
Objective. Part 1: Test if contralateral knee extension consistently reduces normal stretch sensations with the ST. Part 2: Ascertain in cadavers an explanation for the results.

Summary of Background Data. In asymptomatic subjects, contralateral knee extension reduces stretch sensations with the ST. In sciatica patients, contralateral SLR also can temporarily reduce sciatica. We studied this methodically in asymptomatic subjects before considering a clinical population.

Methods. Part 1: Sixty-one asymptomatic subjects were tested in control (ST), sham, or intervention (contralateral ST) groups and their sensation response intensity compared. Part 2: Caudal tension was applied to the L5 nerve root of 3 cadavers and tension behavior of the contralateral neural tissue recorded visually.

Results. Part 1: Reduction of stretch sensations occurred in the intervention group but not in control and sham groups ($P < 0.001$). Part 2: Tension in the contralateral lumbar nerve roots and dura reduced in a manner consistent with the responses in the intervention (contralateral ST) group.

Conclusion. Part 1: In asymptomatic subjects, normal thigh stretch sensations with the ST reduced consistently with the contralateral ST, showing that this is normal and may now be compared with patients with sciatica. Part 2: Contralateral reduction in lumbar neural tension with unilateral application of tension-producing movements also occurred in cadavers, supporting the proposed explanatory hypothesis.

Key words: contralateral, dura, low back pain, lumbar nerve roots, neurobiomechanics, neurodynamic tests, neurodynamics, sciatica, slump test.

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Diagnosis of low back pain and sciatica is a key issue in which physical tests for nerve root tension signs, such as the straight leg raise (SLR) and slump test (ST), are commonly performed clinically. Here, we focus on the ST, which is inexpensive and has been shown to be reliable$^{1–6}$ and has good diagnostic efficacy ratings for disc protrusion.$^{7}$

The clinically applied ST utilizes spinal flexion and lower limb movements to apply tension to the neural tissue of the lumbar spine.$^{8–21}$ The recipient is seated whilst the spine is flexed and the knee extended.$^{22–28}$ Cervical flexion is released to ascertain whether any responses produced by the test change, whether they be a normal stretch sensation (eg, posterior thigh), or symptoms such as back pain and sciatica. At its end position in asymptomatic subjects, the test typically produces sensory responses and here we use the term “evoked sensations” to denote what asymptomatic subjects report.
During the ST, the change of normal evoked sensations or clinical symptoms with cervical movements does not differentiate normal from abnormal. Instead, in both situations, such a change provides support for a neuromechanical mechanism because, on account of anatomical connectivity, cervical flexion/extension produces tension changes in the lumbar neural tissues, which links the change in evoked sensations or clinical symptoms to the neural system.

A key aspect of diagnosis with the ST is to show differences between the normal evoked (stretch) sensations that occur in asymptomatic subjects and reproduction of patient symptoms. Normal evoked sensations for the ST have been established in asymptomatic subjects, one of which consists of ipsilateral posterior thigh stretch at the end of the final knee extension/dorsiflexion phase and this decreases with release of cervical flexion.\(^1\)–\(^5\),\(^26\),\(^27\) Interestingly, even though the stretch sensation in the posterior thigh changes with cervical movements, the tension and myoelectric activity in the hamstrings have been shown not to change.\(^2\)

Hence, the likelihood of myofascial tissues in the posterior thigh producing evoked sensations reduces and other structures come into focus, namely the lumbar neural tissues.

A new variation on the ST is to perform certain movements contralaterally or bilaterally.\(^28\) The contralateral ST is when the usual ST is performed and, whilst holding this position stable, contralateral knee extension is added. In performing this on subjects presumed to be healthy, we have observed that, surprisingly, a typical response to contralateral knee extension is reduction in the original (ipsilateral) thigh stretch sensation. Furthermore, in some patients with unrelenting sciatica, sometimes, the sciatica can be relieved temporarily with such a similar movement, for instance, the contralateral SLR in supine. The mechanism for this effect is not understood and, before investigating it directly, there is a need to ascertain scientifically whether it is artifactual, or something that is significant and consistent that may warrant more detailed investigation.

Hence, the purposes of this study were to first investigate evoked stretch sensations to the contralateral ST (ContraST) in asymptomatic subjects to establish a normal response for future clinical comparison; second, as part of an ongoing line of investigation, we needed to test scientifically whether this effect is consistent. If so, further investigation in patients with low back pain and sciatica may be warranted. Finally, the third purpose was to develop an explanatory mechanical hypothesis for the findings in the form of a cadaver study to establish whether the lumbar neural tissues behave in a manner consistent with the results in asymptomatic subjects.

**MATERIALS AND METHODS**

**Part 1: Slump Test Response Sensations in Asymptomatic Subjects**

This part of the study passed ethical scrutiny by the University Institutional Review Board and was performed in accordance with the Declaration of Helsinki. Informed consent and participation were obtained local university volunteers. All were informed of the upcoming procedures in plain language and an explanation of their rights was given, specifically that they could terminate their participation at any time without reason or prejudice. Subjects answered questions (Table 1) and were tested with active and passive movement in relation to exclusion criteria (Table 2). Subjects were excluded if they satisfied any of the exclusion criteria.

Sixty-one asymptomatic subjects (age range 22–43 years, 19 males, 42 females) were included. An explanation was given that certain maneuvers would be performed and subjects may or may not experience response sensations. If subjects did report any sensations, they were asked to indicate their location and verbally rate their intensity on a numeric pain rating scale (NPRS) between 0 and 10. Subjects were blinded to the research hypothesis and whether any specific movements would or would not produce any changes.

The ST procedure and methods were the same as previously published.\(^1\),\(^2\) The prevention of crossover musculoskeletal effects with contralateral knee extension due to potential for pulling of the hamstrings on the ischial tuberosities, thereby affecting pelvis position, was achieved by placing books between subjects’ sacrum and the laboratory wall, after Herrington et al.\(^1\) and Lew and Briggs.\(^2\) For added measure, we used pressure biofeedback (Chatanooga

**TABLE 1. Subjective Exclusion Criteria**

<table>
<thead>
<tr>
<th>Under 18 years of age</th>
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<tr>
<td>No pain, altered sensation, pins and needles, weakness, or any other discomfort in the spine, hip, or either lower extremity in the previous 12 months</td>
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<tr>
<td>Any injuries to the spine, neck, back, hips, legs, ankles, or feet in the previous 12 months</td>
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<tr>
<td>Condition of the spine, including ankylosing spondylitis, Schmorl’s nodes, disc protrusion, spinal stenosis, tumors, tuberculosis, osteoporosis, spondyloarthritis/opathy, spondylolisthesis or spondylolysis, stenosis</td>
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<tr>
<td>Arthritis or any autoimmune disease</td>
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<td>Previous surgery or malignancy</td>
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<td>Diabetes or thyroid condition</td>
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<tr>
<td>Condition of the nervous system, including spina bifida, hydrocephalus, syrinx or cysts, multiple sclerosis, tethered cord, or Arnold Chiari</td>
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<td>Previous or current psychiatric or mental illness</td>
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Stabilizer) between the subjects’ sacrum and the spacers. The pressure cuff readout was placed behind the subjects such that they could not see it and the examiner looked back over subjects’ shoulders at the readout to ensure that the pressure remained stable at 20 PSI. For fixation of the spine, shoulders, and thighs, seat belts were then placed under the table firmly and comfortably positioned over the subjects’ shoulders and around their thighs.

**Slump Test Procedures**

All subjects underwent the standard clinical ST procedure that consisted of:

1. being seated comfortably on the table with their thighs parallel, knees against the edge of the table, and legs relaxed down at approximately 90 degrees knee flexion;
2. hands resting on the couch behind the subjects’ back;
3. full comfortable lumbar, thoracic cervical spine flexion;
4. right knee extension to the point of comfortable production of sensations in the ipsilateral limb;
5. release and reapplication of cervical flexion to ascertain whether any evoked sensations in the limb changed;
6. maintenance of the response position for 30 seconds;
7. subjects reported the intensity of their sensations in verbal NPRS form at the beginning and end of the 30-second duration and the data recorded.

Before this, subjects were randomly assigned into 3 groups: control (n = 20), sham (n = 21), and intervention (n = 20).

**Control Group**

To control for the possibility that sensations during the test might change over time or per chance, data were collected from a control group and compared with the other 2 groups (sham and intervention). This control group experienced solely the ST to the response sensation at end range for 30 seconds and their sensations recorded at the beginning and end of the 30 seconds (Figure 1A).

**Sham Group**

Subjects in the sham group followed the same procedure as the control group except that, during the 30 seconds in which the ST was maintained at the end of symptomatic range, the contralateral ankle was dorsiflexed passively whilst the contiguous knee remained in 90-degree flexion (Figure 1B). Hence, the dorsiflexion was actually a neurodynamic movement, but one that did not move the lumbosacral nerve roots (ie, sham), as the contiguous knee was in 90-degree flexion and the forces of the dorsiflexion would not be transmitted proximally along the sciatic nerve, preventing the mechanical effects of dorsiflexion reaching the lumbosacral nerve roots.

**Intervention Group**

The subjects in this group also received the same procedure as the control group (ST held for 30 seconds) except that, during the 30 seconds, the contralateral knee was passively extended to end range whilst the ankle was held in the plantargrade position (Figure 1C). As knee extension was moved, the effects would spread along the sciatic nerve to the nerve roots as would occur with the SLR. This would
draw the cord caudally and produce the intended experimental effects.

Reliability was tested on 10 subjects. The procedure for the control group was performed at the same time on 2 different days and agreement in the values of the NPRS was calculated.

Statistical Analysis
Percentage agreement between the NPRS sensation values on the 2 occasions was used to evaluate reliability.

The 1-tailed hypothesis to be tested was that responses would decrease with the contralateral maneuvers performed in the study. This was because, in our experience in testing the maneuver on numerous persons with normal ST response sensations, whenever any sensations changed with contralateral testing, they typically decreased rather than increasing.

One-way analysis of variance (ANOVA) was used to test for significance of differences in self-reported NPRS values between groups, whilst the Tukey posthoc test for multiple comparisons was used to test for differences between the control and sham groups, intervention and sham groups, and intervention and control groups. The alpha value was set at 0.05.

Part 2: Lumbar Neural Tissue Behavior in Cadavers
The use of cadavers in this part of the study was approved by the Centre of Education and Research in Anatomical Sciences, Department of Basic Medical Sciences, University of Ghent, Belgium.

The objective here was solely to ascertain what mechanisms may operate in the lumbar nerve root and dura on one side during manually applied distal traction of the lumbar nerve root on the other, simulating the effects of the ContraST and SLR. The mechanism was tested in 3 cadavers, 2 processed with the Thiel method, in which the soft tissues remain soft and pliable, and 1 embalmed cadaver. The lumbar spine was opened from the posterior direction and the dura and cauda equina exposed. The dura was then opened and forceps placed around the right L5 nerve root. The root was manually drawn caudally in the canal toward its intervertebral foramen and the effects on the other side observed. The events were recorded audiovisually.

RESULTS
Part 1: Asymptomatic Subject Response Sensations
Data were collected from 61 subjects (20 males, 41 females), with an average age 25.3 years. Twenty subjects were in the control group, 21 in the sham group, and 20 in the intervention group.

Reliability testing on the control group resulted in a 91% test–retest agreement of the NPRS measures.

All subjects except 2 (96.7%) reported stretch sensations in the posterior thigh and knee. One of those 2 subjects reported sensations in the calf and the other in the toes and both of these subjects reported their sensations to change with cervical movements. Taking into account the total sample (n = 61), all but 4 (93.4%) reported a change with cervical flexion.

Comparisons were made with the average change in NPRS for each of the control, sham, and intervention groups.

Even though not all subjects in the control and sham groups reported a reduction in evoked sensations, the average for all groups did show a small reduction. However, compared with the intervention group, the change in intensity of response sensations (reduction) in the control and sham groups was negligible. Average changes in NPRS were 0.65 for the control group (n = 20), 0.62 for the sham group (n = 21), and 3.80 for the intervention group (n = 20). All subjects in the intervention group reported the change in sensations to be a reduction.

One-way ANOVA resulted in a significant difference between groups (P ≤ 0.001). The Tukey posthoc test for multiple comparisons revealed no significant difference between the control and sham groups (P = 0.996), but a significant difference was demonstrated between the intervention and sham groups (P ≤ 0.001) and intervention and control groups (P ≤ 0.001).

Hence, the reduction in evoked sensations in the ipsilateral limb with the end-range ST was directly linked to contralateral knee flexion.

Part 2: Cadaver Experiment
All 3 cadavers demonstrated the events shown in Figure 2. In drawing the nerve root caudally, all the neural tissues on the
opposite side became looser. Loosening too of the filum terminale illustrated that the cord had displaced caudally (see Video, Supplemental Digital Content 1, http://links.lww.com/BRS/B38).

DISCUSSION
The data in this study agree with other studies on several counts; excellent reliability in relation to response sensations with the ST, all subjects reported evoked sensations (stretch) in the posterior thigh, and 93.4% of subjects reported a change in these responses with cervical movements.

During the ST to end range, 100% of subjects reported a decrease in the stretch sensation in the “held” (ipsilateral) side with contralateral knee extension.

Clearly, these results warrant caution and raise questions. The sample may have been influenced by the fact that subjects were from a university wherein their health may have been better than other asymptomatic populations. Conversely, what supports the sample is that it may have consisted of subjects who were closer to “ideal” and better suited to investigation of this model. Therefore, we would agree that the effect found in this study is likely to diminish in a broader sample; however, it is likely to remain substantial.

The idea that the measured reduction in intensity of evoked sensations may have been due to relaxation of the soft tissues in the thigh must be considered. However, we think this not to be the case because it was controlled for with randomization, sham and control groups in which subjects and the magnitude of the reduction in responses in the control and sham groups was not statistically significant. Furthermore, Lew and Briggs measured hamstring behavior mechanically and electromyographically, showing that these aspects did not change with the ST and during cervical movements.

An explanatory hypothesis is that the 100% of subjects reporting a reduction in responses with contralateral knee extension correlated with the lumbar neural tissue behavior, as previously described. As the path of the lumbar nerves roots between the cord and foramina approaches vertical, the nerve roots will draw the cord caudally and therefore produce reduction in tension in the roots on the other side, assisting each other in distribution of tension. In vivo, Rade et al have shown that this crossover mechanism exists by using the bilateral SLR, which produces virtually double the caudal cord excursion compared with the unilateral, supporting the hypothesis we propose. However, even though it is not possible to measure lumbar neural tension in conscious humans, we can think of no other structure or tissue that could produce mechanical events that matched the subject responses in this study. However, we acknowledge that this remains a hypothesis and more direct study is necessary for verification.

This study naturally raises questions in relation to the crossed SLR sign. Symptom provocation with the crossed SLR clearly constitutes an abnormal response that may now be compared with the ContraST. However, an instantaneous reduction in response sensations with the ContraST may not in itself differentiate normal from abnormal, particularly if the ContraST were to be found to have an anatomical basis that occurs in both situations. Instead, it may assist in decisions on whether the response has a neural aspect generally and whether it may or may not respond to various interventions. However, more investigation is required before such conclusions could be entertained.

What is of more immediate benefit in this study is that the responses with the ContraST were consistent, highly significant, and are now documented as a normal response sensation that may be compared with those in patients with low back pain and sciatica.

CONCLUSION
In asymptomatic subjects, the passive ContraST was reliable and produced a reduction in the posterior thigh stretch sensations to the ST in all asymptomatic subjects of the intervention group ($P < 0.001$), whereas no significant changes occurred in the control and sham groups ($P = 0.996$).

The reduction of the evoked posterior thigh sensations with the ContraST is now documented as a normal event. Further investigation of the causal mechanism is warranted whereby there may be potential for it to be tested clinically in patients with low back pain and sciatica and there may be a need for more direct investigation of an explanatory mechanism.

An explanatory hypothesis derived from cadaver simulation has been presented in which tension in the lumbar neural tissues reduced during application of the contralateral neurodynamic movement.

Key Points
- The commonly used ST for diagnosis of nerve root tension signs was performed on asymptomatic subjects and the effect of contralateral knee extension on the evoked stretch sensations investigated in asymptomatic subjects.
- Contralateral knee extension reduced evoked sensations in the intervention group but not in the sham and control groups.
- Reduction of evoked sensations with contralateral knee extension during the ST is now a normal finding and can be used to compare in patients with sciatica.
- Simulation of nerve root behavior in cadavers showed that the contralateral nerve root and dura loosen with caudal tension applied to L5 nerve root.
- Further investigation on potential benefits could consider that such responses might be used in decisions on conservative management of patients with sciatica due to disc protrusion.
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References