Equine vet. J. (1986) 18(2), 107-112

Relationship between spinal biomechanics and pathological changes in the equine thoracolumbar spine

H. G. G. TOWNSEND, D. H. LEACH*, C.E. DOIGE† and W. H. KIRKALDY-WILLIS‡
Department of Veterinary Internal Medicine, Department of Veterinary Anatomy and Department of Veterinary Pathology†, Western College of Veterinary Medicine and Department of Orthopedic Surgery, University Hospital‡ University of Saskatchewan, Saskatoon, Saskatchewan, S7N OWO, Canada*

Summary

The relationship between spinal biomechanics and pathological changes occurring in functionally normal equine thoracolumbar spines was studied in 23 horses. Ventrolateral vertebral body osteophytes occurred in 36 per cent of the spines. The majority occurred between the 10th and 17th thoracic vertebrae with the largest being found between the 11th and 13th thoracic vertebrae, the region of the thoracic spine where the greatest amount of lateral bending and axial rotation occurs. Impingement of the dorsal spinous processes was detected in 86 per cent of the spines with most lesions occurring between the 13th and 18th thoracic vertebrae. The severity of occurrence of impingement did not appear to be related to regional spinal mobility. Degeneration of intervertebral discs was observed in three of four specimens that were sectioned sagittally. It occurred in the first thoracic and the lumbosacral intervertebral discs and appeared to be related to the increased dorsoventral mobility and the increased disc thickness of these joints. The characteristic distribution of fractures of the thoracolumbar spine is discussed with respect to the biomechanics of the spine.

Introduction

THE mobility of the equine thoracolumbar spine and the relationship between this and some of the anatomical features of the individual intervertebral joint complexes of the equine back have been described (Townsend, Leach and Fretz 1983; Townsend and Leach 1984). However, the relationship between spinal biomechanics and the reported pathological changes occurring in the equine vertebral column is poorly understood.

Back related lamenesses pose difficult diagnostic problems for the practitioner. Although back pain is frequently diagnosed in the horse, its precise cause is usually difficult to determine and the rationale and efficacy of treatment (Fraser 1961; Herrod-Taylor 1967; Roberts 1968; Swanstrom and Lindy 1973; Gidean 1977; Jeffcott 1980) therefore difficult to assess. The signs demonstrated by affected animals are frequently non-specific and may be difficult to distinguish from many other causes of lameness. The reported causes of equine back pain that are believed to have mechanical origin include muscle strain (Jeffcott and Dalin 1980), ligamentous damage (Jeffcott 1980), vertebral fractures (Sumner 1948; Mason 1971; Jeffcott and Whitwell 1976; Vaughan and Mason 1976), vertebral body osteophytes (Jeffcott 1975b; Geres 1978), osteoarthritis and ankylosis of the lateral joints (Mitchell 1933; Stecher and Goss 1961; Smythe 1962), impingement of the dorsal spinous processes (Roberts 1968; Jeffcott and Hickman 1975; von Salis and Huskamp 1978), chronic sacroiliac strain (Adams 1969; Rooney, Delaney and Mayo 1969; Rooney 1977), degenerative disc disease (Hansen 1959; Rooney 1970; Taylor, Vandevelde and Firth 1977) and subluxation of the articular facets (Herrod-Taylor 1967; Rooney 1970; Stromberg and Norberg 1971; Stromberg 1974; Jeffcott 1080; Purohit and McCoy 1980).

An increased understanding of the pathogenesis of these lesions should assist clinicians in the diagnosis, treatment and management of equine back lameness (Jeffcott 1975b, 1979a). The purposes of this study were to record the incidence and location of pathological changes in functionally normal thoracolumbar spines taken from horses during the course of another study (Townsend *et al* 1983) and to correlate the reported amount and type of spinal movement with the observed and reported incidence of pathological changes of the equine thoracolumbar spine.

Materials and methods

Twenty-three thoracolumbar spines were obtained from routine submissions of equine cadavers to the necropsy room of the Western College of Veterinary Medicine. The age, sex and breed of each horse and the procedure performed with each spine are shown in Table 1. After completion of flexion, extension and rotational studies (Townsend *et al* 1983), four thoracolumbar spines were sectioned mid-sagittally to allow the examination of each intervertebral disc for evidence of degenerative changes. All specimens were then wrapped in cheesecloth and boiled for 12 h to remove the soft tissues. Any remaining tissue was then washed or scrubbed away with a stiff brush. The vertebrae were then soaked in a weak solution of hydrogen peroxide for 8 h and air dried. Following these preparations, the specimens were examined for evidence of pathological change.

The location of each vertebral body osteophyte, relative to the end of each vertebra affected, was recorded and the size of each osteophyte was classified (Morgan, Ljunggren and Read 1967). If more than one osteophyte was present at the end of a vertebra, only the presence of the largest one was recorded (Morgan 1967).

The vertebral columns were also assembled and examined for signs of impingement of the dorsal spinous processes.

TABLE 1: Age, sex, breed, and pathological processes examined for in 23 equine thoracolumbar spines

Spine number	Age (years)	Sex	Breed	Impingement DSP	Osteophytes	IV disc degeneration
1	8	MC	TB	E	E	—
2	28	M	TB	E	E	—
3	4	MC	QH	E	E	—
4	10	MC	TB	E	E	—
5	8	F	QH	E	E	—
6	4	F	TB	E	E	—
7	5	MC	TB	E	E	—
8	3	M	G	E	E	—
9	5	MC	QH	E	E	—
10	5	MC	TB	E	E	—
11	8	F	G	E	E	—
12	25	F	TB	E	E	—
13	7	F	TB	E	E	—
14	23	F	G	E	E	E
15	12	F	G	E	E	E
16	8	MC	AR	—	—	E
17	7	F	TB	E	E	E
18	4	F	TB	E	E	—
19	10	F	TB	E	E	—
20	5	MC	TB	E	E	—
21	9	MC	TB	E	E	—
22	1	M	AR	—	E	—
23	4	MC	TB	E	E	—

DSP Dorsal spinous process
IV Intervertebral
MC Male castrate or gelding
M Male
F Female

TB Thoroughbred
QH Quarterhorse
G Grade or mixed breed
AR Arabian
E Examined

Impingement was considered to have occurred only if there was gross evidence of change visible on the opposing surfaces of the spinous processes. The degree of impingement was classified as follows: 'no impingement'; 'slight impingement' with shaping and eburnation of opposing surfaces; 'moderate impingement' with shaping, eburnation and bony proliferation; 'severe impingement' with marked bony proliferation and cavitation of the region; and 'fusion' of the dorsal spinous processes. The location of each site of impingement was recorded relative to the joint space at which it occurred.

It was assumed that the spines used in this study were functionally normal, based upon the fact that none of the spines were obtained from horses reported to be experiencing back pain.

Results

Of the 22 specimens examined for the presence of ventrolateral vertebral body osteophytes (Figs 1, 2 and 3), eight (36 per cent) had at least one ventrolateral osteophyte. In one instance, a single osteophyte was identified projecting from the fourth lumbar vertebra (L4) in a four-year-old gelding; all the remaining lesions occurred in animals aged seven years or older. The number, size and distribution of the osteophytes is presented in Fig 4. Most were small, with the majority occurring between the 10th thoracic vertebra (T10) and T17. The largest osteophytes were found on T11, T12 and T13. Fusion of vertebral body osteophytes projecting from adjacent vertebrae did not occur in any of these specimens.

Twenty-one thoracolumbar spines were examined for evidence of impingement of the dorsal spinous processes and the results are presented in Table 2. Evidence of impingement was found in 86 per cent of the specimens and the lesions occurred most commonly between T13 and T18 (Fig 5). There did not appear to be any relationship between age and severity or frequency of occurrence of impingement of the spinous processes.

Degeneration of the intervertebral discs was observed in three of the four specimens that were sectioned sagittally (Fig 6). The ages of the affected animals were eight, 12 and 23 years while the unaffected horse was aged seven years. The lesions appeared as a disruption or cavitation of the disc material resulting in the formation of a cleft in the centre of the disc. A yellowish discoloration and fibrillation of the disc material was observed around the edges of the cleft or cavitation. In one case this lesion occurred in the intervertebral disc between T1 and T2 and in the other two cases the lesion was observed in the lumbosacral disc.

Discussion

Fusion of the lateral joints of the lumbar spine was a common finding in these specimens and the frequency of the occurrence of these fusions (59 per cent at L5-6 and 23 per cent

TABLE 2: Frequency and severity of impingement of the dorsal spinous processes in 21 equine thoracolumbar spines

Severity	Percentage affected
No impingement	14
Slight impingement	34
Moderate periosteal reaction	38
Severe reaction and misshaping of spinous processes	14
Fusion	0

Fig 1. Oblique right dorsolateral view of T11 demonstrating a Grade 1, ventrolateral vertebral body osteophyte (arrow). a Cranial articular facet; p Caudal articular facet

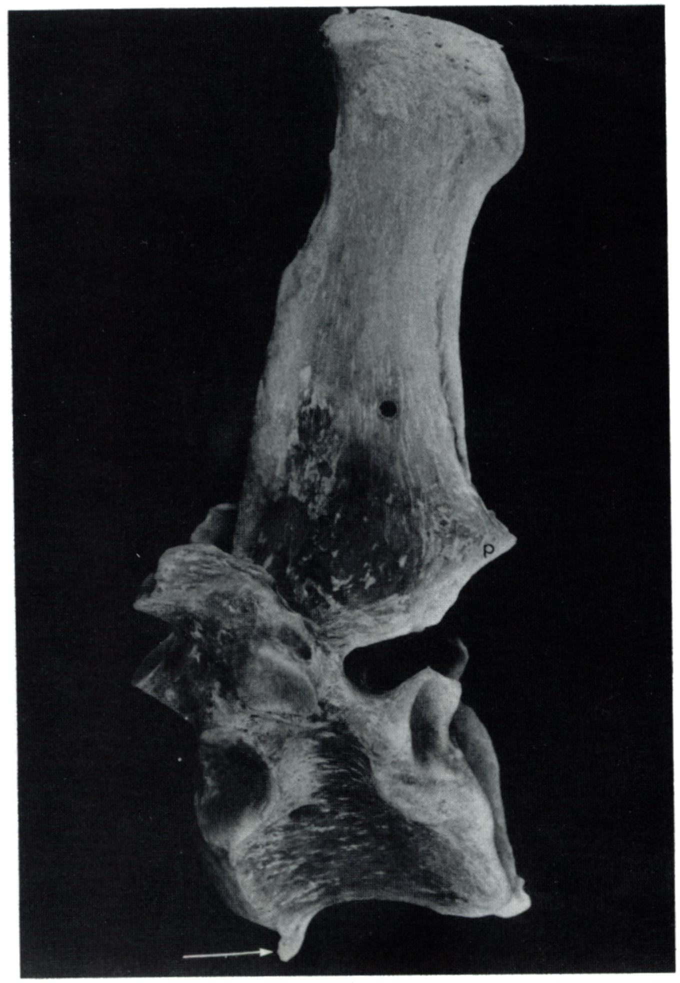

Fig 2. Left lateral aspect of T12 demonstrating a Grade 2 cranial, ventrolateral vertebral body osteophyte (arrow). p Caudal articular facet

at L4-5) has been reported previously (Townsend and Leach 1984). This condition was observed in specimens from horses aged three to 23 years. Stecher (1962) observed a similar frequency of occurrence of ankylosis of the lateral joints of the domestic horse. He stated that these fusions are not the result of advanced age because they may be seen in immature horses before the epiphyses have closed. Stecher (1962) concluded that these fusions are developmental, serving to increase the stability of the equine lumbar spine. The findings of the present and a previous study (Townsend and Leach 1984) support these conclusions. In view of these findings it seems unlikely that lateral joint fusions are an important cause of back pain.

Vertebral body osteophytes were observed with equal frequency in males and females; the lesions were evident in 36 per cent of 21 thoracolumbar spines examined and in 58 per cent of all those spines from animals older than six years of age. Jeffcott (1980) found osteophytes in only 2.7 per cent of 443 horses examined radiographically following a presenting complaint of a 'back problem' with the majority occurring in females. Lesions were not seen radiographically in 110 normal horses aged newborn to 27 years (Jeffcott 1979b). Most of the difference in the incidence reported in the present study as compared to those of Jeffcott is probably owed to the differing detection methods used, the examination of boiled and bleached vertebrae being a more sensitive means of osteophyte detection than radiography (Nathan 1962; Morgan *et al* 1967; Read and Smith 1968). There is, however, close agreement among the studies regarding the usual distribution of vertebral osteophytes (middle of the thoracolumbar spine) and the age of affected horses (seven years and older).

The term 'ossifying spondylosis' (Jeffcott 1975a, 1975b, 1977, 1978, 1979, 1980) has been used to describe vertebral body osteophytes in horses, but the morphological appearance of these lesions is the same as that described in the dog (Morgan 1967; Morgan *et al* 1967), cat (Read and Smith 1968), bull (Thomson 1969; Almquist and Thomson 1973), cetaceans (Lagier 1977) and man (Nathan 1962) as 'spondylosis deformans'. The exact pathogenesis of these lesions is not fully understood but biomechanical factors are thought to be involved (Morgan 1967; Morgan *et al* 1967; Badoux 1968; Read and Smith 1968; Thomson 1969; Gloobe and Nathan 1971, 1973; Almquist and Thomson 1973; Jeffcott 1975b; Ten Have and Eulderink 1980). Thomson (1969) summarises the pathogenesis of spondylosis deformans in the bull as degeneration of the annulus fibrosis leading to impairment of the function of the disc, probably abnormal movements between vertebral bodies; stimulation of bone formation at the vertebral corners and in the annulus fibrosis; and stimulation of periosteal bone formation on the ventral surface of the vertebral body. Although degenerative changes have not been described in the mid-thoracolumbar discs of the horse, the fact that vertebral body osteophytes occur most commonly in the area of maximum lateral and rotational movement of the

Fig 3. Left lateral aspects of T12 and T13 demonstrating a Grade 3 ventrolateral, vertebral body osteophyte projecting from each vertebral body (arrows). Fusion has not occurred

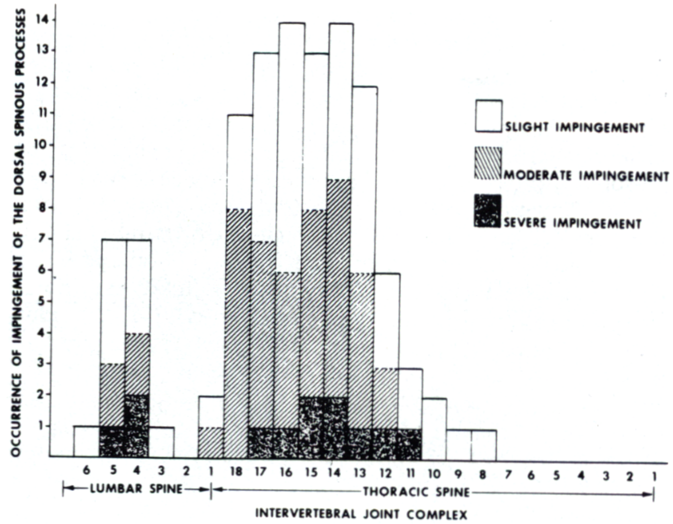

Fig 5. Frequency and severity of impingement of dorsal spinous processes of 21 equine thoracolumbar spines

thoracolumbar spine (Townsend *et al* 1983) is probably significant. Excessive strain of the outer fibres of the annulus fibrosis, with or without grossly detectable changes in the disc, may occur as a consequence of substantial axial rotation or lateral bending, or a coupling of these two motions in the thoracic spine. These lesions usually occur in older horses, suggesting that they are the result of repeated strain of the intervertebral joints over a number of years. To explore further these relationships, a gross and histological survey of equine thoracic intervertebral joints is required.

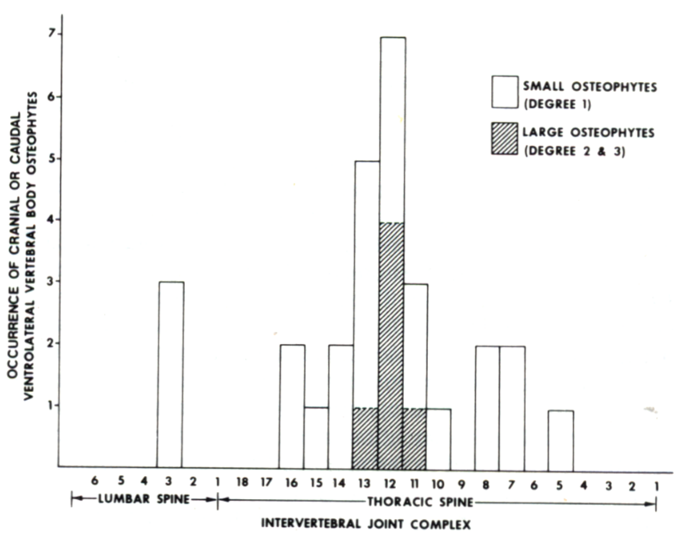

Fig 4. Distribution of ventrolateral vertebral body osteophytes in thoracolumbar spines obtained from horses with at least one detectable osteophyte

Impingement of the dorsal spinous processes of the thoracolumbar spine has been described as a pathological change of clinical significance in the horse by Roberts (1968) and more recently by Jeffcott and Hickman (1975). Affected animals are usually Thoroughbred or Hunter types and are frequently used for competitive jumping or dressage events (Jeffcott 1979a, 1980). The lesion involves the summits of the dorsal spinous processes from T12 to T18 (Jeffcott and Hickman 1975; Jeffcott 1979a; 1980) but the lumbar spine has also been reported to be affected (Roberts 1968). Some degree of impingement or overriding may be seen in normal animals (Jeffcott 1979b), but the likelihood of clinical signs being present increases with the severity of the lesion. Radiographically, impingement of the spinous processes may be accompanied by local periosteal reaction, focal areas of radiolucency and misshaping of the tips of the spinous processes (Jeffcott 1975b, 1980).

Eight-six per cent of the thoracolumbar spines examined in this study showed some evidence of impingement of the dorsal spinous processes, as compared to only 33 per cent in a radiographic study (Jeffcott 1980). The difference between studies is probably owed to the greater accuracy of detection afforded

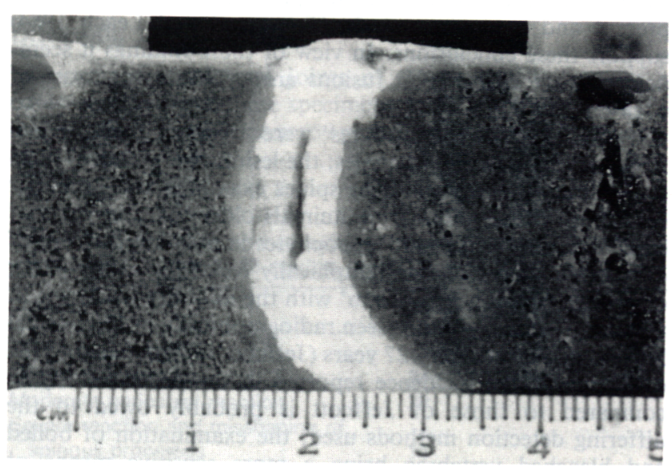

Fig 6. T1-2 intervertebral disc cavitation in a 12-year-old mare

by the direct examination of the macerated specimens. This would be particularly true of the most subtle effects of impingement which are eburnation and shaping of the points of contact between the dorsal spinous processes. There is close agreement between the present studies as to the anatomical location of the lesions in the affected animal, although the reason for its characteristic distribution is not certain. A recent study (Townsend *et al* 1983) did not show increased dorsoventral movement in the region where impingement occurs most commonly. Therefore, the condition appears to be caused by the gradual development of broad, flat dorsal spinous processes from about T12 to T18 resulting in a gradual narrowing of the interspinous spaces in this region during the first years of life. This is consistent with Jeffcott's (1980) suggestion that the underlying cause of the condition involves the conformation of the vertebral column. It also seems probable that back pain may result in severely affected horses if they are required to extend the back maximally, particularly when jumping.

Degeneration or cavitation of at least one intervertebral disc was observed in three of four spines sectioned mid-sagitally in this study. The lesion was observed in two locations, the first thoracic joint complex (T1-2) and the lumbosacral joint. The condition has been reported previously in the equine lumbosacral disc (Rooney 1970). Its pathogenesis is unknown, but may be associated with ageing, the relatively wide range of dorsoventral movement in these joints and the relatively greater thickness of the discs at these locations (Ten Have and Eulderink 1980; Townsend and Leach 1984). In the case of the lumbosacral disc, increased mechanical strain on this joint caused by the fusion of joint complexes cranial to it may also be of importance (Kirkaldy-Willis, Wedge, Yong-Hing and Reilly 1978).

It seems unlikely that degenerative disc disease is of any clinical significance in the equine thoracolumbar spine. The discs of affected joints appear completely fibrous in nature and do not contain a nucleus pulposus that can herniate and place pressure upon the cord or spinal nerve roots. When cavitation of equine intervertebral discs does occur it does not seem to be associated with significant narrowing of the disc space with diminution in the size of the intervertebral foramen and entrapment of the spinal nerve, part of the pathogenesis of back pain in man (Kirkaldy-Willis 1983). Affected joint complexes did not show evidence of pathological change of the articular facets, a painful consequence of degenerative disc disease in the human lumbar spine (Kirkaldy-Willis *et al* 1978).

No vertebral fractures were found during the course of this study, but an interesting relationship appears to exist between the mechanical characteristics of the equine thoracolumbar spine (Townsend *et al* 1983), the anatomical features of the intervertebral joint complexes (Townsend and Leach 1984) and reports of thoracolumbar fractures (Mason 1971; Moyer and Rooney 1971; Vaughan and Mason 1976; Jeffcott and Whitwell 1976). These fractures are not normally associated with evidence of external trauma. The most common circumstance under which they occur is a violent fall, particularly when jumping at speed (Vaughan and Mason 1976). Because of the mass of the animal and the length of its appendages, it is likely that compressive and rotational forces of a very high magnitude are applied to the spine under these circumstances.

Jeffcott and Whitwell (1976) have shown that fractures involving the thoracolumbar vertebral bodies usually occur in one of two areas: between T9 and T16 or between T18 and L6. Fractures occurring between T9 and T16 are usually compression fractures (Rooney 1969; Rooney 1971), resulting primarily in crushing of the vertebral body and tearing of the longitudinal ligaments and the intervertebral disc. Occasionally, fractures of the dorsal spinous processes and the neural arch are found as well (Moyer and Rooney 1971; Jeffcott and Whitwell 1976). The tendency towards compression fractures between T9 and T16 appears to be owed to a combination of the increased amount of axial and lateral movement occurring in this region (Townsend *et al* 1983) and the relatively small size of its vertebrae, particularly the small surface area of the vertebral end plates (Slijper 1946) over which compressive forces are distributed. In the spine, forces of compression and tension are concentrated in areas of high mobility (Weis 1975), leading to high compressive forces being applied to the vertebrae and high tensile forces being applied to the fibres of the intervertebral discs in these regions (Badoux 1965). The importance of axial rotation in spinal injuries is well recognised in man (Roaf 1960; Farfan 1969, 1973; Farfan *et al* 1970) and it has been stated that a combination of compression and rotation can produce almost every spinal injury (Roaf 1960). Therefore, it should not be surprising that the highest incidence of thoracic vertebral body fractures in the horse occurs around T12 (Jeffcott and Whitwell 1976), the region of greatest lateral and axial rotational movement (Townsend *et al* 1983).

Fractures of the region between T18 and L6 are almost invariably comminuted, involving the vertebral bodies, articular facets, neural arches and the spinous and transverse processes (Vaughan and Mason 1976). The articular surfaces of these vertebrae are much larger than those of the region around T12, making them much more resistant to compression fracture. However, the articular facets of the lumbar spine are deeply interlocking and although these structures serve to limit axial rotation (Townsend and Leach 1984), they also limit the ability of this region to absorb excessive axial rotational forces or torque without fracture of the articular facets and associated structures. This appears to account for the comminuted nature of the fractures reported in this region of the spinal column.

Acknowledgements

This work 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.

References

Adams, O. R. (1969) Subluxation of the sacroiliac joint in horses. *Proc. 15th Ann. Conv. Am. Ass. equine Pract.* pp 198-207.

Almquist, J. O. and Thomson, R. G. (1973) Relation of sexual behaviour and ejaculation frequency to severity of vertebral body osteophytes in dairy and beef bulls. *J. Am. vet. med. Ass.* **163**, 163-168.

Badoux, D. M. (1965) A contribution to the study of the body axis in mammals with specific reference to domesticated dog. *Proc. K. ned. Akad. wet.*, **C68**, 374-390.

Badoux, D. M. (1968) On the relation between the shape of the intervertebral discs and the frequency of hernia nuclei pulposi in domestic dog. *Proc. K. ned. Akad. wet.*, **C71**, 2-10.

Farfan, H. F. (1969) Effects of torsion on the intervertebral joints. *Can. J. Surg.* **12**, 336-341.

Farfan, H. F. (1973) *Mechanical Disorders of the Back.* Lea & Febiger, Philadelphia.

Farfan, H. F., Cossette, J. W., Robertson, G. H., Wells, R. V. and Kraus, H. (1970) The effects of torsion on the lumbar intervertebral joints: The role of torsion in the production of disc degeneration. *J. Bone Jt. Surg. (Am.)* **52**, 468-497.

Fraser, A. C. (1961) The treatment of lameness in horses by faradism: a report on one hundred cases. *Vet. Rec.* **73**, 94-100.

Geres, V. (1978) Radiological findings in diseases of skeletal parts of vertebral column, discs and spinal meninges in dog, cat and horse. *Zbl. Vet. Med., A* **25**, 363-382.

Gidean, L. (1977) Acupuncture: clinical trials in the horse. *J. Am. vet. med. Ass.* **170**, 220-224.

Gloobe, H. and Nathan, H. (1971) Vertebral osteophytes in rats. *J. comp. Path.* **81**, 575-579.

Gloobe, H. and Nathan, H. (1973) Osteophyte formation in experimental bipedal rats. *J. comp. Path.* **83**, 133-141.

Hansen, H. J. (1959) Comparative views on the pathology of disc degeneration in animals. *Lab. Invest.* **8**, 1242-1257.

Herrod-Taylor, E. E. (1967) A technique for manipulation of the spine in horses. *Vet. Rec.* **81**, 437-439.

Jeffcott, L. B. (1975a) Radiographic examination of the equine back case. *J. S. Afr. vet. med. Ass.* **46**, 133-134.

Jeffcott, L. B. (1975b) The diagnosis of diseases of the horse's back. *Equine vet. J.* **7**, 69-78.

Jeffcott, L. B. (1977) The diagnosis and treatment of some disorders of the thoracolumbar spine of the horse. Fellowship thesis, Royal College of Veterinary Surgeons.

Jeffcott, L. B. (1978) Disorders of the equine thoracolumbar spine — a review. *J. equine Med. Surg.* **2**, 9-19.

Jeffcott, L. B. (1979a) Back problems in the horse — a look at past, present and future progress. *Equine vet. J.* **11**, 129-136.

Jeffcott, L. B. (1979b) Radiographic features of the normal equine thoracolumbar spine. *Vet. Radiol.* **20**, 140-147.

Jeffcott, L. B. (1980) Disorders of the thoracolumbar spine of the horse — a survey of 443 cases. *Equine vet. J.* **12**, 197-210.

Jeffcott, L. B. and Dalin, G. (1980) Natural rigidity of the horse's backbone. *Equine vet. J.* **12**, 101-108.

Jeffcott, L. B. and Hickman, J. (1975) The treatment of horses with chronic back pain by resecting the summits of the impinging dorsal spinous processes. *Equine vet. J.* **7**, 115-119.

Jeffcott, L. B. and Whitwell, K. E. (1976) Fractures of the thoracolumbar spine of the horse. *Proc. 23rd Ann. Conv. Am. Ass. equine Pract.* pp 91-102.

Kirkaldy-Willis, W. H. (1983) The pathology and pathogenesis of low back pain. In: *Managing Low Back Pain.* Ed W. H. Kirkaldy-Willis, Churchill Livingstone, New York. pp 23-43.

Kirkaldy-Willis, W. H., Wedge, J. H., Yong-Hing, K. and Reilly J. (1978) Pathology and pathogenesis of lumbar spondylosis and stenosis. *Spine* **3**, 319-328.

Lagier, R. (1977) Spondylosis in the whale — an anatomic or radiological study of an osteophyte. *Scand. J. Rheumatol.* **6**, 245-249.

Mason, B. J. E. (1971) A case of spinal cord compression causing paraplegia of a foal. *Equine vet. J.* **3**, 155-157.

Mitchell, W. M. (1933) Some aspects of the general osteoarthritic problem in the horse. *Vet. Rec.* **13**, 918-924.

Morgan, J. P. (1967) Spondylosis deformans in the dog. *Acta. Orthop. Scand. Suppl.* **96**.

Morgan, J. P., Ljunggren, G. and Read, R. (1967) Spondylosis deformans (vertebral osteophytosis) in the dog. *J. small Anim. Pract.* **8**, 57-66.

Moyer, W. A. and Rooney, J. R. (1971) Vertebral fracture in the horse. *J. Am. vet. med. Ass.* **159**, 1022-1024.

Nathan, H. (1962) Osteophytes of the vertebral column. *J. Bone Jt. Surg. (Am.)* **44**, 243-268.

Purohit, R. C. and McCoy, M. D. (1980) Thermography in the diagnosis of inflammatory processes in the horse. *Am. J. vet. Res.* **41**, 1167-1174.

Read, R. M. and Smith, R. N. (1968) A comparison of spondylosis deformans in the English and Swedish cat and in the English dog. *J. small Anim. Pract.* **9**, 159-166.

Roaf, R. (1960) A study of the mechanics of spinal injuries. *J. Bone Jt. Surg. (Br.)* **42**, 810-823.

Roberts, E. J. (1968) Resection of thoracic or lumbar spinous processes for the relief of pain responsible for lameness and some other locomotor disorders of horses. *Proc. 14th Ann. Conv. Am. Ass. equine Pract.* pp 13-30.

Rooney, J. R. (1969) *Biomechanics of Lameness in Horses.* Williams & Wilkins Co, Baltimore.

Rooney, J. R. (1970) *Autopsy of the Horse.* Williams & Wilkins Co, Baltimore.

Rooney, J. R. (1971) *Clinical Neurology of the Horse.* KNA Press Inc, Kennett Square, Pennsylvania,

Rooney, J. R. (1977) Sacroiliac arthrosis and "stifle lameness". *Mod. vet. Pract.* **28**, 138-139.

Rooney, J. R., Delaney, F. M. and Mayo, J. A. (1969) Sacroiliac luxation in the horse. *Equine vet. J.* **1**, 287-289.

Salis, B. von and Huskamp, B. (1978) Vorlaufige erfahrungen mit der konservativen and chirurgischen behandlung der wirbersaulenerkrakrung der pferd. *Der praktische Tierarzt.* **59**, 281-283.

Slijper, E. J. (1946) Comparative biologic-anatomical investigations on the vertebral column and spinal musculature of mammals. *Proc. K. ned. Adak. wet. Verh (Tweed Sectie)* **47**, 1-128.

Smythe, R. H. (1962) Ankylosis of the equine spine: pathologic or biologic? *Mod. vet. Pract.* **43**, 50-51.

Stecher, R. M. (1962) Lateral facets and lateral joints in the lumbar spine of the horse — A descriptive and statistical study. *Am. J. vet. Res.* **96**, 939-947.

Stecher, R. M. and Goss, L. F. (1961) Ankylosing lesions of the spine. *J. Am. vet. med. Ass.* **138**, 248-255.

Stromberg, B. (1974) The use of thermography in equine orthopedics. *J. Am. vet. Rad. Soc.* **15**, 94-97.

Stromberg, B. and Norberg, I. (1971) Infra-red emisson and Xe-disappearance rate studies in the horse. *Equine vet. J.* **1**, 1-7.

Sumner, H. (1948) Equine accidents in the field of sport. *Vet. Rec.* **60**, 579-581.

Swanstrom, O. G. and Lindy, M. (1973) Therapeutic swimming. *Proc. 18th Ann. Conv. Am. Ass. equine Pract.* pp 315-322.

Taylor, H. W., Vandevelde, M. and Firth, E. C. (1977) Ischemic myelopathy caused by fibrocartilaginous emboli in the horse. *Vet. Path.* **14**, 479-481.

Ten Have, H. A. M. and Eulderink F. (1980) Degenerative changes in the cervical spine and their relationships to its mobility. *J. Path.* **132**, 133-159.

Thomson, R. G. (1969) Vertebral body osteophytes in bulls. *Path vet. Suppl.* **6**.

Townsend, H. G. G., Leach, D. H. and Fretz, P. B. (1983) Kinematics of the equine thoracolumbar spine. *Equine vet. J.* **15**, 117-122.

Townsend, H. G. G. and Leach, D. H. (1984) The relationship between the intervertebral joint morphology and mobility in the equine thoracolumbar spine. *Equine vet. J.* **16**, 461-465.

Vaughan, L. C. and Mason, J. E. (1976) A clinico-pathological study of racing accidents in horses. *A Report of a Study on Equine Fatal Accidents on Race Courses.* Financed by the Horserace Betting Levy Board.

Weis, E. B. (1975) Stresses at the lumbosacral junction. *Orth. Clin. N. Am.* **6**, 83-91.

Received for publication 15.11.84
Accepted 30.8.85