Equine vet. J. (1984) 16 (5), 461-465

Relationship between intervertebral joint morphology and mobility in the equine thoracolumbar spine

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Summary

The anatomical features of 21 equine thoracolumbar spines, obtained from horses with clinically normal backs, were examined and the results compared with recent data on the mobility of the joint complexes of the horse's spine. The thoracolumbar spine can be divided into four regions based upon the morphology of the joint complexes: the first thoracic intervertebral joint (T1-2), the cranial and mid thoracic region (T2-T16), the caudal thoracic and lumbar region (T16-L6) and the lumbosacral joint. The mobility of the intervertebral joints in each of these regions can be related to their morphology, particularly the shape, size and orientation of the articular facets and the presence and frequent fusion of the lateral joints of the lumbar spine. The shape and thickness of the intervertebral discs also appear to be of importance.

Introduction

THE amount and type of movement that can take place in the joints of the thoracolumbar spine of the horse have recently been investigated (Jeffcott and Dalin 1980; Townsend, Leach and Fretz 1983). The mobility of each joint complex was found to differ according to its location along the length of the spine. There is evidence that this variation in mobility may be related to the anatomy of the intervertebral joint complex (Gray 1944), a relationship that has been well established in the human spine (Farfan 1969; White 1969, 1971; Farfan *et al* 1970; Markoff 1972; Koreska *et al* 1977; White and Panjabi 1978).

It has been suggested that the mobility of the equine thoracolumbar spine is related to the height and width of the centra of the vertebrae, the size and shape of the articular facets, the ligaments between the dorsal and transverse processes, the articulations between lumbar transverse processes (lateral joints) and the height and orientation of the dorsal spinous processes (Slijper 1946; Badoux 1965, 1968, 1974; Jeffcott and Dalin 1980). The dorsal spinous processes are orientated so that there is limited room for extension of all joints except the lumbosacral articulation, where the dorsal spine processes are widely divergent (Slijper 1946; Jeffcott and Dalin 1980). Extension may be further reduced in vertebral columns where impingement or overriding of the dorsal spinous processes is present between adjacent vertebrae (Jeffcott 1977).

Stecher (1962) suggested that the lateral joints between the lumbar transverse processes, an anatomical feature peculiar to the horse and rhinoceros, increase the stability of this region by preventing excessive lateral bending of the lumbar spine. The ankyloses that are sometimes found in these lateral joints are believed to be further adaptations to this strain.

This paper explores the relationship between intervertebral joint mobility and morphology in the thoracolumbar spine.

Materials and methods

Twenty-one thoracolumbar spines were obtained from routine submissions of adult horses to the necropsy room of the Western College of Veterinary Medicine. The age, sex and breed of each horse and the amount and type of movement occurring at each intervertebral joint complex of these specimens was determined and has been previously reported (Townsend *et al* 1983). The spines were then wrapped in cheesecloth and boiled in water for 12 h to remove the soft tissues, soaked in a weak solution of hydrogen peroxide for 8 h and then air-dried. The shape, size and orientation of the cranial articular facets of each vertebra were then examined. Their orientation was defined as either tangential (upward facing) or radial (inward facing) with shapes being classified as either flat or interlocking (Slijper 1946). The relative size of the facets was also recorded. The lumbar vertebrae were examined for the presence of lateral joints between the transverse processes. The location of each lateral joint was recorded, as was each instance and location of lateral joint fusion.

Before maceration, four thoracolumbar spines were sectioned mid-sagittally to allow measurement of the thickness of the intervertebral discs. Thickness was defined as the distance between the apposing vertebral centra midway between the dorsal and ventral border of the disc and was measured using vernier calipers.

Results

The shape, size and orientation of the articular facets differed along the length of each spine. The articular facets of the first thoracic joint complex were always large and radially orientated (Fig 1). From the second thoracic intervertebral joint (T2-3) caudally to about T16-17 the cranial articular facets were smaller and tangential in orientation (Fig 2). In the region of T16-17 the facets became radial in orientation and the cranial and caudal facets interlocked with one another (Fig 3). The point at which this transition occurred was the joint complex at which each cranial articular facet made direct contact with the adjacent mammillary process (Fig 4). This transition occurred at T15-16 in five horses, at T16-17 in 11 horses and at T17-18 in five horses.

The frequency of occurrence of lateral joints and fusion of lateral joints in 17 thoracolumbar spines are shown in Table 1. The typical appearance of the lateral joints and of lateral joint fusion are shown in Figs 3 and 5 respectively. Lateral joints

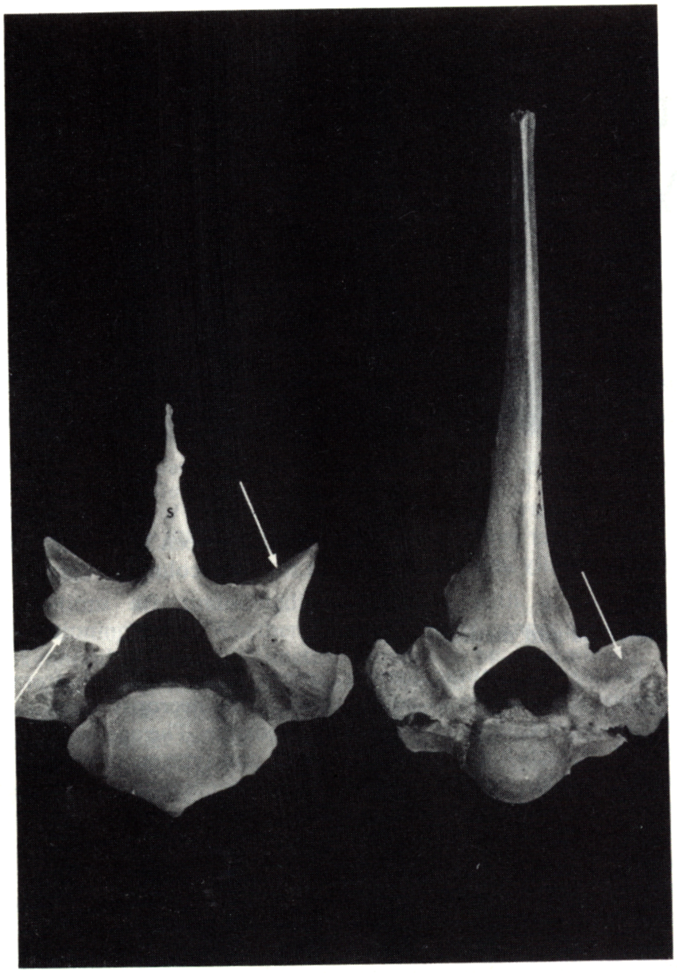

Fig 1. Caudal aspect of the first thoracic vertebra (left) and the cranial aspect of the second thoracic vertebra (right). Note the radial orientation of the articular facets (arrows) and the short dorsal spinous process of the first thoracic vertebra (s)

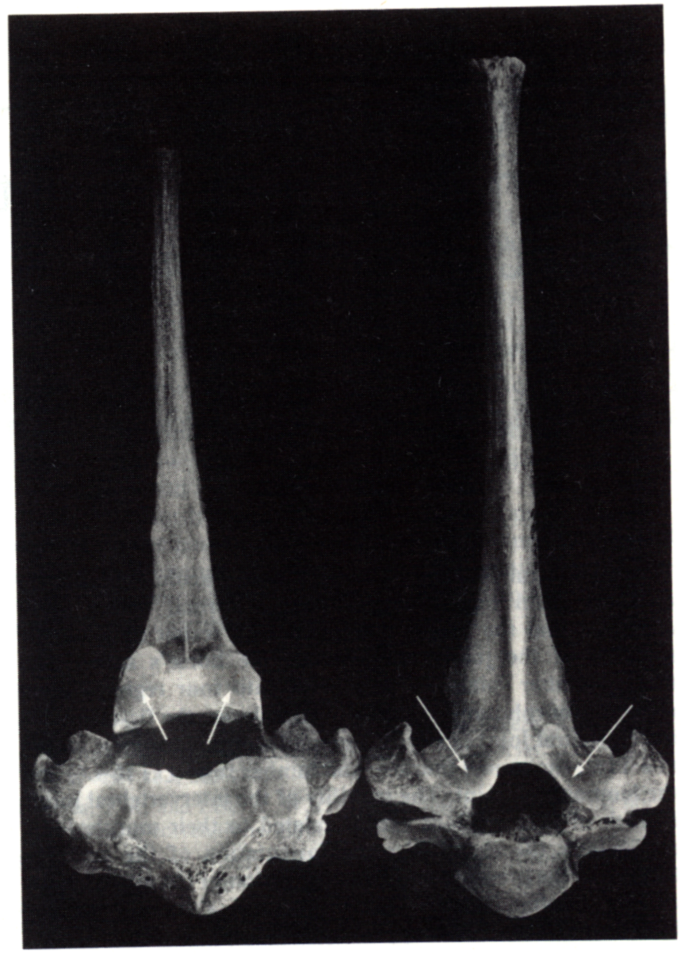

Fig 2. Caudal aspect of the second thoracic vertebra (left) and the cranial aspect of the third thoracic vertebra (right). The arrows are at right angles to the surface of the articular facets. Note the tangential orientation of the cranial articular facets of the third thoracic vertebra (right)

were always found between the alae of the sacrum and the transverse processes of the sixth lumbar vertebra (L6) but fusion of these joints was never observed to occur. The articular facets of the lumbosacral joint were relatively small and always vertically orientated (Fig 6).

The intervertebral discs at T1-2, T2-3 and the lumbosacral joint were thicker than those of the rest of the spine (Table 2). The average thickness of a disc between T3 and T6 was 2.5 mm. The discs were fibrous and a gelatinous centre, possibly a nucleus pulposus, was seen in only three (T8-11 of spine 1) of the 96 intervertebral discs examined.

Discussion

Based upon the morphology of the articular facets, the equine thoracolumbar spine can be divided into four regions: the first thoracic intervertebral joint (T1-2), the cranial and mid-thoracic region (T2-T16), the caudal thoracic and lumbar region (T16-L6) and the lumbosacral joint (L6-S1). The amount and type of movement measured in a previous study (Townsend *et al* 1983) is characteristic for each of these regions (Table 3), suggesting a relationship between vertebral morphology and joint complex mobility.

TABLE 1: Frequency of lateral joints and fusion of lateral joints in 17 thoracolumbar spines subjected to manipulation

Joint complex	Lateral joints %	Fusion or lateral joints† %
L6-S1	100	0
L5-L6	100	59
L4-L5	88*	23
L3-L1	0	0

* Includes one specimen with unilateral lateral joint
† Includes both unilateral and bilateral fusions

TABLE 2: Average thickness of intervertebral discs from four equine thoracolumbar spines

Joint complex*	Disc thickness (mm)	Joint complex	Disc thickness (mm)
T1	5.9	T13	2.9
T2	3.4	T14	2.3
T3	2.9	T15	2.3
T4	2.8	T16	2.4
T5	2.6	T17	2.4
T6	2.4	T18	2.7
T7	2.0	L1	2.5
T8	2.4	L2	2.6
T9	2.3	L3	2.6
T10	2.4	L4	2.6
T11	2.4	L5	1.9
T12	2.4	L6	3.6

* Each joint complex is numbered according to the most cranial vertebra of the complex

Fig 3. Dorsal aspect of a lumbar spine (L1-L6) and sacrum (s) demonstrating the radial, interlocking articular facets (arrows) and the lateral joints (between small arrowheads)

Fig 4. Cranial aspects of the 15th, 16th and 17th thoracic vertebrae. Contact between the cranial articular facets and the adjacent mamillary processes occurs at the 17th thoracic vertebra (arrow). A distinct separation between the two structures is visible at the 15th and 16th thoracic vertebrae (arrows)

Movement in the first thoracic joint complex (T1-2) consists principally of dorsoventral flexion and extension, with little axial rotation or lateral bending. The flat, oval facets allow dorsoventral movement but their radial orientation results in

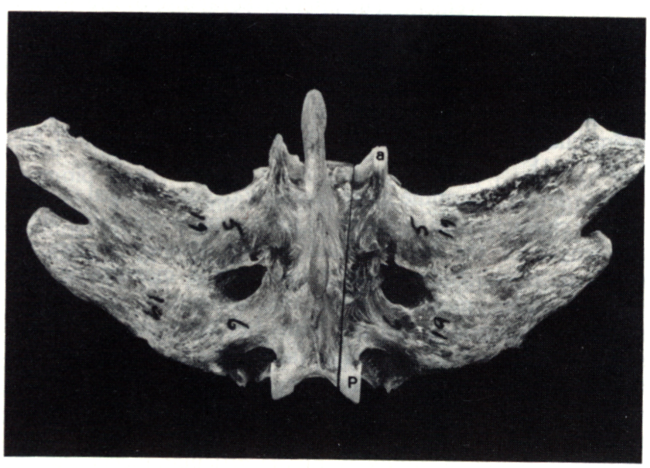

Fig 5. Dorsal aspect of a typical fusion between the fifth and sixth lumbar vertebrae, a cranial articular facet of the fifth lumbar vertebra; p caudal articular facet of the sixth lumbar vertebra

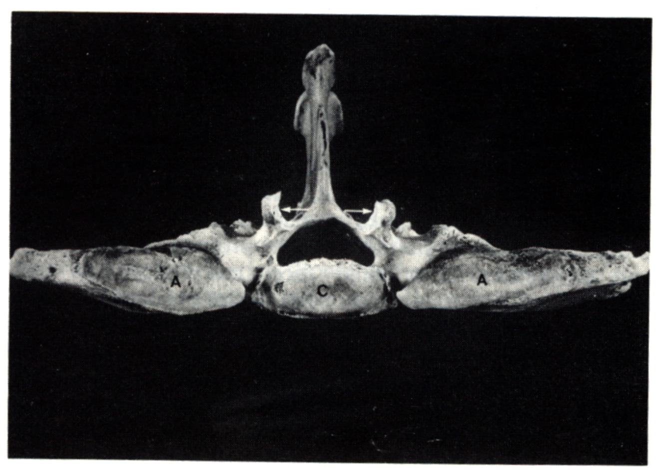

Fig 6. Cranial aspect of the first sacral vertebra, demonstrating the large lateral alae of the sacrum (A) which articulates with the transverse processes of the sixth lumbar vertebra. Note the horizontally oval centrum (C) and the vertically orientated articular facets (arrows)

TABLE 3: Relative amounts of movement in the joint complexes of the four regions of the equine thoracolumbar spine, with the ribs and sternum removed (adapted from Townsend *et al* 1983)

Region	Dorsoventral flexion and extension	Axial rotation	Lateral bending
T1-2	+ +	+	+
T2-T16	+	+ + +	+ + +
T16-L6	+	+	+
L6-S1	+ + + +	+	+

an interlocking of cranial and caudal facets which markedly restricts axial rotation. Their large size suggests substantial resistance against such movement. The importance of the articular facets in limiting axial rotation in this joint complex is further demonstrated by the fact that removal of the ribs and sternum does not increase the amount of axial rotation occurring between T1 and T2 (Townsend *et al* 1983). Other factors which may be of importance in the dorsoventral mobility of this joint are the height of the dorsal spinous process and the thickness of the intervertebral disc (Table 2). In addition, the height of the dorsal spinous process of T1 is less than half the height of the dorsal spinous process of T2 (Slijper 1946) and strong ligamentous attachments were not observed between these two spines.

The importance of dorsoventral mobility of T1-2 becomes obvious when one considers the length of the cervical vertebral column and its relationship to the first thoracic intervertebral joint complex. Mechanically, the cervical spine has been compared to a loaded beam which articulates caudally with the thoracic vertebral column (Slijper 1946). The cervical spine is then a long third-class lever (Littler 1961) and the T1-2 joint complex acts as a fulcrum in this system. A small amount of dorsoventral movement between T1 and T2 will therefore result in a large deflection at the level of the cranial cervical spine.

The articular facets of the joint complexes in the cranial and mid-thoracic spine (T2-T16) are much smaller than those of T1-2. They are tangential in orientation and relatively flat. The shape and orientation of these facets allows movement in three planes: dorsoventral flexion and extension, lateral bending and axial rotation. The amount of dorsoventral movement occurring in these joints is relatively small and no significant difference in the amount of this type of movement occurs between the joint complexes of this region (Townsend *et al* 1983).

Significant differences in the amount of axial rotation and lateral bending do occur in the region between T2 and T16 (Table 3). The greatest amount of axial rotation and lateral bending occurring in the equine thoracolumbar spine is found in the region T9-T14 (Townsend *et al* 1983). Cranial to T9 the thoracic spine is stabilised against axial rotation by the presence of fixed or sternal ribs. The presence of sternal ribs and differences in articular facet morphology do not, however, account for the decreased lateral bending cranial to T9 and further studies are required to determine the origin of this stability. Caudal to T14, the gradual development of radially orientated, interlocking facets appears to account for the decreased amount of axial rotation and lateral bending observed from this point caudally.

Relatively little movement occurs in the joint complexes of the caudal thoracic and lumbar spine (T16-L6) (Table 3) and this appears to be clearly related to the shape, size and orientation of the articular facets and the presence of lateral joints and fusions of these joints. The cranial facets of the vertebrae of this region are recessed and in contact with the mamillary processes (Figs 3 and 4) and their form accommodates the pointed shape of the caudal articular facets of the contiguous vertebra (Fig 3). This interlocking of the articular facets is associated with the decreased axial rotation observed in this region of the spine (Townsend *et al* 1983). The transition in facet morphology from tangential to radial occurred most commonly at T16-17. As the cranial facets of T16 are tangential and the caudal facets are radial, this vertebra is defined as the 'diaphragmatic vertebra' of the equine spine (Slijper 1946).

The presence of lateral joints between the transverse processes of the lumbar vertebrae must also be of importance in limiting axial rotation and lateral bending. In addition to the soft tissues that cross these articulations, the cranial aspect of the lateral joints face slightly upwards and are orientated at an oblique angle with respect to the longitudinal axis of the lumbar spine (Stecher 1962), resisting both axial rotation and lateral bending. The lateral joints start to appear at L4 and were present in 88 per cent of L4-5 joint complexes with fusion occurring in one or both of these lateral joints in 23 per cent of specimens examined. The lateral joints were larger at L5-6 and were always present at this level. In 59 per cent of the spines examined, the lateral joints at L5-6 were fused, thus preventing any movement in these joint complexes. These findings are consistent with the predictions of Slijper (1946) and Stecher (1962) that the lateral joints are important in the stability of the lumbar spine.

The fourth change in the general morphology of the articular facets occurs at the lumbosacral joint. The facets of this joint tend to be smaller than those of the rest of the lumbar spine and the joint surfaces are flat and approximately vertical in orientation. The cranial facets of S1 face inwards and the caudal facets of L6 face outwards to meet them. In this way the facets do not limit dorsoventral movement but do appear to resist axial rotation (Figs 3 and 6).

Movement in the lumbosacral joint is characterised by a great amount of dorsoventral flexion and extension in combination with a very small amount of axial rotation and lateral bending (Table 3). Significantly more dorsoventral movement occurs in this joint than in any other joint complex of the equine thoracolumbar spine (Slijper 1946; Townsend *et al* 1983). The wide divergence of the dorsal spinous processes, the poorly developed interspinous ligamentous tissue between the dorsal spinous processes of L6 and S1 (Jeffcott and Dalin 1980), the small, vertically orientated facets and the decreased height of intervertebral discs (Fig 6) all allow for increased dorsoventral movement. The intervertebral disc of this joint is thicker than those of the rest of the lumbar spine, possibly increasing the range of motion of this joint. Fusion of the lateral joints of this articulation has not been reported, suggesting that movement in this joint is of essential biomechanical importance to the normal horse (Stecher and Goss 1961).

In order to determine more precisely the anatomical reasons for the characteristic variation in joint complex mobility along the length of the horse's back, more detailed studies are required. Such studies should involve the measurement of joint complex mobility after the sequential removal of stabilising components of the joints (ie, ligaments, the dorsal spinous processes, the articular facets, the neural arches and the transverse processes). However, the results reported in this paper demonstrate the relationship between joint complex mobility and two anatomical features of the equine thoracolumbar spine; morphology of the articular facets and the presence and frequent fusion of lateral joints between lumbar transverse processes.

Acknowledgements

The work reported in the paper was carried out while the senior author was supported by an Equine Health Fellowship from the Western College of Veterinary Medicine Equine Health Research Fund. The project was funded by the Government of Alberta Horse Industry Branch and the Saskatchewan Department of Agriculture.

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Accepted for publication 20.6.83

ABSTRACT

Locomotor system and diseases

Apical fractures of the proximal sesamoid bones in 109 Standardbred horses

SPURLOCK, G. H. and GABEL, A. A. (1983) *J. Am. vet. med. Ass.* **183**, 76-79.

OVER a five year period, 109 apical fractures of the proximal sesamoid bones were diagnosed in Standardbred racehorses at the Ohio State University. Only the records of horses with fractures involving less than one third of the estimated mass of the sesamoid bone were examined.

Eighty horses were treated surgically by removal of the apical fragment and 29 treated non-surgically. Lateral sesamoid bones of the hindlimbs accounted for 61 of 109 fractures, a significantly greater proportion than in all other sesamoid bones. Two- and three-year-old horses accounted for the majority of fractures.

Forty-five per cent of the surgical candidates had raced before surgery and 50 per cent raced afterwards. Average before injury and after injury performance values based on earnings, starts or order of finish score did not significantly alter. Horses that had raced before the injury had significantly better performance after surgery than those not raced before injury. Sixty per cent of horses undergoing surgery within 30 days of injury returned to race and these horses had significantly better performance than those operated on more than 30 days after injury.

Of the non-surgical group, 69 per cent had raced before injury and only 37 per cent after treatment. The pre-injury and after injury performances were significantly different with the latter being poorer.

Abstractor's comment. – Fractures of the proximal sesamoid bones are common injuries in both racing Standardbreds and Thoroughbreds. Various surgical and non-surgical treatments have been described. The results of these various treatments have sometimes been reported but never an objective statistical analysis of athletic performances. This paper does just this and is therefore of importance. However because the group consisted of Standardbreds some of the results may vary from the situation in the Thoroughbred. The basic conclusions that the practising veterinarian should gather from this paper are: Good surgical candidates were those in which the fractures involve only the apex of the sesamoid bone and less than one third of its total mass; surgical removal gave the best prognosis for horses that had proven their ability to perform at race speeds, were operated on within 30 days of injury, and had no evidence of suspensory desmitis or osteoarthritis.

Conservative methods of treatment severely decreased the post injury performance values although in this survey some horses treated non-surgically had concurrent injuries, which may have contributed to their poor performance.

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