Evaluation of the anatomic effect of physical therapy exercises for mobilization of lumbar spinal nerves and the dura mater in dogs

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**Objective**—To adapt and standardize neural tissue mobilization exercises, quantify nerve root movement, and assess the anatomic effects of lumbar spinal nerve and dural mobilization in dogs.

**Animals**—15 canine cadavers.

**Procedures**—5 cadavers were used in the preliminary part of the study to adapt 3 neural tissue mobilization physical therapy exercises to canine anatomy. In the other 10 cadavers, the L4 to L7 nerve roots and the dura at the level of T13 and L1 were isolated and marked. Movements during the physical therapy exercises were standardized by means of goniometric control. Movement of the nerve roots in response to each exercise was digitally measured. The effects of body weight and crow-rump length on the distance of nerve root movement achieved during each exercise were also assessed. Each exercise was divided into 4 steps, and the overall distance of neural movement achieved was compared with distances achieved between steps.

**Results**—Neural tissue mobilization exercises elicited visible and measurable movement of nerve roots L4 to L7 and of the dura at T13 and L1 in all cadavers.

**Conclusions and Clinical Relevance**—The physical therapy exercises evaluated had measurable effects on nerve roots L4 to L7 and the dura at T13 and L1 segments. These exercises should be evaluated in clinical trials to validate their efficacy as primary treatments or ancillary postsurgical therapy in dogs with disorders of the thoracolumbar and lumbosacral segments of the vertebral column. (Am J Vet Res 2006;67:1773–1779)

Interest in physical therapy as adjunctive treatment for neurologic and orthopedic disorders has increased among veterinarians and pet owners. Substantial progress has been made in understanding the effects of physical therapy and development of techniques. However, the discipline is still often conducted on the basis of personal experiences rather than results of anatomic and clinical studies. Few guidelines exist for the use of physical therapy in the post-operative care of veterinary patients, and the guidelines that are available are often tailored to orthopedic problems. Because many structures are involved in the complex act of locomotion, physical therapy should not be considered as a treatment option for joint mobilization and joint diseases alone. In addition to joint function, muscular activity and neuronal circuits are also involved in gait and movement.

The practice of nerve tissue mobilization originated in 1864 when it was discovered that pain could be induced in humans with sciatica by stretching the sciatic nerve via extension of the knee (stifle joint in dogs) with concurrent flexion of the hip joint. Remarkably, pain disappeared after flexing the knee. In 1950, Woodhall and Hayes reported that pain was elicited by simultaneous dorsiflexion of the ankle joint, extension of the knee joint, flexion of the hip joint, and flexion of the neck in patients with ruptured intervertebral disks in the lower portion of the vertebral column. This phenomenon was described as the positive straight-leg (limb)-raising test and was introduced as a diagnostic aid to detect sciatic nerve damage.

Nerve roots can be mobilized by certain passive exercises, many of which were analyzed and developed in the 1960's and 1970's. Findings from these studies were used to develop physical therapy exercises and a protocol for nerve root mobilization in humans with pain in the lower portion of the back. The goal of nerve root mobilization in lumbar nerve root disorders is to shorten rehabilitation time after surgical procedures by treating specific lesions such as adhesion of nervous tissue and edema in the region of the nerve roots.

Most physical therapy protocols for veterinary patients have been derived from procedures established in humans, but to the authors’ knowledge, the effect of these exercises has not been studied in quadrupeds. The purpose of this study was to compare the macroscopic positional changes of lumbar neural tissue and dural-meningeal mobilization in humans and dogs, determine whether exercises must be adapted to canine anatomy, and quantify movement that can be achieved in the nerve roots.

**Materials and Methods**

Five adult Beagle (3 males and 2 females) cadavers were used in the preliminary study to establish protocols for the neural tissue mobilization exercises, and 10 adult Beagle (6 males and 4 females) cadavers were used in the quantitative part of the study. All dogs had been purpose bred and were donated by a Swiss laboratory animal breeding company to the Department of Veterinary Anatomy of the Vetsuisse Faculty, University of Zurich, for educational and study purposes in veterinary science. Dogs were euthanized by IV

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The dogs' care and euthanasia were conducted in accordance with Swiss national law for the protection of animals. The 10 dogs used in the main part of the study were weighed, and the crown-rump length was measured for each. The cadavers were frozen and stored at −25°C. Within a 24-hour period before dissection, cadavers were thawed in a water bath at 37°C. The skin overlying vertebral column segments T8 to Cc1 was shaved, and dogs were positioned in sternal recumbency. The skin and fascia were incised, and the lumbar muscles were elevated from the vertebral column until the intervertebral foramina and nerve roots from L4 to L7 were visible. The criteria for selecting the specific angles were that the selected forces and angles should be applicable to live dogs without causing harm and that the maximal visible effect on the nerve root would be achieved by the applied maneuvers. All exercises were performed with the cadavers positioned in lateral recumbency and consisted of 3 or 4 steps.

The passive stifle joint-bending exercise—The passive stifle joint exercise is designed to elicit movement of nerve roots L4 to L6. This exercise is performed in humans with nerve root disorders affecting the L1 to L4 segment with the aim of mobilizing the roots of the femoral nerve. In the neutral position, the pelvic limb is held parallel to the table with an angle of 90° between the greater trochanter of the femur and the lumbar portion of the vertebral column. The first step of the exercise is extension of the hip joint from 90° to 180° in extension. The position achieved with those first 2 steps is defined as the pretension position. The third and fourth steps entail continuous movement of the stifle (femorotibial) joint from a 40° angle in flexion to 180° in extension. In humans, steps 3 and 4 are considered to be the therapeutic component of the exercise and are the steps during which the nerve roots glide back and forth at the level of the intervertebral foramina.

The straight-limb–raising exercise—This exercise is used in humans with nerve root disorders involving the L4 to S2 segment of the vertebral column and is designed to mobilize the sciatic nerve roots. In the neutral position, the pelvic limb is held parallel to the table with an angle of 90° between the greater trochanter of the femur and the lumbar portion of the vertebral column. The first step is flexion of the hip from 90° to 35° while the limb is held parallel to the table. The second step is a 30° outward rotation of the hip, performed while maintaining the hip in the flexed position. The position achieved with steps 1 and 2 is defined as the pretension position. The third and fourth steps consist of continuous movement of the stifle joint from 40° in flexion to 180° in extension.

Palpable anatomic landmarks such as the greater trochanter, the transverse processes of the lumbar vertebrae, the lateral condyle of the femur, and the lateral malleolus of the fibula were used for measuring the angles in the passive stifle joint-bending and straight-limb–raising exercises.

The dural stretch exercise—In humans, the dural stretch exercise is designed to move the dura in the region of T12 to L1. This test enhances the effects of the straight-leg raising and the passive knee-bending exercises by stretching the meningeal structures of the spinal cord. In the present study, the first step was to flex the vertebral column until the rostral portion of the lower jaw was in contact with the pelvic limbs. This was defined as the pretension position. The second and third steps consisted of continuous maximal flexion and maximal extension of the atlantooccipital joint.

![Figure 1](https://example.com/figure1.png)

Figure 1—Photographs of the passive stifle joint-bending exercise being performed in a Beagle cadaver and the resultant positions of the L4, L5, and L6 nerve roots in the same dog. Increments represented by markings on measuring tape are 1 mm. Cranial is to the right. A—Appearance of the limb (left) and nerve roots (right) in a neutral position. Notice that the pelvic limb is held parallel to the table with an angle of 90° between the greater trochanter of the femur and the lumbar portion of the vertebral column. B—Appearance of the limb (left) and nerve roots (right) at the end position of the exercise. The limb was moved from a stifle joint flexion angle of 40° to extension at 180° while the limb was maintained in the pretension position.
Measurement of the gliding distances of the nerve roots—For the passive stifle joint-bending exercise, the dissected L4 to L6 nerve roots were marked with synthetic resin paint. The exercise was performed and digitally photographed. Measurement of the distances between vertebral column landmarks and the nerve roots was performed with the limb in the following positions: neutral and hip-extended position, hip joint extended with additional abduction of the limb (ie, pretension position), pretension position with additional stifle joint flexion, and stifle joint in flexed and extended positions with the limb maintained in pretension position. Distance was defined as movement of the nerve root elicited by moving the limb from the neutral position to positions with the hip joint in extension and abduction and with the stifle joint also in flexion (Figure 1).

For the straight limb-raising exercise, the L7 nerve root was marked with synthetic resin paint and movements of the L7 nerve root relative to the vertebral column were digitally photographed. Computerized measurements of the distances between the vertebral column landmarks and the nerve roots were performed with the limb in the following positions: neutral and hip joint-flexed position, hip joint flexed with additional abduction (ie, pretension position), pretension position with stifle joint extension, and flexed-to-extended stifle joint positions with concurrent maintenance of the pretension position. Distance was defined as movement of the L7 nerve root elicited by moving the limb from the neutral position to the pretension position with additional stifle joint extension (Figure 2).

For the dural stretch exercise, a dorsal laminectomy with preservation of the facet joints was performed by use of Rongeur forceps on the T13 to L1 vertebrae. The dura and the vertebral column were marked at the level of T13-L1 with synthetic resin paint. The dural stretch exercise was performed and movements were digitally photographed. Measurements of the position of the dura relative to the vertebral column were made with the dog in the following positions: neutral position to maximal flexion of the vertebral column (ie, pretension position), pretension position with additional flexion of the atlantooccipital joint, and flexion and extension of the atlantooccipital joint (Figure 3). Measurements were performed with an open-source medical viewer program. In each photograph, measurements were calibrated with a small measuring device of known distance.

Statistical analysis—Mean ± SD and SEM values for nerve root or dural movement were calculated for the 10 dogs at the different positions and were compared separately for each exercise by use of 1-way repeated-measures ANOVA with succeeding pairwise Bonferroni t tests. For each exercise, correlations between body size (expressed by crown-rump length) and maximal movement of the nerve root were investigated with the Pearson correlation. All statistical analyses were performed with commercially available software. Values of P < 0.05 were considered significant.

Results
Movement of nerve roots L4 to L6 during the passive stifle joint-bending exercise and of nerve root L7 during the straight-limb–raising exercise was observed in all cadavers. Results for the passive stifle joint-bending exercise, the straight-limb–raising exercise, and the dural stretch exercise were summarized (Tables 1–3).
Distances measured for nerve root movement during the exercises varied among dogs. In the preliminary study involving 5 dogs, extension and abduction of the hip joint elicited more nerve root movement than did extension of the joint alone. The distance gained with additional abduction in the extended hip joint varied from 0.1 to 0.4 mm for L4, 0.1 to 0.9 mm for L5, and 0.1 to 0.7 mm for L6; each of these distances was significant. The distance of dynamic gliding for nerve roots L4 to L6 under pretension during flexion and extension of the stifle joint was significant.

In the straight-limb–raising exercise for the L7 nerve root, the extent of nerve root movement resulting from the different steps of the exercise was not constant among dogs. In the preliminary study group, abduction of the hip joint in flexion resulted in increased movement of the nerve root, compared with that elicited by flexion of the joint alone. The movement of the L7 nerve root gained with additional abduction of the hip joint after flexion varied from 0.1 to 0.7 mm; this distance was significant. The gliding of the L7 nerve root achieved under pretension during extension and flexion of the stifle joint was also significant.

The dural stretch exercise resulted in movement of the dura when dogs were moved from the neutral position to the pretension position. While the vertebral column was in maximal flexion, a flattening of the spinal cord was observed. Only minimal movement (between 0 and 0.2 mm) of the dura with additional flexion and extension of the atlantooccipital joint was observed. No effects of body weight, crown-rump length, or sex on the measurements were detected.

**Discussion**

Results confirmed that there was measurable gliding movement of the lumbar nerve roots during the passive stifle joint-bending and straight-limb–raising exercises. The maximum distances over which gliding occurred ranged from 0.2 to 2.6 mm, depending on the nerve root. In the passive stifle joint-bending exercise, the L4 nerve root had the shortest gliding distance,
whereas movement over a longer distance was characteristic for L6 and particularly for L5. There was, however, considerable individual variation among dogs. The fact that the L5 nerve root is the major root contributing to the femoral nerve\textsuperscript{13} may account for the increased mobilization of the L5 nerve root during the passive stifle joint-bending exercise.

In the straight-limb–raising exercise, distances of L7 nerve root movement ranged from 0.4 to 1.5 mm. Additionally, the L6 nerve root, which forms a part of the sciatic nerve,\textsuperscript{13} was investigated in 7 dogs. The L6 nerve root underwent gliding movement in the proximal direction of up to 0.4 mm during flexion of the hip joint. This could be caused by decreased tension on the femoral nerve, including the L6 nerve root, during flexion of the hip. Other than these observations, movement of the L6 nerve root in response to this exercise was not investigated further because the straight-limb–raising exercise is designed to mobilize the L7 nerve root.

The straight-limb–raising and passive stifle joint-bending exercises can be useful diagnostic tools for the clinician. Given the difficulties inherent in distinguishing nerve root irritation from orthopedic diseases that cause joint pain, the clinician might be able to focus the list of tentative diagnoses by adding these exercises to the standard examination protocol. Dogs with lumbar and lumbosacral nerve root problems often have a pain response to movements that elicits a nerve root stretch. For example, in dogs with nerve root irritation in the L4 to L6 segments, signs of pain can be elicited in response to the passive stifle joint-bending manipulation. Similar observations can be made in dogs with L7 nerve root irritation. The straight-limb–raising exercise elicits a much more painful response in these dogs, compared with the reaction in dogs with S1 nerve root irritation. These findings

<table>
<thead>
<tr>
<th>Nerve root</th>
<th>Hip joint Pretension Pretension Pretension position with position with position with</th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>extension</td>
<td>Pretension position</td>
<td>with</td>
<td>stifle</td>
</tr>
<tr>
<td>L4</td>
<td>Mean</td>
<td>0.3985</td>
<td>0.561</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.38</td>
<td>0.42</td>
<td>0.44</td>
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<tr>
<td></td>
<td>SEM</td>
<td>0.12</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>L5</td>
<td>Mean</td>
<td>0.83</td>
<td>1.22</td>
<td>1.61</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.32</td>
<td>0.47</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.10</td>
<td>0.15</td>
<td>0.17</td>
</tr>
<tr>
<td>L6</td>
<td>Mean</td>
<td>0.655</td>
<td>0.86</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.35</td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.11</td>
<td>0.11</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Table 2—Mean ± SD and SEM gliding distances (mm) of nerve root L7 during different stages of hip joint flexion and rotation during the straight-limb–raising exercise in the same 10 dogs as in Table 1.

<table>
<thead>
<tr>
<th>Value</th>
<th>Hip joint flexion</th>
<th>Pretension position</th>
<th>Pretension position with stifle joint flexion</th>
<th>Pretension position with stifle joint extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.227</td>
<td>0.637</td>
<td>0.935</td>
<td>0.637</td>
</tr>
<tr>
<td>SD</td>
<td>0.18</td>
<td>0.41</td>
<td>0.38</td>
<td>0.37</td>
</tr>
<tr>
<td>SEM</td>
<td>0.06</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 3—Mean ± SD and SEM dural gliding distances (mm) during different stages of the dural stretch exercise in the same 10 dogs as in Tables 1 and 2.

<table>
<thead>
<tr>
<th>Vertebral column flexion (pretension position)</th>
<th>Pretension position with flexion of AO joint</th>
<th>Pretension position with extension of AO joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.744</td>
<td>0.822</td>
</tr>
<tr>
<td>SD</td>
<td>0.59</td>
<td>0.62</td>
</tr>
<tr>
<td>SEM</td>
<td>0.20</td>
<td>0.21</td>
</tr>
</tbody>
</table>

AO = Atlantooccipital.
should be interpreted in context with the findings of general, orthopedic, and neurologic examinations.

In the present study, the dural stretch exercise resulted in measurable gliding of the spinal cord only when dogs underwent vertebral column flexion from the neutral position to the pretension position. The gliding distances were small (ie, from 0.1 to 0.2 mm), even with extreme flexion of the vertebral column. This finding was in contrast with findings in humans, in which gliding distances of up to 10 mm have been observed. The difference may be explained by the different length of the spinal cord relative to the vertebral canal in dogs and humans. In humans, the spinal cord has a more distinct ascendus medullaris than the spinal cord in dogs, in which the spinal cord is nearly as long as the vertebral canal. The spinal cord in dogs therefore has a pivotal point similar to that in the vertebral column. Consequently, an applied stretching force is distributed equally on both sides of the pivotal point. If the forces applied to the spinal cord with flexion of the vertebral canal are simplified in a parallelogram, the resulting net force has a ventral direction, resulting in spinal cord compression. In humans, the pivotal point of the vertebral column is near the distal end of the spinal cord. If the forces applied to the spinal cord during flexion of the vertebral canal are simplified in a parallelogram, the resulting net force is in the cranial direction. This results in an increased gliding movement of the spinal cord in humans.

In human medicine, the hypothesis that enhanced regional blood flow results in reduction of edema, induction of retrograde and anterograde axonal transport, and prevention of nerve root adhesions resulting from externally applied nerve root movements has been investigated. Originally, the straight-leg-raising maneuver was used as an examination to verify disk disease in the lower lumbar region. Fahrni standardized the straight-leg-raising protocol and assessed its effect in 3 patients, with a special focus on nerve root adhesions. Several models for neural mobilization were developed by Breig et al., who studied the straight-leg-raising and passive knee-bending exercises in cadavers and found nerve root gliding distances of 1 to 10 mm. Additional inward and outward rotations of the hip joint resulted in increased gliding movements.

On the basis of these principles of neural mobilization, specific exercises have been developed. Radicular blood flow in clinically normal dogs and the effect of the compression of radicular blood vessels have been investigated. Intraoperative investigations have also been performed in humans with sciatic and femoral nerve compressive lesions and with positional nerve root pain induced by straight-leg-raising and passive knee-bending maneuvers. Interestingly, a correlation between nerve root movement and regional blood flow in the nerve root before and after surgical release of the compressed nerve root was found. The authors postulated that the origin of nerve root pain is not only a result of compression, but may also develop secondary to reduced venous blood flow, intraneural edema, and inflammation.

Clinical studies in which the outcome of physical therapy exercises was investigated have yielded conflicting results. Excellent results have been reported in shortening rehabilitation time after surgery of the lower portion of the back by applying the passive knee-bending and straight-leg-raising exercises as soon as possible after surgery, and it has been concluded that a higher rate of full rehabilitation in humans results when these exercises are used. In another study, an aggressive exercise protocol initiated shortly after disectomy was associated with rapid clinical improvement. The exercises were designed specifically for active-muscle and joint training. However, the long-term results were identical to those of the group that received standard physical therapy. The usefulness of early postoperative physical therapy was supported by findings from an earlier study in which aggressive training was initiated soon after minimally invasive neurosurgical procedures. However, it has also been reported that neuronal mobilization does not yield superior effects when performed in addition to conventional physical therapy. The authors of that study postulated that there was a less favorable outcome in the group undergoing frequent neural mobilization. On the basis of those results, use of the neural mobilization protocol in patients after lumbar surgery was not recommended.

Results of the present study indicate that, in dogs, nerve roots L4 to L7 can be mobilized by external passive manipulations of the pelvic limb. The dural stretch manipulation elicited movement of the dura during movement of the animal into the pretension position. However, the resulting gliding distances during flexion and extension of the atlantooccipital joint as a result of manipulating the dog into this uncomfortable position were not considered to be effective. Use of that manipulation in dogs is, therefore, of questionable value. On the basis of present findings, the effectiveness of neural mobilization in rehabilitation of lumbar disorders should be assessed in clinical trials.

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b. Madena X, version 3.20, Department of Radiation Oncology, University of Southern California, Los Angeles, Calif.
c. SigmaStat, version 11.0, SPSS Inc, Point Richmond, Calif.

Correction: Neurohormonal, hemodynamic, and electrocardiographic evaluations of healthy dogs receiving long-term administration of doxorubicin

In “Neurohormonal, hemodynamic, and electrocardiographic evaluations of healthy dogs receiving long-term administration of doxorubicin” (AJVR, Vol 67, pp 1319–1325), the corresponding author, Dr. Rute Chamié Alves de Souza’s address should read, “Av. Visconde de Albuquerque, 258, apto.603, 50610-090, Recife-PE, Brazil.”