The ability of horses to move and dynamically stabilize the neck and back are integral to all forms of equine locomotion, including natural gaits and sport-specific performance. Cervical dynamic mobilization exercises involve voluntary movements of the neck through a wide range of motion into positions that cannot be achieved during locomotion. They are used with the goals of improving athletic performance and reducing the risk of injury by activating and strengthening the muscles that move and stabilize the vertebral column. These exercises also have potential therapeutic value in restoring locomotor function following injury, immobilization, or surgery. In humans, cervical injuries or neck pain affect and modify cervical motor control. For example, pain may inhibit contraction of the cervical muscles and interfere with stabilization by the deep cervical flexors (longus colli and longus capitis muscles) and extensors (musculi multifidi). When control problems involving these cervical muscles are addressed with specific gentle exercise strategies, neck pain and its associated symptoms are reduced. Dynamic mobilization exercises potentially have functional therapeutic effects by increasing the active range of joint motion and strengthening the associated musculature. In humans, it has been suggested that therapeutic exercises for neck pain should coordinate neck muscle activity with visual and vestibular input. In horses, dynamic mobilization exercises may fulfill these requirements via coordinated muscular activity to move and stabilize the joints during different types of cervical movement. Anecdotal evidence suggests that regular performance of dynamic mobilization exercises may be an appropriate therapeutic technique for restoration of normal function in horses with signs of neck or back pain or dysfunction. Experimental evidence has confirmed that regular performance of a series of dynamic mobilization exercises is associated with hypertrophy of the thoracic and lumbar musculi multifidi. Restoration of normal motor control and strengthening the epaxial and hypaxial musculature are likely to improve postural stability, joint position sense, and whole body postural orientation after injury to the neck or back. To understand the benefits and contraindications to the use of these exercises, it is important to evaluate their effects on the intersegmental vertebral column.

**Objective**—To identify differences in intersegmental bending angles in the cervical, thoracic, and lumbar portions of the vertebral column between the end positions during performance of 3 dynamic mobilization exercises in cervical lateral bending in horses.

**Animals**—8 nonlame horses.

**Procedures**—Skin-fixed markers on the head, cervical transverse processes (C1-C6) and spinous processes (T6, T8, T10, T16, L2, L6, S2, and S4) were tracked with a motion analysis system while the horses standing in a neutral position and in 3 lateral bending positions to the left and right sides during chin-to-girth, chin-to-hip, and chin-to-tarsus mobilization exercises. Intersegmental angles for the end positions in the various exercises performed to the left and right sides were compared.

**Results**—The largest changes in intersegmental angles were at C6, especially for the chin-to-hip and chin-to-tarsus mobilization exercises. These exercises were also associated with greater lateral bending from T6 to S2, compared with the chin-to-girth mobilization or neutral standing position. The angle at C1 revealed considerable bending in the chin-to-girth position but not in the 2 more caudal positions.

**Conclusions and Clinical Relevance**—The amount of bending in different parts of the cervical vertebral column differed among the dynamic mobilization exercises. As the horse’s chin moved further caudally, bending in the caudal cervical and thoracolumbar regions increased, suggesting that the more caudal positions may be particularly effective for activating and strengthening the core musculature that is used to bend and stabilize the horse’s back. (Am J Vet Res 2012;73:1153–1159)
of specific exercises in a therapeutic context, it is first necessary to evaluate their effects in horses that do not have signs of neck or back pain. In a previous study, we investigated the kinematic effects of dynamic mobilization exercises performed in cervical flexion. The findings indicated that the upper cervical intervertebral joints have most flexion when the chin moves toward the manubrium, whereas lower neck positions with the chin between the carpi or metacarpophalangeal joints (forelimb fetlocks) are associated with extension of the cranial cervical joints and greater flexion at the base of the neck and in the thoracic region. Thus, by enticing the horse to adopt a variety of positions, the segmental musculature in different areas of the vertebral column can be recruited to stabilize the intervertebral joints. The kinematic effects of cervical dynamic mobilization exercises performed in lateral bending have not been described. This information would be useful to veterinarians and therapists who use baited stretches or manually induced bending to assess intervertebral mobility and to detect areas with increased or decreased movement, compared with the expected range of motion.

The purpose of the study reported here was to measure and compare lateral bending of the cervical, thoracic and lumbar vertebral column in a neutral standing position and at end range of motion in 3 dynamic mobilization exercises that involve bending the neck laterally into specific positions. This information will indicate which dynamic mobilization exercises are most and least effective in bending different parts of the horse’s cervical, thoracic, and lumbar vertebral column. The experimental hypotheses were that the 4 positions (neutral standing and chin-to-girth, chin-to-hip, and chin-to-tarsus mobilization exercises) are associated with major changes in the intersegmental angles in different regions of the cervical, thoracic, and lumbar vertebral column and that, during performance of the dynamic mobilization exercises, the amount of intersegmental bending is equal to the left and right sides.

Materials and Methods

Horses—The study protocol was approved by the Michigan State University Institutional Animal Care and Use Committee. The 8 Arabian horses used in the study were evaluated at rest and in motion and had a lameness grade < 1 on the 5-point lameness scale described by the American Association of Equine Practitioners. Horses were subjected to a palpatory physical examination by an experienced physiotherapist (NCS); none had overt signs of neck or back pain. The horses were (mean ± SD) 13.4 ± 4.3 years old and were similar in height (149.1 ± 2.0 cm) and body weight (435.6 ± 19.5 kg). In the 3 months preceding data collection, the horses had not been ridden or forcibly exercised but they had been turned out daily in small paddocks. Dur-
ing this time, they had performed dynamic mobilization exercises on 5 d/wk as part of another study.\footnote{7}

In preparation for data collection, 6-mm reflective markers were attached to each horse's skin with doublesided tape over the following bony landmarks: the head (6 markers [2 on the dorsal midline and 1 each on the left and right facial crests and caudal parts of the zygomatic arch]); bilaterally over the caudal part of the transverse processes of the first 6 cervical vertebrae; on the dorsal midline overlying the spinous processes of the thoracic (T6, T8, T10, T12, T14, and T16), lumbar (L2 and L6), sacral (S2 and S4), and caudal (Ca1) vertebrae; proximally and distally on the tail; bilaterally over ribs 10, 13, and 16, the tuber spinae scapulae, and the ventral part of the tuber coxae; on the ventral midline at the level of the 3 rib markers; and on the lateral wall of each hoof (Figure 1).

**Dynamic mobilization exercises**—Three dynamic mobilization exercises were performed in cervical lateral bending. A piece of carrot was used as bait to entice the horses to take the chin to the desired position. In all exercises, the chin was laterally separated from the body wall on the same side by at least 0.3 m. The 3 positions were chin-to-girth mobilization, in which the chin was moved laterally to a position just caudal to the triceps at the height of the ventral body wall; chin-to-hip mobilization, in which the chin was moved caudally to the level of the flank then dorsally toward the coxofemoral joint; and chin-to-tarsus mobilization, in which the chin was moved caudally to the level of the flank and then ventrally toward the tarsus (Figure 1).

**Data collection**—A 10-camera motion analysis system\footnote{8} was used to collect kinematic data. A 4 × 2.5 × 3-m volume was calibrated via a wand technique, resulting in an error < 0.8 mm in a linear measurement of 1.0 m within the calibrated volume. The longitudinal axis of the horse's body was aligned with the longitudinal axis of the data collection volume. When viewed from the side, the 2 forelimbs and the 2 hind limbs were offset by ≤ 10 cm. Recordings were made with each horse standing stationary in a neutral position and in the end position for the 3 mobilization exercises. Five repetitions were recorded to the left and right sides in random order.

**Data analysis**—The markers were tracked with proprietary software,\footnote{9} and the marker coordinate data were filtered by a Butterworth low-pass digital filter with 15-Hz cutoff frequency. Trials were screened for correct starting position and correct performance of the exercises by evaluating software-generated stick figures on the basis of rigid segments connecting specific skin markers. Trials were discarded if the horse's body was not aligned with the coordinates of the data collection volume, the mobilization exercises were performed incorrectly, or the hooves moved during the trial. Three trials that were representative of the correct performance of each exercise were analyzed. Angles were measured in the dorsal plane on the side of the body toward which the horse was bending.

The angles in the neutral position are close to 180° for most joints, although the cervical angles vary a little because of the shape and contours of the neck (Figure 1). At the cervicothoracic junction, a rigid segment was constructed that ran obliquely from the laterally placed marker on the transverse process of C6 to the dorsal spinous process of T6. As a consequence of the lateral to medial deviation of the C6-T6 segment, the neutral angle at C6 was < 180° and the neutral angle at T6 was > 180°. In the thoracic, lumbar, and sacral regions, successive markers on the dorsal spinous processes were connected to form rigid segments and the angles between adjacent segments were measured in the dorsal plane.

**Statistical analysis**—Statistical software\footnote{10} was used to calculate descriptive statistics (mean ± SD) for the angular variables for each mobilization exercise and for the corresponding neutral position. The measured variables were found to be normally distributed via the Shapiro-Wilks test. Differences in angulations between the neutral position and the end positions for the 3 mobilization exercises to each side were sought via repeated-measures ANOVA with Bonferroni post hoc tests. Paired \( t \) tests were used to compare values recorded when the exercises were performed to the left and right sides. For all statistical tests, values of \( P < 0.05 \) were considered significant.
Results
Comparison of the end positions for the 3 dynamic mobilization exercises and the neutral position indicated significant differences in lateral bending angles at almost every level in the cervical vertebral column (Table 1; Figure 3). The angle at C1 bent the most (concave on the inside of the turn; angle < 180°) in the chin-to-girth mobilization and was counter-bent (convex on the inside of the turn; angle > 180°) in the chin-to-hip and chin-to-tarsus mobilization exercises. The joints at C2, C3, C4, and C5 had moderate amounts of bending in all mobilization exercises. At C6 and throughout the thoracolumbar vertebral column, the largest amounts of bending were associated with the chin-to-hip and chin-to-tarsus mobilization exercises, which did not differ from each other but were both significantly different from the neutral and chin-to-girth positions at most vertebral levels (Table 1; Figure 3).

The mean SD over all vertebral levels and conditions was 1.5°, which allowed small differences between the left and right sides to be detected. The smallest significant difference between left and right sides (Table 1) was 2.31° for the chin-to-girth mobilization at C3. In the cervical region, an exercise resulted in asymmetric bending to the left and right sides at a specific spinal level in 6 instances and, for 5 of these positions, the lateral bending angle was smaller when performing the exercise to the left. Asymmetries were also recorded in the region of the lumbosacral junction, where there was more lateral bending to the right at L5 and to the left at S2 in all 3 mobilization exercises.

Table 1—Mean ± SD dorsal plane intervertebral joint angles (°) in the neutral standing position and in end position in 3 dynamic mobilization exercises performed in lateral bending by 8 nonlame horses.

<table>
<thead>
<tr>
<th>Vertebral segment</th>
<th>Left dynamic mobilization exercises</th>
<th>Right dynamic mobilization exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Neutral</td>
<td>Chin-to-girth</td>
</tr>
<tr>
<td>C1</td>
<td>184.83 ± 3.44</td>
<td>149.92 ± 4.17*</td>
</tr>
<tr>
<td>C2</td>
<td>181.29 ± 3.58</td>
<td>163.78 ± 6.93</td>
</tr>
<tr>
<td>C3</td>
<td>156.00 ± 3.70</td>
<td>162.69 ± 4.62*</td>
</tr>
<tr>
<td>C4</td>
<td>183.52 ± 3.94</td>
<td>167.67 ± 5.07</td>
</tr>
<tr>
<td>C5</td>
<td>175.93 ± 8.02</td>
<td>156.17 ± 3.82</td>
</tr>
<tr>
<td>C6</td>
<td>161.62 ± 6.05</td>
<td>125.91 ± 6.79</td>
</tr>
<tr>
<td>T6</td>
<td>192.59 ± 7.55</td>
<td>159.12 ± 10.68</td>
</tr>
<tr>
<td>L5</td>
<td>191.73 ± 9.82</td>
<td>172.57 ± 3.39</td>
</tr>
<tr>
<td>L6</td>
<td>179.72 ± 7.64</td>
<td>177.03 ± 9.23</td>
</tr>
<tr>
<td>T12</td>
<td>178.87 ± 7.24</td>
<td>176.68 ± 6.87</td>
</tr>
<tr>
<td>T14</td>
<td>176.96 ± 7.67</td>
<td>176.47 ± 7.92</td>
</tr>
<tr>
<td>T16</td>
<td>181.60 ± 7.24</td>
<td>183.04 ± 7.74</td>
</tr>
<tr>
<td>L1</td>
<td>179.93 ± 12.99</td>
<td>177.27 ± 12.52</td>
</tr>
<tr>
<td>L3</td>
<td>181.27 ± 9.95</td>
<td>181.52 ± 9.54</td>
</tr>
<tr>
<td>L5</td>
<td>183.88 ± 3.03*</td>
<td>184.62 ± 3.05*</td>
</tr>
<tr>
<td>S2</td>
<td>176.85 ± 4.27</td>
<td>176.92 ± 4.69*</td>
</tr>
<tr>
<td>S1</td>
<td>182.64 ± 4.43</td>
<td>182.85 ± 4.49*</td>
</tr>
</tbody>
</table>

Angles are measured on the side to which the horses are bending.
*Values differ significantly between left and right sides.
**Values with similar superscript letters differ significantly between the neutral and bent positions performed to the same side.
Discussion

Results of the study indicated that when horses performed dynamic mobilization exercises in cervical lateral bending, most movement took place in the cranial and caudal parts of the cervical vertebral column, with smaller movements in the midcervical and thoracolumbar regions. In general, these findings supported our experimental hypothesis that cervical lateral bending angles for the 3 mobilization exercises differ significantly from the neutral standing position. The hypothesis regarding symmetry of bending to the left and right sides was not supported for some positions at specific levels in the cervical region or around the lumbosacral junction.

Regardless of whether dynamic mobilization exercises are performed in cervical flexion or lateral bending, the intersegmental angles with the largest angular displacement are at the base of the neck and in the poll region. In preliminary studies, the authors found that if horses perform the dynamic mobilization exercises in lateral bending with the chin adjacent to the body wall, the neck tends to jackknife from its base. To avoid this effect, therapists perform the exercises with the chin separated from the body wall by approximately 30 cm, and this was the position used in the study. When assessing neck motion and detecting sites where motion is reduced, it is important for veterinarians and therapists to realize that the midcervical joints bend considerably less than those at the base of the neck. Furthermore, the amount of bending measured in vivo in the present study differed from that in in vitro studies that indicate a progressive increase in range of motion in lateral bending at each intervertebral joint from C2-C3 to C5-C6. The deep vertebral musculature, which was removed in the in vitro studies, may provide stiffness to the intervertebral joints and may account for the apparent reduction in mobility in vivo.

The joints between the occipital condyles and C1 and between C1 and C2 are highly specialized to allow 3-D movements of the head to provide a stable platform for visual, vestibular, and proprioceptive input. In addition to having a large range of motion in flexion-extension, the atlanto-occipital joint allows lateral bending and gliding, which are ultimately limited by impingement of the jugular process of the skull on the lateral arch of the atlas rather than by soft tissue constraints. The joint bends further when it is extended, compared with when it is flexed, which may explain the relatively large range of lateral bending at C2 for the chin-to-girth mobilization, compared with in vitro measurements that revealed 44° range of motion between maximal lateral bending to the left and right sides. The large range of motion in flexion-extension and lateral bending at the cervicothoracic junction both in vitro and in vivo allows the neck as a whole to be raised, lowered, or turned in all directions from its base. Preservation of the range of motion at the base of the neck is important for everyday activities, such as grazing and self-grooming. Mobilization exercises that move the chin ventrally, as in the chin-between-carpi or chin-between-fetlocks mobilization exercises, or caudolaterally, as in the chin-to-hip or chin-to-tarsus mobilization exercises performed in this study, are particularly effective in stimulating and maintaining a large range of motion at the base of the neck. The fact that asymmetric bending to the left and right sides revealed more bending to the left may be related to the subjective assessment that most horses are more supple or flexible on the left.

The segments contributing to intersegmental motion at both L5 and S2 span the lumbosacral joint. Clearly, the segment from S2 to S4 is rigid and lateral bending at S2 is attributed to motion at the lumbosacral joint and the last lumbar intervertebral joint. The angle measured at S2 bent more to the left in all mobilization exercises, whereas the angle at L5 bent more to the right both in the standing position and during all the mobilization exercises. The low SDs at these 2 joints indicated consistency across horses. The opposite pattern was seen in one horse, which had more bending to the left at L5 and more bending to the right at S2 across all conditions; another horse had more bending to the right at S2. These findings suggest a greater contribution at the lumbosacral or last lumbar intervertebral joints for bending to the left and a greater contribution from the lumbar intervertebral joints between L3 to L5 during bending to the right even in the standing position, which may be indicative of an inherent sidedness pattern. Anecdotal evidence suggests that the majority (70%) of horses move with their haunches deviated to the left, which could be indicative of neuromuscular patterning differences. Future research on the sidedness patterns of individual horses and their effects on locomotor kinematics and kinetics may shed further light on the lumbar asymmetries noted in the present study.

In humans and horses, the deep vertebral stabilizing muscles, such as musculi multifidi and musculus longus colli, are characterized by having short fibers that unite adjacent vertebrae or that cross few intervertebral levels and play a primary role in controlling movements of individual intervertebral joints. Typically, these muscles are stratified, with the deepest fascicles being the shortest. In humans, the deeper fascicles of musculi multifidi in the thoracolumbar vertebral column are coactivated with the abdominal muscles in anticipation of the need for trunk stability and act primarily to resist bending moments and axial rotational moments created by the abdominal muscles. The more superficial fascicles, which have longer moment arms, contribute to the bending moment at the intervertebral joints. The architecture and functions of the equine musculi multifidi appear similar to those of their counterparts in humans. The main reason for investigating the kinematics of dynamic mobilization exercises relates to the potential value of these exercises in the treatment and prevention of signs of neck and back pain through their ability to activate the deep vertebral stabilizing muscles.

Human back pain is associated with ipsilateral atrophy of musculi multifidi and probable loss of preparatory activity in the vertebral stabilizing musculature. Horses with severe osseous vertebral pathological lesions in the thoracolumbar region have also been confirmed to have atrophy of musculi multifidi ipsilaterally and at the same vertebral level as the osseous lesion. In rehabilitation of human back pain,
exercises that involve a sequence of vertebral movement followed by static holding of the position before controlled release back to the initial position have been determined to be particularly effective in reactivating and strengthening the deep vertebral stabilizing musculature. Dynamic mobilization exercises follow this pattern, with the horse being encouraged to maintain the end position for 5 seconds. The horses used in this study had performed dynamic mobilization exercises 5 d/wk for 3 months prior to the data collection, and during this time, cross-sectional area of musculi multifidi increased significantly at all 6 vertebral levels between T10 to L5 at which it was measured. The present study revealed that the chin-to-hip and chin-to-tarsus mobilization exercises were associated with thoracolumbar bending. It is likely that musculi multifidi are activated to stabilize the intervertebral joints in opposition to the bending and rotational moments created by the longissimus dorsi and abdominal muscles. Strengthening of the deep stabilizing muscles has a therapeutic effect in restoring vertebral stability and has a prophylactic effect in preventing micromotion of the intervertebral joints that predisposes to arthritic changes.

Humans with chronic neck pain have atrophy of the cervical musculi multifidi and longus colli. An evaluation of evidence-based studies of noninvasive treatments for human neck pain suggested that manual treatment and exercise are most effective. A combination of isometric, dynamic, and stretching exercises may be more effective than any of these exercise types alone. Patients with chronic neck pain benefit from a neck exercise program and have considerable improvements in disability, pain, and isometric cervical muscle strength within 6 weeks. In horses, dynamic mobilization exercises fulfill the criteria for effective rehabilitation exercises by requiring dynamic movement of the neck into a stretched position with isometric muscular activity to hold that position. This type of exercise is likely to activate musculi multifidi and musculus longus colli to stabilize the intervertebral joints in a variety of neck positions. Cervical facet arthritis occurs most frequently at the joints between C5 to T1. If signs of pain associated with arthritis changes result in inactivity and atrophy of the horse’s deep stabilizing muscles as in humans, then instability of the joints may predispose to further arthritic changes. The joints at the base of the neck have the largest amount of motion in the dynamic mobilization exercises, suggesting the likelihood that beneficial effects will be seen in this region.

Some therapists use passive mobilization techniques that manipulate the neck into more extreme positions than those achieved by voluntary muscular contraction. It is uncertain whether this type of manual manipulation is desirable or has a potentially destabilizing effect by stretching the supporting soft tissues beyond their normal length. At the present time, it is also uncertain whether equine manipulative or mobilization techniques are more effective when combined with exercise-based treatment. Sources of errors in the present study include skin displacement relative to the underlying bones and errors inherent in the projection of 3-D data onto a 2-D plane. In the equine thoracic vertebral column, lateral bending is coupled with axial rotation; when the intervertebral joint bends to one side, the spinous processes rotate toward the opposite side. This effect is most apparent around T11-T12, which coincides with the region with the largest amount of lateral bending. When viewed in the dorsal plane, both lateral bending and axial rotation cause the dorsal spinous processes to be displaced laterally and may result in some of the motion ascribed to lateral bending being caused by axial rotation. During locomotion, it has been estimated that 15% to 30% of the errors in measuring lateral bending angles in the equine thoracolumbar vertebral column are caused by skin displacement and the 2-D analysis procedure. Skin displacement relative to the underlying bony landmarks has not been quantified in the cervical region, and consequently, correction algorithms are not available. The skin in the neck is quite mobile, so errors may be similar in magnitude to those in the proximal portions of the limbs. As in the limbs, kinematic data from the cervical and cranial thoracic regions that have not been corrected for skin displacement may be adequate for repeated-measures comparisons as in the present study, but the absolute values should be regarded as approximations. It should be noted that the end positions were assessed subjectively and that some horses appeared more motivated than others to reach the bait. Inevitably, this introduced some variation among subjects, but there was still consistency among horses in the areas of the vertebral column with more or less bending in the different mobilization exercises. In making comparisons between bending to the left and right sides, it is expected that skin displacement artifacts will be similar on the 2 sides. Despite these limitations, the methodology used in the present study should be representative of the general patterns of vertebral motion in vivo. The intersegmental angles measured in this study are not the same as the intervertebral angles, but they do indicate relative changes in orientation in different parts of the neck and back. A further limitation of the study was that all the horses were Arabsians, and it is not known whether horses of other breeds would respond differently.

In conclusion, when horses performed cervical dynamic mobilization exercises in lateral bending, the largest angular changes occurred in the upper (C1) and lower (C6) regions. The chin-to-girth position induced significant lateral bending at all cervical levels, especially C1. When the chin moved more caudally in the chin-to-hip and chin-to-tarsus mobilization exercises, lateral bending was greatest at C6. The 2 more caudal positions were also associated with bending of the thoracolumbar vertebral column from T6 to the lumbarosacral junction, which may activate the deep stabilizing musculi multifidi. The findings of this study support the potential clinical applications of dynamic mobilization exercises in horses.

References


