Upper Limb Neural Tension and Seated Slump Tests: The False Positive Rate among Healthy Young Adults without Cervical or Lumbar Symptoms

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Physical therapists and other health-care providers use neural tension tests (neurodynamic tests) as part of the clinical examination to help differentiate the underlying pathoanatomic structures¹⁻⁷. The most common neural tension tests include the straight leg raise test (SLR), the seated slump test (SST), and the upper limb neural tension test (ULNTT)¹⁻⁷. The advancement of neural tension testing, particularly the SST and ULNTT, is credited to Butler^{1,2}, Elvey³, Shacklock^{6,7}, and Maitland^{5,8,9}. Today,

neural tension testing has become a ubiquitous part of the orthopedic physical therapy examination. Despite numerous publications and the common use of these tests, there is relatively little scientific evidence available to support the diagnostic accuracy of these tests⁶.

Several investigations have shown that a combination of specific body movements can create tension and gliding of neural tissues within the confines of the musculoskeletal system^{10,11}. If a nerve or nerve root becomes inflamed or damaged

by chemical mediators, macroscopic or microscopic trauma, or entrapment, normal functional movements can produce or exacerbate neural mediated signs or symptoms^{1,3,11-13}. Chronic repetitive compression or traction can result in both intraneural and extraneural pathology^{1,12}. Nerve injury of this type is often manifested by sensory changes such as paresthesias and neurological signs such as motor weakness; and altered deep tendon reflexes can result from prolonged neural insult¹¹⁻¹³. Therefore, neural tension testing that places mechanical tension on the nervous system has the potential to serve as a useful clinical test to help differentiate between neural and non-neural anatomic structures^{1,4,6,12}.

There are three common upper limb tension tests that assess neural tissues originating from the C5 to T1 nerve roots^{1,4}. The most commonly used ULNTT has been defined as (ULNTT 1) and is thought to emphasize tension on the median nerve^{1,2,6,14}. This test consists of a combination of scapular depression, shoulder abduction and external rotation, elbow extension, forearm supination, wrist and finger extension, and cervical lateral flexion first away from the tested extremity and then toward the tested extremity^{1,2}. Although the literature is not consistent, the ULNTT is often considered positive when there is a production of neural-mediated symptoms

ABSTRACT: This study examined the false positive rate of the upper limb neural tension test (ULNTT) and seated slump test (SST) among healthy young adults with no history of cervical, lumbar, or peripheral symptoms. Eighty-four subjects (27 men and 57 women) with a mean age of 22.9 years participated in the investigation. All participants completed a screening questionnaire designed to exclude subjects with a history of cervical or lumbar spine pain or injury, or upper or lower extremity neurological symptoms. The ULNTT and the SST were performed on the left upper and lower extremity of each participant. Of the 84 participants tested, 73 (86.9%) were found to have a positive ULNTT at some point in the available range of elbow extension. Twenty-eight (33.3%) of the 84 subjects had a positive SST at some point in the available range of knee extension. The mean knee extension angle for those subjects with a positive SST was 15.1° with a 95% confidence interval (CI) of 12.3 and 19.7°. The mean elbow extension angle for those with a positive ULNTT was 49.4° with a 95% CI of 44.8 and 54.0°. The number of positive tests for both the ULNTT and the SST was found to be high in this sample of asymptomatic healthy young adults. Based on the results of this investigation, the authors suggest that the current criteria for determining a positive test for both the ULNTT and the SST should be examined using the proposed range of motion cut-off scores.

KEYWORDS: Neural Tension Testing, Neurodynamics, Radiculopathy, Test Validity

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during elbow extension, and reduction of symptoms or an increase in elbow extension when the cervical spine is laterally flexed toward the involved extremity^{1,2}. This last maneuver is referred to as structural differentiation and is used to differentiate a neurodynamic response from a musculoskeletal response⁶.

Shacklock⁶ stated that a musculoskeletal response (symptoms, range of motion, or resistance to movement) remains constant during differentiation, while a neurodynamic response is present when the symptoms, range of motion, or resistance to movement changes during structural differentiation. According to Shacklock, an *overt* abnormal neurodynamic response requires positive structural differentiation and reproduction of the patient's symptoms⁶.

Sandmark and Nisell¹⁵ determined that the ULNTT 1 has a sensitivity of 0.77 and a specificity of 0.94 in a sample of patients with neck pain. The intra-tester reliability of the ULNTT 1 in asymptomatic subjects has been reported to be 0.98^{16,17}. Hines et al¹⁸ reported poor inter-tester reliability when assessing resistance to movement rather than patient response based on structural differentiation.

The SST is thought to examine the sensitivity of neural structures including meningeal tissues, nerve roots, and the sciatic and tibial nerves^{4,5}. The SST involves the patient sitting on the edge of the examination plinth in a slumped or slouched position (flexion of the thoracic and lumbar spine and a posterior pelvic tilt), flexion of the cervical spine with gentle manual overpressure, and passive extension of the subject's knee, while the ankle is dorsiflexed. This sequence is referred to as ST1 by Butler¹. A positive test again requires structural differentiation by noting a change in symptoms, range of motion, or resistance when the cervical spine is extended and that reproduces the patient's symptoms⁶.

In a study examining patients with suspected herniated nucleus pulposus, Stankovic et al¹⁹ found the diagnostic sensitivity of the SST to be 0.83 and the specificity to be 0.55. Additionally, a study performed by Gabbe et al²⁰ found the intra-rater reliability using ICC_(3,1) as

0.95 and 0.80, while the inter-rater reliability was found as 0.92 using ICC_(2,1). Philip and Lew²¹ found strong agreement among physical therapists (Kappa = 0.89) when defining a positive test as reduction of symptoms and increased knee ROM upon cervical extension.

As stated previously, several modifications have been proposed for both the SST and the ULNTT; thus, there is not a universally accepted procedure for either test^{1,5}. One suggested modification is to have proximal or distal initiation of the testing sequence⁶. In the distal-initiated SST, the subject's ankle is dorsiflexed first for pretension of the sciatic and tibial nerves. In the proximal-initiated test, the subject is asked to flex the cervical spine first for pretension of the dura. A second alteration of the SST is to have the subject axially rotate the thoracic spine²². The order in which the test is performed is believed to influence the direction of neural glide but it may also affect symptom reproduction⁶.

Clinical observation and experience teaching neural tension testing for many years led the present investigators to observe that many asymptomatic subjects without frank cervical, lumbar, or peripheral symptoms present with neural-mediated symptoms and positive structural differentiation when full-range testing of the SST and ULNTT is performed. Thus, clinical observation indicated that there might be an unusually high false positive rate among these tests when performing full-range testing of the elbow (ULNTT) and the knee (SST). Shacklock⁶ referred to the production of neural-mediated symptoms among asymptomatic subjects as a *normal positive* test and suggested reproduction of the patient's symptoms should be an integral part of the diagnostic criteria. It should be noted that reproduction of symptoms is impossible in asymptomatic subjects (no pathology); therefore, this criteria cannot be used when examining the rate of false positive tests. Therefore, the purpose of this investigation was to determine the false positive rate of the SST and ULNTT in otherwise healthy young adults without cervical, lumbar, or peripheral symptoms and to identify possible cut-off

scores based on knee (SST) and elbow (ULNTT) range of motion.

Methods

Subjects

A total of 94 healthy adult subjects between the age of 18 and 40 were recruited to participate in this investigation. Ten subjects were excluded based on previous medical conditions identified by an exclusion questionnaire, resulting in a sample size of 84 (57 women and 27 men). The exclusion criteria consisted of history of upper or lower extremity paresthesia/numbness, history of cervical or lumbar pain in the last two years, previous diagnosis of spinal stenosis or disc pathology, history of circulatory or neurological disorder, and history of spine or extremity fracture in the last two years.

Before testing commenced, the examination procedures were explained and all subjects gave informed consent, which was approved by the University's Institutional Review Board for the Protection of Human Subjects.

Testing Procedures

All data were collected during a single testing session in a university laboratory. After completing the medical screening questionnaire, each subject underwent neural tension testing in the same order, ULNTT followed by the SST. Both tests were performed on the subject's left upper and lower extremities.

Seated Slump Test

The subject was positioned in an erect sitting position on an examination plinth with the popliteal creases just off the edge of the plinth (Figure 1). The subject was asked to sit in a slouched position (thoracic and lumbar flexion with a posterior pelvic tilt). The subject was then asked to actively flex the cervical spine as far as comfortably possible. One investigator then applied gentle overpressure to the upper thoracic and lower cervical spine and maintained this position throughout the examination procedure. The subject's ankle was then pas-

FIGURE 1. (LEFT) Seated slump test (SST).

FIGURE 2. (RIGHT) Upper limb neural tension test (ULNTT).

sively dorsiflexed to slight resistance, while the knee was slowly passively extended. The knee was extended until full knee extension was achieved or the subject reported onset of neural-mediated symptoms (widespread aching, burning, or pain consistent with sciatic or tibial sensory distribution). If neural symptoms were experienced during knee extension, the motion was halted and the subject was asked to actively extend the cervical spine to determine structural differentiation. The SST was only classified as positive if the participant experienced relief of the peripheral symptoms with active cervical extension. For subjects identified as having a positive test, the degree of knee extension was measured with a large universal goniometer with one-degree increments (Baseline, White Plains, NY) by a second investigator. The goniometer was aligned in standard fashion with the axis over the lateral femoral epicondyle, the stationary arm aligned with the femoral trochanter, and the moveable arm aligned with the lateral malleolus.

Upper Limb Tension Test

The ULNTT was described to each participant by the investigator before the test was performed. Each subject was placed in the supine position on the examination plinth with the left shoulder slightly off the edge of the plinth (Figure 2). The subject was asked to relax so the investigator could passively maneuver the left upper extremity and cervical spine. The cervical spine was passively laterally flexed to the right, away from the tested upper extremity, until a firm

end-feel was noted. Passive lateral flexion was used to avoid cervical rotation, which is commonly associated with active lateral flexion. The left shoulder girdle was then passively positioned in slight scapular depression. The glenohumeral joint was then abducted to 90° in the frontal plane. The glenohumeral joint was externally rotated 90° with the elbow in 90° of flexion. The forearm was supinated, and the wrist, fingers, and thumb were passively extended. The elbow was extended until full elbow extension was achieved or the subject reported onset of neural-mediated symptoms (widespread aching, burning, or pain consistent with median nerve sensory distribution). If symptoms were experienced before the elbow was fully extended, the subject's cervical spine was laterally flexed back to the neutral starting position to determine structural differentiation. For subjects identified as having a positive test, the degree of elbow extension was measured with a large universal goniometer in one-degree increments (Baseline, White Plains, NY) by a second investigator. To accommodate the subject's position, the goniometer was aligned with the axis over the medial humeral epicondyle, the stationary arm aligned with the acromion process, and the moveable arm aligned with the ulnar styloid process.

Data Analysis

All data were analyzed using JMP statistical software (version 5.0; Cary, NC). To find the false positive rate of each test, a simple percentage of positive tests divided by the total sample size was calcu-

lated. Descriptive statistics included the mean, range, standard deviation, 95% confidence interval; and the 75th percentile were calculated for each test. A chi-square statistic was used to determine if a difference existed between the dominant and non-dominant extremities. A chi-square statistic was also used to determine if a difference existed between men and women. A Kappa statistic was used to identify agreement between results of the ULNTT and SST.

Results

A total of 94 subjects participated in this investigation. Ten subjects were excluded based on previous medical conditions identified in the exclusion questionnaire resulting in a sample size of 84. Twenty-seven males (32.1%) and 57 females (67.9%) with a mean age of 22.9 years (SD=2.48) participated in this study. Seventy-six participants (90.5%) were right-hand dominant and eight participants (9.5%) were left-hand dominant. For the SST, there were 28 positive (33.3%) and 56 negative (66.6%) tests. For the ULNTT, there were 74 positive tests (88.1%) and 10 negative (11.9%) tests.

The mean knee extension angle for all positive SSTs was 15.1° with a 95% CI between 12.3° and 19.7°. The mean elbow extension angle for all positive ULNTTs was 49.4° with a 95% CI between 44.8° and 54.0°. The 75th percentile for SSTs and ULNTTs was 22° and 60°, respectively.

There was no significant difference between males and females on the SST ($p = 0.56$). There was a significant differ-

ence between males and females on the ULNTT ($p = 0.02$), with women having a greater number of false positive tests than men. There were no significant differences between right-hand and left-hand dominant subjects on either the SST or ULNTT ($p = 0.06$ and $p = 0.25$), respectively. The Kappa statistic revealed minimal agreement between positive and negative results of the SST and the ULNTT (Kappa = 0.14).

Discussion

With any pain sensitive structures, i.e., those containing nociceptive innervation, the application of a sufficient deforming force will produce an undesired symptomatic response. Therefore, it should be of no surprise that maximally stretching a nerve or nerve root to the anatomical limit would produce an undesired neural-mediated response^{3,12,23-25}. The dura mater is innervated by sinuvertebral nerves while peripheral nerves are thought to be innervated intrinsically by myelinated *nervi nervorum* fibers that are located in the epineurium. The *nervi nervorum* fibers are often implicated in neurogenic pain^{1,26,27}. This investigation attempted to identify possible range of motion cut-off scores within the range of knee and elbow extension that could be used in conjunction with bilateral comparison and reproduction of the patient's symptoms to help differentiate between normal and pathologic neural tension.

Using structural differentiation as the criterion, this investigation found the false positive rate for the SST to be 33.3%. Since all participants were determined to be asymptomatic, every positive test was considered a false positive result. For those participants with a positive SST, knee extension measurements were found to range from 6° to 30° with a mean of 15.1°. In a sample of 34 healthy male subjects, Johnson and Chiarello²⁸ investigated several variations of the SST and reported a mean knee extension angle of 18.2° with a range of 0–40° when the SST was performed with cervical flexion and ankle dorsiflexion. They suggested that knee extension angles less than 7° to 11.2° be considered normal. It is important to note that Johnson

and Chiarello were measuring the ability of the subject to fully extend the knee rather than trying to ascertain the exact onset of neurogenic symptoms.

The false positive rate found in this investigation is supported by the findings of Kuilart et al²⁹, who reported a 33.3% false positive rate for the SST among asymptomatic subjects when posterior leg symptoms were reproduced with the SST and relieved by structural differentiation. Yeung et al³⁰ examined the knee angle associated with the SST in a group of patients with whiplash-associated disorder and a control group consisting of 40 asymptomatic subjects. Using 90° of knee extension as the zero point, they found the mean knee extension angle to be 16°. Based on the data obtained in this investigation, we suggest the possible upper limit for interpreting a positive test be extended to 22° of knee extension, which represents the upper limit of the 75th percentile.

In a similar study, Walsh et al³¹ performed the SST on 84 young healthy adults without lumbar or lower extremity symptoms. They reported that 97.6% of the asymptomatic subjects experienced a lower extremity sensory response during the SST. They also reported that 79.2% of the subjects experienced complete or partial relief of symptoms with structural differentiation. While the Walsh et al investigation supports the high rate of positive neurogenic response in asymptomatic individuals, they made no attempt to quantify the onset of symptoms based on knee range of motion.

This present investigation used a modified version of the SST to allow uniform comparison of subjects based on the isolated knee joint angle. Therefore, our recommendation of using 22° as a possible cut-off for a positive test should only be used when cervical flexion and ankle dorsiflexion are performed before knee extension. Currently, it is unclear if a different test sequence will affect the false positive rate.

The false positive rate for the ULNTT was found to be high at 86.9% in this sample of asymptomatic adults. This is consistent with the low specificity of 0.13 reported by Wainner et al³² in a

study examining the diagnostic validity of the ULNTT in patients with carpal tunnel syndrome. A high false positive rate will result in a low specificity, where specificity is calculated as the number of true negative tests divided by the number of subjects without the pathology³³. Pullos^{34,35} examined the normal range of motion deficit with the ULNTT in 100 asymptomatic individuals and found a range of 16.5° to 53.2° to elicit symptoms. Coppieters et al¹⁷ reported a mean onset of symptoms at 132.8°, which corresponds to 47.2° of elbow flexion. This closely agrees with the mean of 49.4° and the 95% confidence interval for a positive ULNTT of 44.0° to 53.4° identified in this investigation. Sterling et al³⁶ examined 95 asymptomatic control subjects as part of a larger study of patients with whiplash-associated disorder (WAD). Using a modified ULNTT, they reported a mean elbow angle of 12.9°. The description of their testing procedure makes it unclear if the forearm was supinated as part of the testing procedure. Based on the results of this investigation, we suggest 60° of elbow flexion as a possible cut-off score for the interpretation of a positive ULNTT.

Using the 75th percentile (22°) of all positive tests as the cut-off for the SST would have resulted in eight false positive tests for a false positive rate of 9.5%. Using the 75th percentile (60°) of all positive tests as the cut-off for the ULNTT would have resulted in 19 false positives for a false positive rate of 22.6%. The use of the 75th percentile may be considered somewhat arbitrary but it is presented as a possible cut-off score that would limit the number of false positive tests to a more clinically acceptable level. Further research using these cut-off scores in both healthy subjects and pathologic patients is needed to validate these proposed cut-offs scores.

All symptoms for those with a positive SST or ULNTT were relieved by structural differentiation (returning the cervical spine to a neutral position). Thus, it is believed that the symptoms were produced explicitly from tension on neural tissues rather than musculoskeletal tissues⁶. When examining the agreement between the SST and ULNTT, a weak agreement ($k = 0.14$) of positive

tests was found between the two neural tension tests. Therefore, there does not appear to be a strong relationship between the neural sensitivity of the upper extremity to that of the lower extremity. However, it is important to note that for every participant with a positive SST, he or she also had a positive ULNTT.

Limitations

Several limitations of the investigation should be noted. This investigation included healthy young adults with a mean age of 22.9 years. This may have resulted in spectrum bias, which may have affected the false positive rate in this sample³⁷. Further investigation of this type is warranted in a sample of older adults. Next, because a few subjects reported to the laboratory without proper attire, palpation of the femoral trochanter for the SST was performed through clothing. Third, to avoid maintaining the subject in a position of maximal neural tension for an extended period, the investigator performing the goniometry measurements was not blinded to the patient's report of symptoms. In another limitation related to all neural tension testing, the report of symptoms was subjective. To control for this subjectivity, the investigators only identified a positive test if symptoms were relieved with cervical flexion (SST) or cervical lateral flexion (ULNTT). Additionally, some of the subjects may have had an occult pathology that was undiagnosed or asymptomatic. The researchers assumed that successful completion of the screening questionnaire resulted in a subject without overt spinal or nervous system pathology.

Another limitation of this investigation was that bilateral comparison was not performed. Based on the current literature, it is suggested that clinicians also compare symptoms bilaterally to determine if there is a difference between the involved and uninvolved extremities. It should be noted that in this sample of asymptomatic subjects, there was not an involved side; however, bilateral comparison would be helpful to ascertain the left to right variability in normal subjects. Future investigations of

this type should include bilateral comparison in a sample of patients with cervical and lumbar pathology to help validate these proposed cut-off scores.

Further investigation is warranted to determine the diagnostic validity of the SST and ULNTT in both symptomatic and asymptomatic subjects based on the proposed cut-off scores. The false positive rate, using structural differentiation as the defining criteria, found in this group of healthy asymptomatic subjects raises concern regarding the diagnostic validity of these clinical tests to identify a negative test among normal healthy subjects when full-range testing is performed. It should be noted that this investigation did not address the rate of false negative tests among symptomatic patients with neural mediated signs or symptoms.

Conclusion

The purpose of this investigation was to determine the false positive rate of the seated slump test (SST) and the upper limb tension test (ULNTT) in a sample of healthy adults without spine or peripheral symptoms. The false positive rate was found to be high for both the SST (33.3%) and the ULNTT (86.9%), which raises question about the diagnostic validity of these tests as previously described using full-range knee and elbow testing. Based on the results of this investigation, it appears that there is a significant degree of inherent neural sensitivity among healthy adults without a history of spinal or peripheral symptoms when full-range testing is performed. To increase the diagnostic accuracy of these tests, we have proposed possible cut-off scores for these tests. Based on the 75th percentile, we suggest that a positive test only be identified when peripheral symptoms are reproduced before 22° of knee extension in the SST and 60° of elbow extension in the ULNTT.

REFERENCES

- Butler DA. *Mobilisation of the Nervous System*. Melbourne, Australia: Churchill Livingstone, 1991.
- Butler D, Gifford L. The concept of adverse mechanical tension in nervous system. Part 1: Testing for dural tension. *Physiother* 1989;75:623–636.
- Elvey R. Treatment of arm pain associated with abnormal brachial plexus tension. *Aust J Physiother* 1986;32:225–230.
- Magee D. *Orthopedic Physical Assessment*. 4th ed. Philadelphia: Saunders, 2002.
- Maitland G. The slump test: Examination and treatment. *Aust J Physiother* 1985;31: 215–219.
- Shacklock M. *Clinical Neurodynamics: A New System of Musculoskeletal Treatment*. Sydney, Australia: Elsevier Butterworth Heinemann, 2005.
- Shacklock M. Neurodynamics. *Physiother* 1995;81:9–16.
- Maitland GD. Movement of pain sensitive structures in the vertebral canal and intervertebral foramina in a group of group of physiotherapy students. *S Afr J Physiother* 1980;36:4–12.
- Maitland GD. Negative disc exploration: Positive canal signs. *Austr J Physiother* 1979; 25:129–134.
- McLellan DL, Swash M. Longitudinal sliding of the median nerve during movements of the upper limb. *J Neurol Neurosurg Psychiatry* 1976;39:566–570.
- Wilgis EF, Murphy R. The significance of longitudinal excursion in peripheral nerves. *Hand Clin* 1986;2:761–766.
- Walsh MT. Upper limb neural tension testing and mobilization: Fact, fiction, and a practical approach. *J Hand Ther* 2005;18:241–258.
- Calvin WH, Devor M, Howe JF. Can neuralgias arise from minor demyelination? Spontaneous firing, mechanosensitivity, and after-discharge from conducting axons. *Exp Neurol* 1982;75:755–763.
- Jaberzadeh S, Scutter S, Nazeran H. Mechanosensitivity of the median nerve and mechanically produced motor responses during upper limb neurodynamic test 1. *Physiother* 2005;91:94–100.
- Sandmark H, Nisell R. Validity of five common manual neck pain provoking tests. *Scand J Rehabil Med* 1995;27:131–136.
- Coppieters MW, Stappaerts KH, Everaert DG, Staes FF. Addition of test components during neurodynamic testing: Effect on range of motion and sensory responses. *J Orthop Sports Phys Ther* 2001;31:226–237.
- Coppieters MW, Stappaerts KH, Janssens K,

- Jull G. Reliability of detecting 'onset of pain' and 'submaximal pain' during neural provocation testing of the upper quadrant. *Physiother Res Int* 2002;7:146-156.
18. Hines T, Noakes R, Manners B. The upper limb tension test: Inter-tester reliability for assessing the onset of passive resistance R1. *J Man Manip Ther* 1993;1:95-98.
 19. Stankovic R, Johnell O, Maly P, Willner S. Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus: A prospective clinical study. *Man Ther* 1999;4:25-32.
 20. Gabbe BJ, Bennell KL, Wajswelner H, Finch CF. Reliability of common lower extremity musculoskeletal screening tests. *Phys Ther in Sport* 2004;5:90-97.
 21. Philip K, Lew P. The inter-therapist reliability of the slump test. *Aust J Physiother* 1989;35:89-94.
 22. Sizer PS, Phelps V, Dedrick G, Matthijs O. Differential diagnosis and management of spinal nerve root-related pain. *Pain Practice* 2002;2:98-121.
 23. Asbury AK, Fields HL. Pain due to peripheral nerve damage: An hypothesis. *Neurology* 1984;34:1587-1590.
 24. Kenneally M, Rubenach H, Elvey R. The upper limb tension test, the SLR test of the arm. In *Physical Therapy of the Cervical and Thoracic Spine*. New York, NY: Churchill Livingstone, 1988.
 25. Yaxley GA, Jull GA. A modified upper limb tension test: An investigation of responses in normal subjects. *Aust J Physiother* 1991;37:143-152.
 26. Bogduk N. Lumbar dorsal ramus syndrome. *Med J Aust* 1980;2:537-541.
 27. Williams PL, Warwick R. *Gray's Anatomy*. Philadelphia, PA: W.B. Saunders, 1980.
 28. Johnson EK, Chiarello CM. The slump test: The effects of head and lower extremity position on knee extension. *J Orthop Sports Phys Ther* 1997;26:310-317.
 29. Kuilart KE, Woollam M, Barling E, Lucas N. The active knee extension test and slump test in subjects with perceived hamstring tightness. *Int J Osteopath Med* 2005;8:89-97.
 30. Yeung E, Jones M, Hall B. The response of the slump test in a group of female whiplash patients. *Aust J Physiother* 1997;43:245-252.
 31. Walsh J, Flatley M, Johnston N, Bennett K. Slump test: Sensory responses in asymptomatic subjects. *J Man Manip Ther* 2007;15:231-238.
 32. Wainner RS, Fritz JM, Irrgang JJ, Delitto A, Allison S, Boninger ML. Development of a clinical prediction rule for the diagnosis of carpal tunnel syndrome. *Arch Phys Med Rehabil* 2005;86:609-618.
 33. Portney LG, Watkins MP. *Foundations of Clinical Research: Application to Practice*. 2nd ed. Upper Saddle River, NJ: Prentice Hall, 2000.
 34. Pullos J. *The Upper Limb Tension Test*. Honours Thesis, Department of Physiotherapy, University of Queensland, Australia, 1985.
 35. Pullos J. The upper limb tension test. *Aust J Physiother* 1985;32:258-259.
 36. Sterling M, Treleaven J, Jull G. Responses to a clinical test of mechanical provocation of nerve tissue in whiplash associated disorder. *Man Ther* 2002;7:89-94.
 37. Mulherin SA, Miller WC. Spectrum bias or spectrum effect? Subgroup variation in diagnostic test evaluation. *Ann Intern Med* 2002;137:598-602.