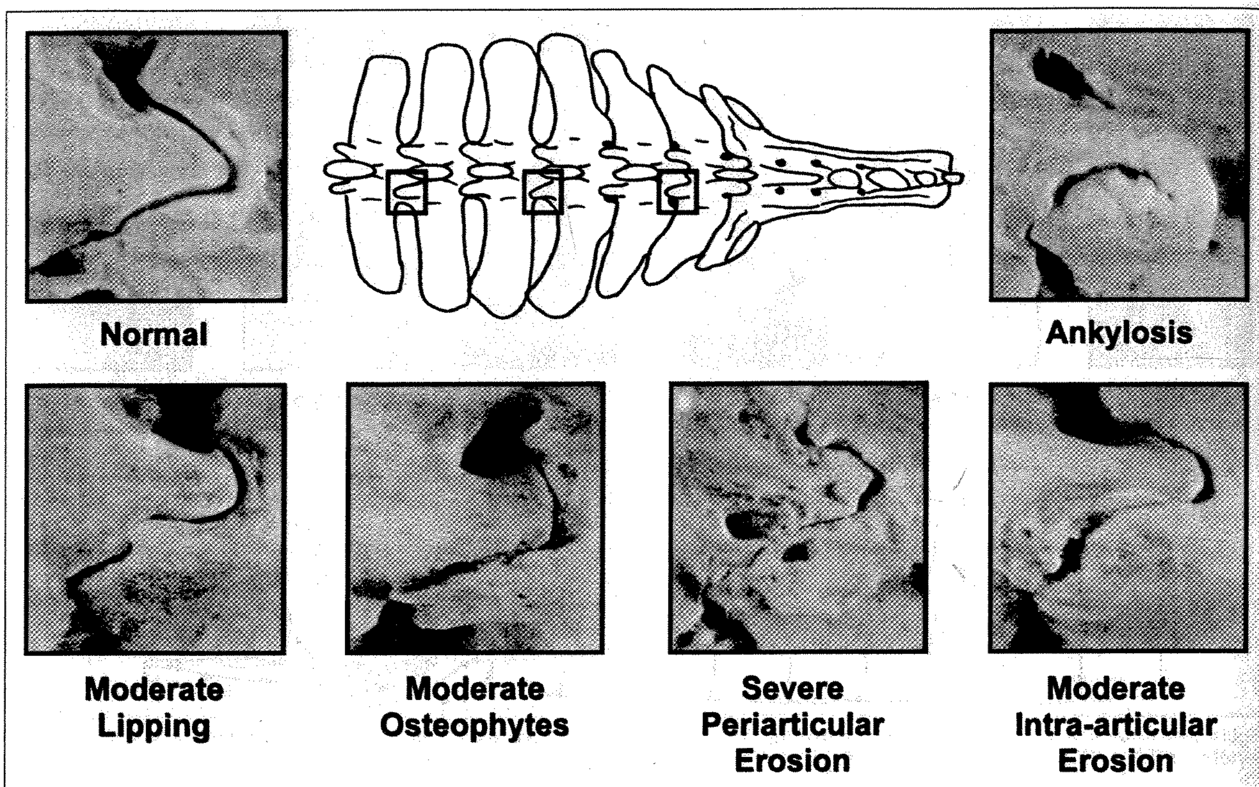


Figure 4—Photographs illustrating degenerative changes in the articular process in the caudal portion of the thoracic and lumbar vertebral column. Boxes on the drawing of the dorsal view represent regions illustrated in photographs.

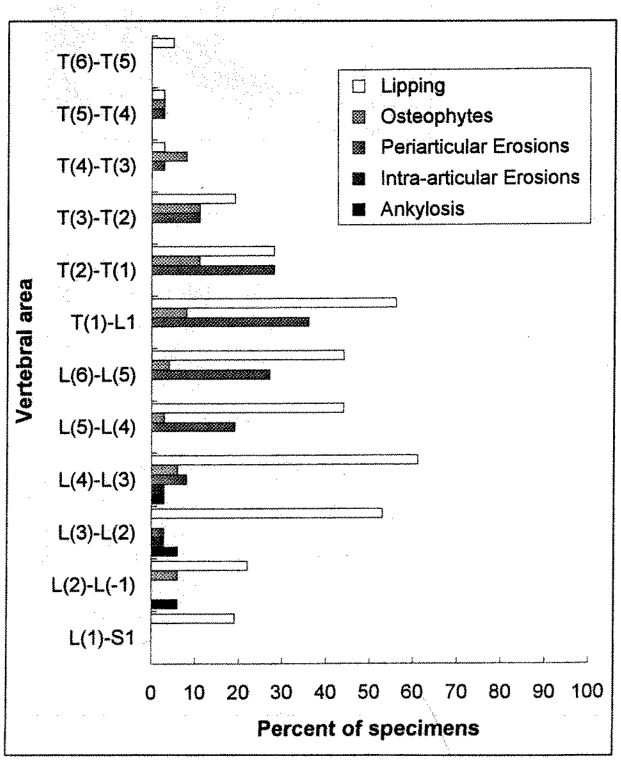


Figure 5—Distribution of degenerative changes of the articular process in the caudal portion of the thoracic and lumbar vertebral column. *See* Figure 1 for key.

lesions of the sacral region per specimen was 1.0 ± 1.2.

The prevalence and severity of impingement of dorsal spinous processes were lower in the cranial portion of the lumbar spine (**Fig 1**). Impingement was not observed at the lumbosacral junction or S5-S6. Overall severity (**Fig 2**) was grade 1 (n = 2 specimens; 6%), 2 (7; 19%), 3 (13; 36%), 4 (8; 22%), or 5 (3; 8%). Ankylosis (ie, grade 5) of the dorsal spinous processes was detected at L(3)-L(2) in 3 (8%) specimens and within the sacrum in 8 (22%) specimens.

Impingement or overlap of the transverse processes in the lumbar vertebral column was found in 97% of specimens, affected 42% (86/205) of lumbar vertebrae, and was localized to the cranial and caudal margins of the abaxial third of transverse processes. Zero to 4 lumbar vertebrae were affected unilaterally or bilaterally with a mean number of 2.3 ± 1.0 impingement sites/specimen. Impingement of the transverse processes was detected unilaterally or bilaterally at 1 (8 specimens; 22%), 2 (10; 28%), 3 (13; 36%), or 4 (4; 11%) intertransverse spaces. Greater prevalence and severity of impingement were detected in the caudal portion of the lumbar vertebral column. Impingement of the transverse processes was not found at the lumbosacral junction. Overall severity (**Fig 3**) was grade 1 (8 specimens; 22%), 2 (23; 64%), 3 (2; 6%), or 5 (2; 6%). Ankylosis of the L(2)-L(1) transverse processes was detected unilaterally and bilaterally in 1 specimen each. The specimen with unilateral ankylosis had erosion of the intertransverse articular cartilage bilaterally and irregular joint margins. The specimen with bilateral ankylosis had these lesions on the adjacent intertransverse joints.

**Degenerative joint disease**—Evidence of spondylosis or ankylosis of the vertebral body was not found.

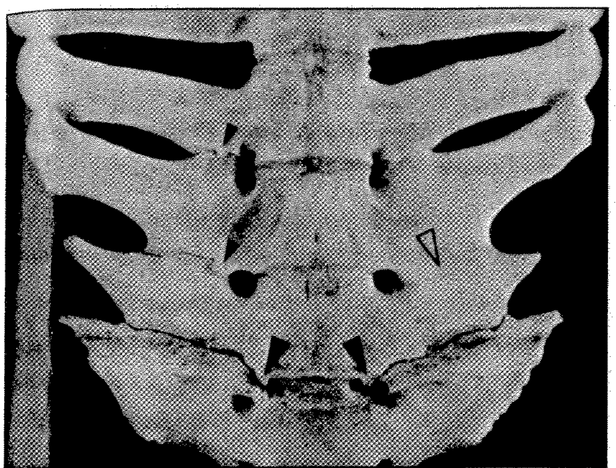

Figure 6—Photograph illustrating the ventral aspect of the lumbar and lumbosacral intertransverse joints. Notice severe lipping (small arrows), moderate osteophytes (large arrows), and ankylosis (open arrow).

However, 2 horses had severe vertebral fractures related to racing accidents. A 5-year-old horse that fell during a race had acute fractures of the dorsal spinous process of C2 and cranial articular processes of C2 and C3 and evidence of vertebral cord compression at C1-2. A 3-year-old horse had fractures of the right scapula, humeri, right third metacarpal bone, right vertebral lamina of T18, dorsal spinous processes of T18 and L1, and a comminuted fracture of the caudal vertebral end plate of T18.

Variable degrees of degenerative changes observed in the articular processes of 35 (97%) specimens affected 38% (153/407) of intervertebral articulations. Degenerative changes were detected at 0 to 9 (of 11 or 12) articulations (mean, 4.3 ± 2.5 affected articulations/specimen) and included lipping of the articular surface (n = 33; 92%), osteophytes (10; 28%), periarticular erosions (17; 47%), intra-articular erosions (3; 8%), and ankylosis (4;11%; **Fig 4**). Of affected specimens, mean numbers of articulations per specimen affected with lipping, osteophytes, periarticular erosions, intra-articular erosions, and ankylosis were 3.6 ± 2.1 (range, 1 to 8), 2.2 ± 1.9 (range, 1 to 7), 2.5 ± 1.5 (range, 1 to 5), 1.0 ± 0.0, and 1.3 ± 0.5 (range, 1 to 2), respectively.

Articular lipping of articular processes was common from the thoracolumbar junction to the midlumbar spine (**Fig 5**). Periarticular erosions tended to center around the thoracolumbar junction. Intra-articular erosions and ankylosis were found only in caudal lumbar vertebral segments. Overall degenerative changes of the thoracolumbar articular processes were mild (n = 13 specimens; 36%), moderate (13; 36%), or severe (9; 25%). Severe changes tended to be found in the caudal thoracic and caudal lumbar vertebral regions.

Variable degrees of degenerative changes were found at the lumbar intertransverse joints in 100% of specimens. Degenerative changes affected 95% (94/99) of the L(4)-L(1) intertransverse joints, but only 72% (52/72) of the L(1)-S(1) intertransverse joints, and included lipping of the articular surface (n = 30 specimens; 83%), cortical buttressing (23; 64%), osteophytes (4; 11%), intra-articular erosions (8; 22%), and ankylosis (10; 28%; **Fig 6**). The greatest prevalence and most severe degenerative changes of intertransverse joints were detected at L(2)-L(1). The exception was cortical buttressing, which was detected with increasing frequency from the midlumbar spine to the lumbosacral joint. Ankylosis of the lumbosacral joint was not observed.

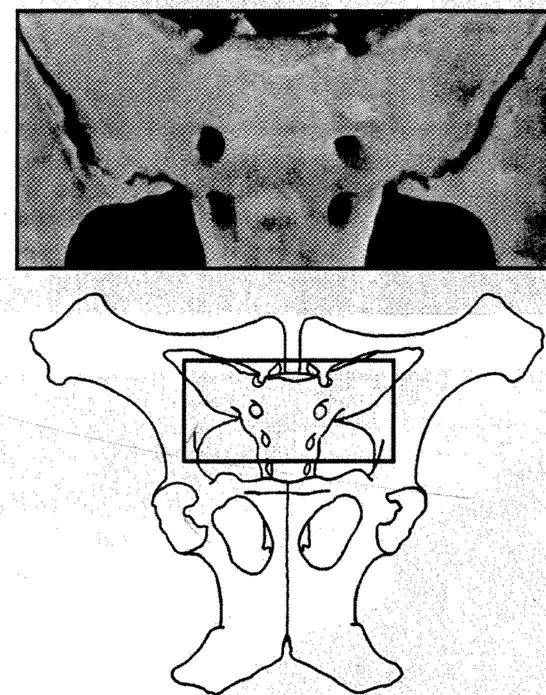

Figure 7—Photograph of the medial surface of the sacroiliac joints illustrating severe osteophytes. Box on the ventral view of the sacrum and pelvis represents region illustrated in photograph.

Degenerative changes in the intertransverse joints in the lumbar vertebral column were bilateral at 32 and unilateral at 25 (14 left, 11 right) intervertebral sites, whereas those in the lumbosacral area were bilateral in 25 of 27 affected specimens. Lipping, cortical buttressing, and osteophytes of the intertransverse joints of L(4)-L(1) were observed on the dorsal (24 specimens), ventromedial (ie, intervertebral foramina, 8), and ventral (34) surfaces. Lipping, cortical buttressing, and osteophytes of the lumbosacral intertransverse joints were more common on the ventral (17 specimens) and ventromedial (14) surfaces than on the dorsal surfaces (4). Overall degenerative changes of intertransverse joints of the lumbar and lumbosacral spine were mild (6 specimens; 17%), moderate (14; 39%), or severe (16; 44%). Degenerative changes were less common and milder at the lumbosacral joint.

Degenerative changes were observed at the sacral and ilial articular surfaces in 100 and 72% of specimens, respectively. Twenty (56%) specimens had lipping of the articular surface, 23 (64%) had cortical buttressing, 9 (25%) had indentation of the articular surface, 12 (33%) had osteophytes, and 3 (8%) had intra-articular erosions (**Fig 7**). Lesions were usually bilaterally symmetrical.

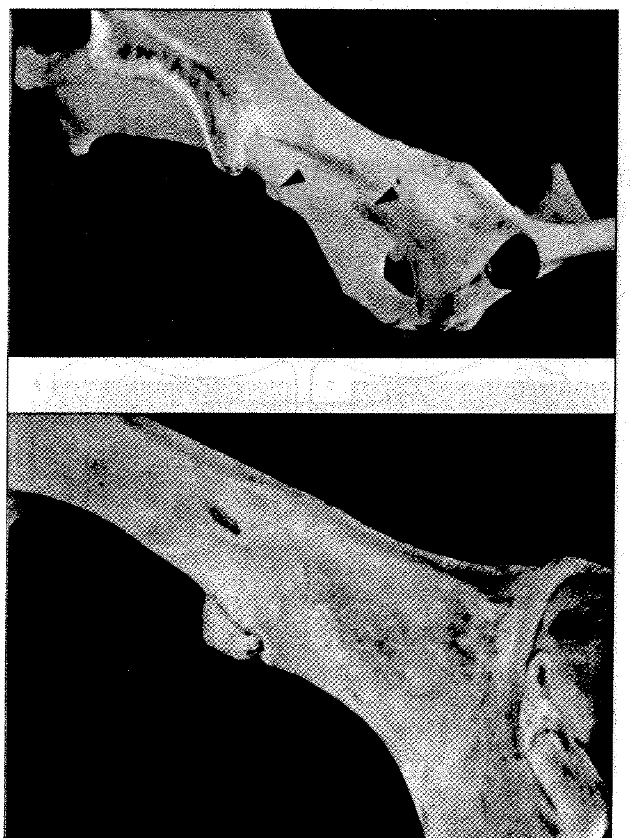

Figure 8—Photograph of the pelvis illustrating bilateral discontinuous enthesophytes at the tubercle for the psoas minor muscle (arrows) on a lateral (top) and close-up, cranioventral (bottom) view.

Ankylosis of the sacroiliac joint was not observed. Overall degenerative changes were mild (3 specimens; 8%), moderate (22; 61%), or severe (11; 31%). Sacral articular lesions, except for osteophytes, tended to be more prevalent and severe than ilial lesions.

The sacroiliac joint had the greatest prevalence of overall degenerative changes on the medial aspect. Articular lipping of the sacral articulation was medial (7 specimens), ventromedial (6), and ventral (4), whereas at the ilial articulation, lipping was found only at the medial aspect (8). Cortical buttressing detected only at the sacral articular surface was ventromedial in 8 specimens and ventral in 15. Articular indentation was observed only at the ilial articular surface on the ventromedial surface in 4 specimens and ventral surface in 7. Osteophytes associated with the sacroiliac joint were uniformly distributed around the dorsomedial, medial, ventromedial, and ventral margins of the articular surfaces of the ilium and the ventromedial and ventral margins of the articular surfaces of the sacrum.

Articular crevices (9 specimens; 25%) and focal indentations (3; 8%) were observed bilaterally only in the sacral articular surfaces. Degenerative changes were not found in the acetabulum of the coxofemoral joint.

**Enthesophytes**—Overall, 20 (56%) specimens had enthesophytes that were considered mild (5; 14%), moderate (13; 36%), or severe (2; 6%). Enthesophytes of the articular processes of the thoracolumbar vertebrae were observed in 5 (14%) specimens and were considered mild in 2 (6%) and moderate in 3 (8%). Enthesophytes were located at insertion sites of paraspinal muscles and did not interfere with intervertebral articulations. Enthesophytes were not observed near the intertransverse joints of the lumbar or lumbosacral vertebrae. Enthesophytes near the sacroiliac joints were detected in 14 (39%) specimens, in which the sacrum was affected in 11 (31%) and the ilium in 7 (19%). These were usually bilaterally symmetrical and associated with attachment sites for the sacroiliac ligaments. One enthesophyte adjacent to the sacroiliac joint was categorized as severe. Sacral enthesophytes tended to be larger and were distributed on the dorsomedial (5 specimens), medial (2), ventromedial (1), and ventral (3) surfaces. Ilial enthesophytes were found on the dorsal (1 specimen), medial (4), and ventromedial (2) surfaces.

Enthesophytes were observed in 7 (19%) specimens at 4 additional pelvic locations: at the tubercle for the psoas minor muscle (3 specimens; **Fig 8**), cranioventral ischial tuberosity (3), dorsocranial margin of the obturator foramen (2), and the origin of the deep gluteal muscle (1). Pelvic enthesophytes were usually bilaterally symmetrical and were considered mild in 1 (3%) specimen, moderate in 5 (14%), or severe in the specimen in which it was located at the origin of the left deep gluteal muscle.

**Statistical Associations: Impingement of vertebral processes**—The prevalence and severity of impingement of the dorsal spinous processes were positively associated ($\chi^2_2$ = 12.1; $P$ = 0.002). Age was not associated with the prevalence (Fisher's exact test; $P$ = 0.481) or overall severity ($\chi^2_2$ = 5.1; $P$ = 0.078) of impingement of the thoracolumbar dorsal spinous processes. Prevalence of impingement of the thoracolumbar dorsal spinous processes was not significantly associated with the presence (Fisher's exact test, $P$ = 0.070) or overall severity ($\chi^2_2$ = 4.0; $P$ = 0.138) of impingement of the sacral dorsal spinous processes. Impingement of the thoracolumbar dorsal spinous processes was not significantly associated with asymmetry (ie, size, shape, or facet orientation)[16] of the articular processes (Fisher's exact test, $P$ = 0.057) or presence of thoracolumbar transitional vertebrae (Fisher's exact test, $P$ = 0.076).[a]

Prevalence and overall severity of impingement of the lumbar transverse processes were positively associated ($\chi^2_2$ = 10.1; $P$ = 0.007), but prevalence and age of horse were not (Fisher's exact test, $P$ = 0.706). Prevalence of impingement of the transverse processes was not significantly associated with the total number of lumbar vertebrae (Fisher's exact test, $P$ = 0.070). Overall severity of impingement of the lumbar transverse processes was positively associated with the presence of impingement of the sacral dorsal spinous processes ($\chi^2_2$ = 6.2; $P$ = 0.046).

**Degenerative joint disease**—Overall prevalence and severity of degenerative changes in articular processes were positively associated ($\chi^2_2$ = 9.3; $P$ = 0.010). Age was not significantly associated with ankylosis of the articular processes (Fisher's exact test, $P$ =

0.081). Associations were not found between articular asymmetry and the overall prevalence (Fisher's exact test, $P$ = 0.182) or severity ($\chi^2_2$ = 0.1; $P$ = 0.951) of degenerative changes. Periarticular erosions were positively associated with prevalence (Fisher's exact test, $P$ = 0.003) but not severity ($\chi^2_2$ = 5.1; $P$ = 0.078) of impingement of the thoracolumbar dorsal spinous processes. Ankylosis of the articular processes was not significantly associated with periarticular erosions (Fisher's exact test, $P$ = 0.081).

Overall prevalence was positively associated with severity of degenerative changes in the lumbar intertransverse joints ($\chi^2_2$ = 11.9; $P$ = 0.003). Age was not associated with overall prevalence (Fisher's exact test, $P$ = 0.192) or severity ($\chi^2_2$ = 0.5; $P$ = 0.787) of degenerative changes. Overall prevalence of degenerative changes was positively associated with the number of lumbar intertransverse joints (Fisher's exact test, $P$ = 0.025) but not with the number of lumbar vertebrae (Fisher's exact test, $P$ = 1.000). Ankylosis of the lumbar intertransverse joints was positively associated with impingement of the lumbar transverse processes (Fisher's exact test, $P$ = 0.039). Overall severity of degenerative changes in the intertransverse joints and articular processes were not associated ($\chi^2_4$ = 8.5; $P$ = 0.076). Degeneration of the lumbosacral joint was positively associated with prevalence (Fisher's exact test, $P$ = 0.012) and severity ($\chi^2_2$ = 7.0; $P$ = 0.031) of impingement of the thoracolumbar dorsal spinous processes and osteophytes of the articular processes (Fisher's exact test, $P$ = 0.039).

The types of intertransverse degenerative changes were associated with unilateral or bilateral articular distributions ($\chi^2_4$ = 13.0; $P$ = 0.011). Articular lipping, cortical buttressing, and osteophytes were detected more frequently bilaterally, and end-stage articular degeneration (ie, intra-articular erosions and ankylosis) tended to occur unilaterally. The presence and severity of intertransverse joint lipping and cortical buttressing were negatively associated (Fisher's exact test, $P$ = 0.026; $\chi^2_4$ = 11.2; $P$ = 0.025, respectively). Intra-articular erosion and ankylosis of the intertransverse joints were not associated (Fisher's exact test, $P$ = 0.958). Degeneration of the lumbosacral joint was not significantly associated with intra-articular erosions of the lumbar intertransverse joints (Fisher's exact test, $P$ = 0.089). The presence and severity of degenerative changes of the lumbosacral joint were not associated with any degenerative changes in the lumbar intertransverse joints.

Age and sex were associated with the overall presence of osteophytes at the sacroiliac joint (Fisher's exact test, $P$ = 0.035 and 0.027, respectively). Older male horses had more osteophytes of the sacroiliac joint. Age was not associated with overall prevalence (Fisher's exact test, $P$ = 0.489) or severity ($\chi^2_2$ = 4.2; $P$ = 0.124) of degenerative changes of the sacroiliac joint. Overall severity of degenerative changes was positively associated with severity of impingement of the thoracolumbar dorsal spinous processes ($\chi^2_4$ = 11.7; $P$ = 0.020) and lumbar transverse processes ($\chi^2_4$ = 13.9; $P$ = 0.008).

Overall severity of degenerative changes of the sacroiliac articular surfaces of the sacrum was positively associated with ankylosis (Fisher's exact test, $P$ = 0.001) and overall severity of degenerative changes of the articular processes ($\chi^2_2$ = 7.6; $P$ = 0.023). Overall severity of degeneration of the sacroiliac joint was not significantly associated with overall severity of degenerative changes of articular processes ($\chi^2_4$ = 7.9; $P$ = 0.095). Intra-articular erosion of the sacroiliac and intertransverse joints was not significantly associated (Fisher's exact test, $P$ = 0.095). Degenerative changes of the sacroiliac joint were not associated with ankylosis of the lumbar intertransverse joints or lumbosacral degeneration. Lipping of the sacral articular surfaces was negatively associated with cortical buttressing (Fisher's exact test, $P$ = 0.001), indentation of the ilial articular surface ($P$ = 0.018), and osteophytes ($P$ = 0.007).

Sacral articular lesions were bilaterally symmetrical for overall prevalence (Fisher's exact test, $P$ = 0.014) and severity ($\chi^2_4$ = 19.3; $P$ = 0.001) of degenerative changes, lipping ($P$ = 0.001), cortical buttressing ($P$ = 0.001), and osteophytes ($P$ = 0.002); but not for intra-articular erosion ($P$ = 1.000). However, sacral intra-articular erosions were found in only 3 specimens. Ilial articular lesions were also bilaterally symmetrical for overall prevalence ($P$ = 0.006) and severity ($\chi^2_4$ = 8.9; $P$ = 0.064) of degenerative changes, lipping ($P$ = 0.001), cortical buttressing ($P$ = 0.001), and osteophytes ($P$ = 0.001) but not for intra-articular erosions. Ilial intra-articular erosions were found in only the left sacroiliac joint in 2 specimens. Sacral and ilial associations for the overall prevalence or severity of sacroiliac joint degenerative changes were not significant. Overall lipping and osteophytes of the sacroiliac joint were negatively associated ($P$ = 0.001).

**Enthesophytes**—Age was not associated with the presence of any enthesophytes. Enthesophytes and asymmetry of the articular processes were not associated (Fisher's exact test, $P$ = 0.564).[a] Ilial articular enthesophytes were positively associated with overall severity of impingement of the lumbar transverse processes ($\chi^2_2$ = 8.5; $P$ = 0.014). Enthesophytes of the articular processes were not associated with overall prevalence (Fisher's exact test, $P$ = 1.000) or severity ($\chi^2_2$ = 0.9; $P$ = 0.626) of degenerative changes in articular processes. Sacral articular enthesophytes were not significantly associated with overall prevalence of degenerative changes of the articular processes (Fisher's exact test, $P$ = 0.070). Enthesophytes of the sacroiliac joint were not significantly associated with degenerative changes of the lumbosacral joint (Fisher's exact test, $P$ = 0.071). Enthesophytes were not associated with overall prevalence or severity of degeneration of the sacroiliac joint. Sacral and ilial articular enthesophytes were positively associated (Fisher's exact test, $P$ = 0.018). Enthesophytes of the sacroiliac joint were not associated with other pelvic enthesophytes (Fisher's exact test, $P$ = 0.438).

## Discussion

Acute subluxation of the sacroiliac joint in 2 specimens was most likely secondary to catastrophic acute traumatic musculoskeletal injuries. Abnormal laxity of the sacroiliac joint was related to isolated disruption of the dorsal sacroiliac ligament near its attachment to the medial portion of the sacroiliac joint. This is in contrast with a report[4] of 2 horses with unilateral acute injury of the sacroiliac joint in which there were tears in the cranial portion of the ventral sacroiliac ligaments with extensive local hemorrhage.

Jeffcott[1,5] reported clinical and radiographic findings for chronic injury of the sacroiliac joint in horses referred for chronic pelvic injuries and thoracolumbar disorders. Radiographically, some horses had an apparent increase in the sacroiliac joint space; however, changes in the sacroiliac ligament, or laxity or subluxation of the joint were not observed.[3,5] In contrast, Rooney et al[4,21] found that the cranial portion of the ventral sacroiliac ligament was elongated or torn on the affected side in several horses with chronic injuries to the sacroiliac joint. Gross evidence of chronic ligamentous injury or subluxation of the sacroiliac joint was not observed in any specimen from Thoroughbreds in this study. However, this could be because horses with chronic injuries of the sacroiliac joint that resulted in poor performance or lameness had been removed from racing.

Impingement of the thoracolumbar dorsal spinous processes is the most common osseous cause of back pain in horses.[1] Radiographic evidence of impingement has been found in 34% of horses with functionally normal thoracolumbar specimens[9] and 33% of horses with a history of thoracolumbar problems.[1] Horses with functionally normal backs had fewer severe radiographic changes. Gross anatomic evidence of impingement has been found in 86% of functionally normal thoracolumbar specimens.[7] The discrepancy between gross and radiographic evidence of impingement is most likely related to inherent differences in the evaluation techniques. Thoroughbred racehorses in our study had greater prevalence and severity of impingement, compared with mixed-breed horses of previous studies. Whereas grading systems varied between studies, our system attempted to incorporate these differences into a standard grading protocol.

The distribution of gross and radiographic evidence of impingement of the thoracolumbar dorsal spinous processes in other studies was similar to our findings in Thoroughbred racehorses.[1,7] Impingement in the thoracic vertebrae is found most commonly between T13 and T18 and is related to morphometric changes in the dorsal spinous processes.[7,9] Thoroughbreds have been reported to have a greater prevalence of impingement, compared with other breeds, because of misshaped dorsal apices and narrower interspinous spaces.[1,9] We hypothesized that the irregular-shaped dorsal spinous processes may be induced by biomechanical stimuli from the supra- and interspinous ligaments.

Competitive jumping or dressage horses have a greater prevalence of impingement of the thoracolumbar dorsal spinous processes related to ventroflexion or spinal maneuvers that are highly demanding.[1] However, dorsoventral mobility in the caudal portion of the thoracic vertebrae does not differ from other adjacent vertebral regions; therefore, increased dorsoventral movement may not account for the vertebral distribution of impingement of the dorsal spinous processes.[7,22] Additional weight carrying requirements have also been implicated, because this vertebral region is covered by the saddle when ridden.[14] However, impingement of the thoracolumbar dorsal spinous processes has been reported in Standardbreds and an extinct equine species, *Equus occidentalis*, which presumably did not have extraneous weight placed on their backs.[23] Aging has not been a factor in the pathogenesis of impingement.[1,7,9]

Impingement of the dorsal spinous processes has also been found in the caudal portion of the lumbar spine.[7,24,25] In specimens with 5 lumbar vertebrae, a greater prevalence of impingement was detected at L(2)-L(1), which is related to the L(2)-L(1) interspinous space conformation. A significant positive association between the status (ie, open vs closed) of the L(2)-L(1) interspinous space and number of lumbar vertebrae present has been found.[16] The L(2)-L(1) interspinous space was open in 13 of 25 specimens with 6 lumbar vertebrae but was closed in all specimens with 5 lumbar vertebrae. Ankylosis of the sacral dorsal spinous processes is probably related to developmental changes associated with sacral fusion and not to biomechanical factors.

Overlap or malalignment of the dorsal spinous processes is often caused by impingement of spinous processes.[9] However, we also found overlap without any evidence of osseous impingement in several dorsal spinous processes and most transverse processes. In human beings, deviation of the dorsal spinous processes can be related to vertebral rotation (eg, scoliosis), developmental asymmetries in the neural arch, or the cause may be unknown.[26] We hypothesized that localized overlap or malalignment of vertebral processes was a developmental or acquired deformation that may be related to asymmetric ligamentous or musculotendinous forces that induce osseous remodeling and subsequent deviation. Biomechanically, a presumed prerequisite for optimal spinal function is alignment of the vertebral processes. Evidence of overlap of vertebral processes without any osseous impingement was found in the horses of this study; thus, the only other adjacent structures capable of inducing osseous deformation were vertebral ligaments or muscles. Isolated asymmetric ligamentous or musculotendinous forces may arise from insertions of the interspinous ligaments or multifidi muscles on dorsal spinous processes and intertransverse ligaments or quadratus lumborum muscles on transverse processes.

Additional osseous proliferation without gross evidence of impingement or overlap was found in a few specimens near the dorsolateral aspect of the caudal border of the spinous processes. Areas of periosteal irregularity have been reported in the midportion of thoracic dorsal spinous processes but have unknown clinical importance.[9] Enthesophytes of the interspinous ligaments and multifidi muscles near the dorsocaudolateral aspect of the dorsal spinous processes could account for these osseous changes but would have to be differentiated from impingement of the dorsal spinous processes.[18]

Bilateral, multisegmental overlap or malalignment was found in most transverse processes. Impingement and overlap of the transverse processes were limited to the most distal aspect of the vertebral processes. Overlap of the transverse processes without osseous contact (grade 1) was the most common. In most specimens, small triangular osseous projections extended from the cranial edge of the transverse processes, cranioventrally under the transverse processes of adjacent lumbar vertebrae. These projections serve as insertion sites for portions of the quadratus lumborum muscle and the intertransverse ligaments of the lumbar vertebrae. Axial rotation, but not dorsoventral or lateral flexion, might be limited in areas of overlap. Vertebral motion is normally limited in this vertebral region so transverse process overlap would probably not be clinically evident.

Transverse process impingement (grades 2 to 4) was less common and might be related to altered conformation of vertebral processes. Axial rotation and lateral flexion in the lumbar vertebrae would potentially be limited by impingement of the transverse processes. Ankylosis of the transverse processes was found in 1 specimen that did not have ankylosis of the adjacent intervertebral joints. This is contrary to a report[12] that ankylosis must develop in the intertransverse joints before the transverse processes.

Spondylosis or ankylosis of the vertebral body was not found in any specimen, despite the presence of unilateral or bilateral ankylosis of the lumbar intertransverse joints. Other researchers reported ventrolateral osteophytes of the vertebral body in 36% (8/22) of specimens from functionally normal horses evaluated grossly.[7] However, the mean age of those horses was 9.2 ± 7.2 years, compared with 4.5 ± 1.5 years in our study. Most osteophytes of the vertebral body are thought to develop in older horses (> 6 years) as a result of tearing of the outer annular fibers of the intervertebral disk with subsequent periosteal stimulation and osteophyte formation.[1,7] In a radiographic study,[1] osteophytes of the vertebral body were found in only 3% (14/443) of horses referred for thoracolumbar problems. The discrepancy in prevalence of osteophytes of the vertebral body is presumably related to differences between gross and radiographic evaluations.[7]

Degenerative joint disease of the lumbar articular processes is common in older horses but reportedly not clinically important.[27] However, we found various types of degenerative changes of the articular processes in young Thoroughbred racehorses and severe changes in 25% of our specimens. Lipping of the articular surface and periarticular erosions of the articular processes were common at the thoracolumbar junction and cranial portion of the lumbar vertebral column. Intra-articular erosions and ankylosis were restricted to the caudal lumbar vertebral segments where vertebral mobility is typically limited.[22]

Positive associations between articular facet tropism and degenerative changes have been reported in human beings.[28-30] However, significant associations were not observed between overall prevalence or severity of degenerative changes of the articular processes and asymmetry of the articular processes in Thoroughbred racehorses or between many of the degenerative changes and impingement of the thoracolumbar dorsal spinous processes. Nonetheless, horses with evidence of impingement of the dorsal spinous processes should also be evaluated for degenerative changes of the articular processes.

Degenerative changes were found at the lumbar intertransverse joints in all specimens and were most prevalent and severe at L(2)-L(1). Cortical buttressing was detected with increasing prevalence toward the lumbosacral joint. This pattern corresponded to the typical increasing size of the intertransverse joints in the caudal portion of the lumbar vertebral column and lumbosacral junction. Cortical buttressing and increasing size of the intertransverse joints cause an increased articular surface area that may contribute to regional spinal stability and subsequent force transfer between the hind limbs and lower portion of the back.

Ankylosis of the intertransverse joints was observed in 28% of Thoroughbred racehorses of this study, compared with 39% in a population of mixed-breed horses.[31] Commonly, ankylosis of the intertransverse joints develops at L(3)-L(2) and L(2)-L(1).[12,16,32] Ankylosis of the lumbosacral joint was not detected in 245 specimens of mixed equine species,[31] which is consistent with results of our study of Thoroughbred racehorses. Age has not been associated with ankylosis of the intertransverse joints,[7,31] which is also consistent with our findings. Ankylosis of the intertransverse joints is thought to be a developmental condition and to not be a cause of signs of pain in the lower portion of the back.[7,8,31] However, intra-articular erosions were detected in our specimens that, if allowed to progress, would apparently result in ankylosis of the intertransverse joints. Therefore, developmental and acquired ankylosis of the intertransverse joints probably can be found in horses.[12]

Degenerative changes were observed commonly at the ventromedial (ie, intervertebral foramina) aspect of the lumbosacral intertransverse joints, and it is possible that nerve compression could develop with severe, proliferative changes. Significant positive associations were found between the prevalence and severity of impingement of the thoracolumbar dorsal spinous processes and presence of lumbosacral degenerative changes. Therefore, horses with evidence of impingement of the dorsal spinous processes might also be candidates for degeneration of the lumbosacral joint. Radiography and linear tomography have been used clinically to image the lumbosacral joint in horses presumed to have back problems.[9,10]

Lumbosacral arthrosis is presumed to develop more commonly in horses that gallop (ie, racehorses, jumpers), whereas arthrosis of the sacroiliac joint develops more commonly in trotters or pacers; this may be related to differences in vertebral column biomechanics.[8] However, lumbosacral degenerative changes were found in only 72% of specimens from Thoroughbred racehorses in our study, whereas sacroiliac joint degenerative changes were found in 100% of specimens. This prevalence for the sacroiliac joint is greater than that reported in a survey of necropsy findings from functionally normal mixed-breed horses.[11] The prevalence of sacroiliac damage in performance horses is probably great, and many cases may go undiagnosed.[3] Bilaterally symmetrical degenerative changes were found at the sacral and ilial articular surfaces of the sacroiliac joint in ours as well as in another study.[11] The ilial surface of the sacroiliac joint reportedly has more degenerative changes than the sacral articular surface in horses that do not have a history of problems on the lower portion of the back.[11] However, this is contrary to our findings.

Lipping, cortical buttressing, and osteophytes were found at the sacroiliac articulation. The pathogenesis of these proliferative changes is uncertain but thought to be related to chronic instability resulting in gradual remodeling and subsequent enlargement of the ventromedial joint surfaces.[3] Osseous changes have been found at the ventromedial margins of the sacroiliac joint in horses suspected of having chronic sacroiliac injury; however, obvious laxity of the sacroiliac ligament has not been found at necropsy.[1,3,5] Similar expansions of the ventromedial surfaces of the sacroiliac joint have been found in a few clinically normal horses[11] and may develop in response to altered mechanical stresses and assist in the distribution of biomechanical forces. These proliferations reportedly develop more often at the sacral articular surface than the ilial articular surface,[3,11] which is consistent with our findings of lipping and cortical buttressing. However, osteophytes were found more commonly at the ilial articular surface of the sacroiliac joint in our study.

Erosion of the articular cartilage was the only lytic process found at sacroiliac articular surfaces. Erosion of the articular cartilage is thought to increase with age.[11,17] However, only osteophytes of the sacroiliac joint were positively associated with age in our study. Erosion presumably leads to joint ankylosis. However, ankylosis of the sacroiliac joint has not been found in a study[11] of the sacroiliac joint, which is consistent with our findings.

Indentation of the articular surface, characterized by a concavity or recession, was a unique feature of the ilial surfaces of the sacroiliac joint. This did not appear to be related to cortical buttressing of the adjacent periarticular cortex of the wing of the ilium. However, periarticular osteophytes or enthesophytes were often associated with the margins of the articular indentation that added apparent depth to the recessed surface.

Significant positive associations were found between the overall severity of degenerative changes of the sacroiliac joint and the severity of impingement of the thoracolumbar dorsal spinous processes and lumbar transverse processes. Positive associations were also found between the overall severity of degenerative changes of the sacroiliac articular surfaces of the sacrum and ankylosis of the articular processes and the overall severity of degenerative changes of the articular processes. This suggests that horses with severe impingement of the vertebral processes or degenerative changes of the articular processes may also be predisposed to degenerative sacroiliac joints. Few significant associations were found between degenerative changes of the sacroiliac joint and the lumbar intertransverse joints or lumbosacral articulations. This suggests that degenerative changes at the intertransverse joints or lumbosacral joint may have minimal effects on the sacroiliac articulations. Significant negative associations were observed between the presence of lipping at the sacral and ilial articular surfaces and several other degenerative changes at the sacral and ilial articular surfaces. It appears that as certain degenerative changes of the sacral and ilial articular surfaces become more severe, lipping of the articular surfaces is less prevalent.

Articular clefts and focal indentations were found on sacral, but not ilial, articular surfaces of the sacroiliac joint in specimens from Thoroughbreds in our study. However, Dalin and Jeffcott[11] found articular crevices and focal indentations in sacral and ilial articulations in clinically normal horses. The prevalence of sacral articular crevices increased with age, whereas focal indentations decreased with age. These seemed to be developmental lesions in that the articular crevices were related to cartilage retention and focal indentations were related to superficial vascular channels within articular cartilage.[11,17]

Degenerative changes of the acetabula of the pelvis were not seen in our sample of Thoroughbred racehorses. This is consistent with a study[6] in which primary hip osteoarthritis was rare.

In specimens of our study, enthesophytes were discontinuous and continuous with the underlying cortical bone. A fibrous transitional region was found between the cortical bone and discontinuous ossified enthesophytes. Discontinuous and continuous enthesophytes may represent a spectrum of enthesophyte formation within the unmineralized and mineralized fibrocartilaginous zones of tendons or ligaments.[33] The presence of enthesophytes infers prior inflammatory or biomechanical stimuli acting on associated entheses.[19,20,33] Enthesophytes form because of an inflammatory reaction within the connective tissue-bone interface with subsequent osseous remodeling and proliferation. In our study, most enthesophytes were bilaterally symmetrical, compatible with a biomechanical cause. The sacroiliac ligaments were most commonly affected in specimens from Thoroughbred racehorses in our study and were in similar articular regions (ie, ventromedial) as were degenerative changes. However, significant associations were not found between the presence of enthesophytes and the different types of degenerative changes of the sacroiliac joint, which supports the premise that enthesophytes and degenerative joint disease have different etiopathogeneses.[19]

## Appendix

Grading system* for impingement of dorsal spinous and transverse processes

| Grade | Morphologic or pathologic characteristics |
|---|---|
| 0 | No evidence of vertebral process impingement or overlap. |
| 1 | Overlapping of vertebral processes without osseous contact. No periosteal proliferation. |
| 2 | Mild impingement with or without vertebral process malalignment: minimal periosteal proliferation (< 2 mm in height); minimal eburnation (dorsal spinous processes < 1 $cm^2$; transverse processes < 0.5 $cm^2$). |
| 3 | Moderate impingement with or without vertebral process malalignment: moderate periosteal proliferation (2 to 4 mm in height); moderate eburnation (dorsal spinous processes 1 to 2 $cm^2$; transverse processes 0.5 to1.0 $cm^2$). |
| 4 | Severe impingement with or without vertebral process malalignment: marked periosteal proliferation (> 4 mm in height); marked eburnation (dorsal spinous processes > 2 $cm^2$; transverse processes > 1 $cm^2$). |
| 5 | Ankylosis of adjacent vertebral processes |

*Modified from radiographic[1,9] and anatomic[7] grading schemes for impingement of dorsal spinous processes.



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