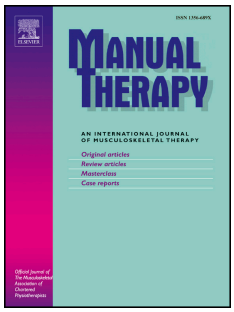
# Accepted Manuscript




The short term effects of straight leg raise neurodynamic treatment on pressure pain and vibration thresholds in individuals with spinally referred leg pain

Dr Colette Ridehalgh, PhD, MSc, MCSP, MMACP, Senior Lecturer, Professor Ann Moore, PhD, FCSP, FMACP, Cert Ed, Dr Alan Hough, PhD, MCSP, Honorary Associate Professor

PII: S1356-689X(16)00032-1

DOI: 10.1016/j.math.2015.12.013

Reference: YMATH 1834

To appear in: *Manual Therapy*

Received Date: 2 September 2015

Revised Date: 15 December 2015

Accepted Date: 16 December 2015

Please cite this article as: Ridehalgh C, Moore A, Hough A, The short term effects of straight leg raise neurodynamic treatment on pressure pain and vibration thresholds in individuals with spinally referred leg pain, *Manual Therapy* (2016), doi: 10.1016/j.math.2015.12.013.

# Title Page

The short term effects of straight leg raise neurodynamic treatment on pressure pain and vibration thresholds in individuals with spinally referred leg pain.

Dr Colette Ridehalgh (PhD, MSc, MCSP, MMACP) Senior Lecturer, School of Health Sciences, University of Brighton, UK

Professor Ann Moore (PhD, FCSP, FMACP, Cert Ed) Head of the Centre for Health Research, School of Health Sciences, University of Brighton, UK

Dr Alan Hough (PhD, MCSP) Honorary Associate Professor, School of Health Professions Faculty of Health and Human Sciences, University of Plymouth, UK

Work attributed to: Centre for Health Research, School of Health Sciences, University of Brighton, Aldro Building, 49 Darley Rd, Eastbourne, BN20 7UR, UK.

Corresponding author: Colette Ridehalgh, School of Health Sciences, University of Brighton, Robert Dodd Building, 49 Darley Rd, Eastbourne, BN20 7UR, UK.

Tel +44 1273 643686, Fax +44 1273 643652

Email: cr19@brighton.ac.uk

## ABSTRACT

### Background

Limited research exists for the effects of neurodynamic treatment techniques. Understanding short term physiological outcomes could help to better understand immediate benefits or harm of treatment.

### Objectives

To assess the short-term effects of a straight leg raise (SLR) tensioner on pressure pain thresholds (PPT) and vibration thresholds (VT), and establish if additional factors influence outcome in individuals with spinally referred leg pain.

### Design

Experimental, repeated measures.

### Methods

Sixty seven participants (mean age (SD) 52.9 (13.3), 33 female) with spinally referred leg pain were divided into 3 sub-groups: somatic referred pain, radicular pain and radiculopathy. Individuals were assessed for central sensitisation (CS) and completed 5 disability and psychosocial questionnaires. PPT and VT were measured pre and post a 3 x 1 minute SLR tensioner intervention.

### Results

No significant differences ($p>0.05$) were found between the 3 groups for either outcome measure, or after treatment. Slight improvements in VT were seen in the radiculopathy group after treatment, but were not significant. Only 2 participants were identified with CS.

Disability and psychological factors were not significantly different at baseline between the 3 sub-groups, and did not correlate with the outcome measures.

Conclusions

No beneficial effects of treatment were found, but the trend for a decrease in VT indicated that even in individuals with radiculopathy, no detrimental changes to nerve function occurred. Psychosocial factors and levels of disability did not influence short term outcome of SLR treatment.

Key Words: Neurodynamics; Nerve function; Pressure pain thresholds; Spinally referred leg pain; Straight leg raise.

## TEXT

## INTRODUCTION

Spinally referred leg pain predominantly occurs from nociceptive referral of spinal structures such as ligaments, muscles and disc (somatic)[1] or neural tissue. Where loss of nerve function is found, this is described as radiculopathy, whereas nerve root irritation without loss of nerve function is termed radicular pain[1]. The management of such conditions varies, but for individuals where nerve root irritation is present, neurodynamic treatment (NDT) has been proposed. [2,3]

Adding NDT treatments to other techniques for spinally referred leg pain has shown some benefits [2,4,5], however it is not known why such improvements in outcome occur. Limitations of the studies do not clarify the reason for the improvements. Some authors have suggested that applying NDT tensioner techniques to individuals with neuropathic pain may have detrimental effects [6,7]. In contrast, recent animal studies have indicated that tensioner techniques not only positively influence pain behaviours, but may also have

positive effects on inflammatory cells within the dorsal horn. [8,9] Such gaps on the effects of NDT in the literature and potential for detrimental changes require further investigation.

Change in pain is an essential measurement when assessing the effects of treatment interventions, and pressure pain thresholds (PPT) are widely used within the literature. [10,11] PPT are reliable [12,13] and provide a semi-objective measure of pain. However, pain changes alone only give an indication of one aspect of outcome. In individuals with neuropathic pain, changes to nerve function after NDT are important because inducing strain to the nerve of greater than 8% may reduce circulation [14,15], and impair nerve conduction [16,17]. Whilst small levels of strain have been found in the nerve roots during SLR in cadavers (<3.4% [18]), neuropathy may detrimentally affect normal nerve mechanics [6,19].

Vibration thresholds (VT) have been utilised as an early indicator of deterioration in nerve function. They are more useful than nerve conduction testing because they are sensitive to minor nerve dysfunction and specifically test the large diameter afferents, which deteriorate after nerve root compression [20,21].

Treatment outcomes may be affected by a number of variables, including high levels of disability [23,24] and psychosocial factors [25,26]. The presence of central sensitisation (CS) is also considered to be a poor predictor of outcome for manual based interventions. [27] It isn't known whether these factors influence the physiological responses to NDT.

The aim of this study was to assess the short term effects of a SLR tensioner technique on PPT and VT in individuals with spinally referred leg pain, and to establish if certain factors had an impact on outcome. Whilst short term outcomes have limitations in terms of extrapolation into clinical practice, this study looked at what factors might impact on these physiological measures in different sub-groups of individuals with spinally referred leg

pain, rather than looking at the overall effectiveness of treatment, where long term and functional outcomes are most desirable.

## METHODS

The study received ethics approval from the host university's Faculty of Health and Social Science Ethics and Governance panel, and the UK's NHS ethics panel (REC reference 12/LO/0397).

### Participants

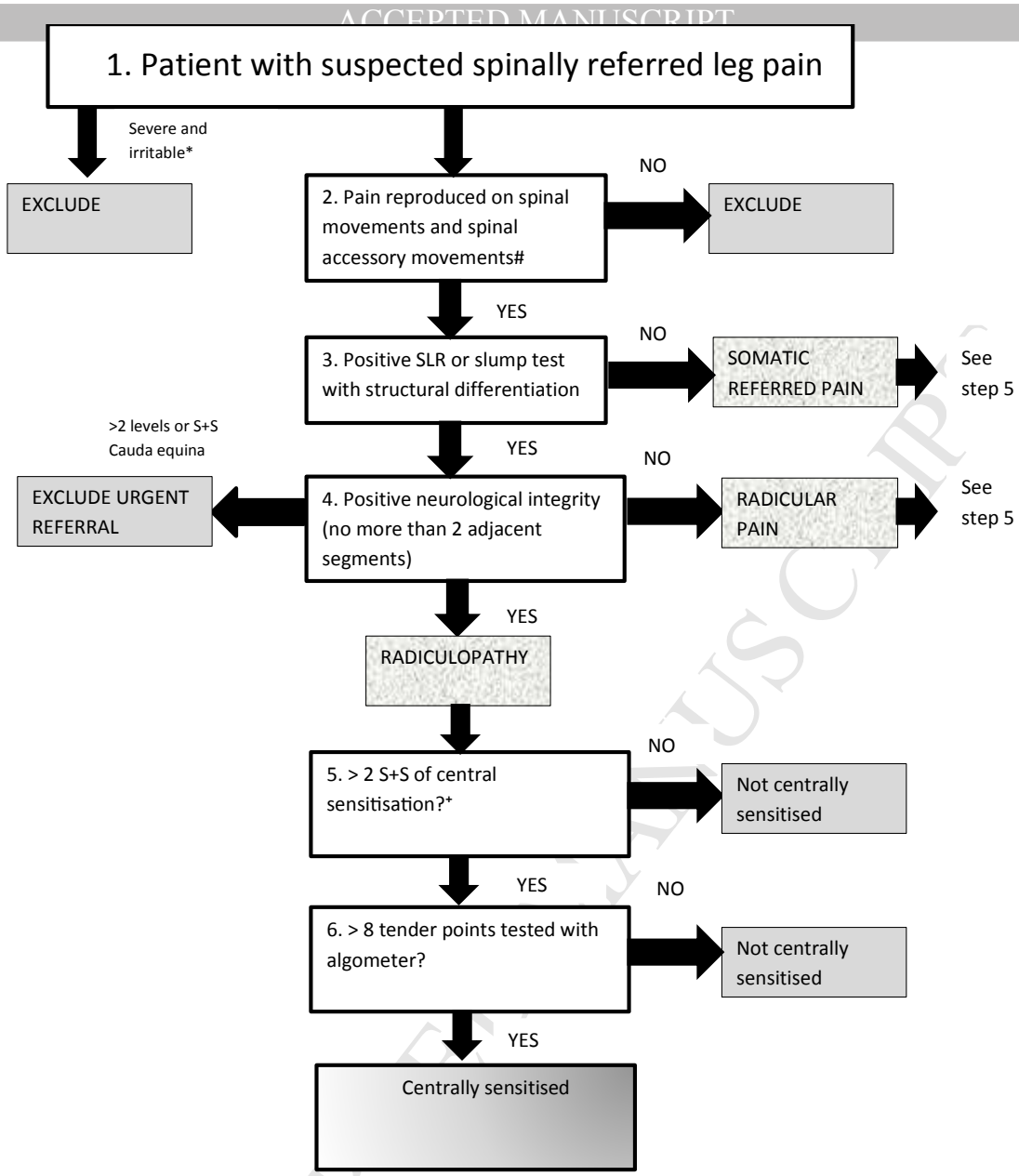
Participants were recruited from Physiotherapy waiting lists of 3 NHS trusts in the South East region of the UK. Participants who were not currently undergoing treatment for their pain were also recruited via University email and adverts in local newspapers. Participants were included if they had spinally referred leg pain for greater than 3 months, without other medical problems such as diabetes, rheumatoid arthritis or other systemic disorders. All participants were given an information sheet and signed a consent form prior to commencement in the study. The participants attended 2 sessions; the first to sub- group and ensure their eligibility and the second was the experimental stage of the study.

### Sub-grouping

Participants were assessed by one of 6 experienced Physiotherapists with at least 4 years' experience in musculoskeletal practice. Training was given to all Physiotherapists prior to the commencement of the study.

Full subjective and physical examinations of each participant were performed, before allocating each individual into one of 3 sub-groups (Figure 1). If participants complained of

more than 2 signs of CS (pain > 6 months [28], widespread areas of pain [26], hypersensitivity to warmth or cold[29], and hypersensitivity to touch [26,28]), an examination of painful points was undertaken (Figure 2). The algometer (Wagner FPK, Greenwich, USA) was placed on each of the points, and the pressure increased up to 4kg/cm². If more than 8 of the points were painful, the participants were considered to have CS.[26]




* severity based on patient's ability to be able to sustain their painful position. Irritability based on time to aggravate and time to ease symptoms on simple planar movements (Petty, 2011).

# If pain not reproduced on planar movements, combined, repeated or sustained movements performed. PAIVMS performed in provocative position where indicated.

+S+S central sensitisation- pain> 6 months, widespread areas of pain, hypersensitivity to warmth, cold or touch.

103

104 **FIGURE 1** flow chart of sub-grouping procedure

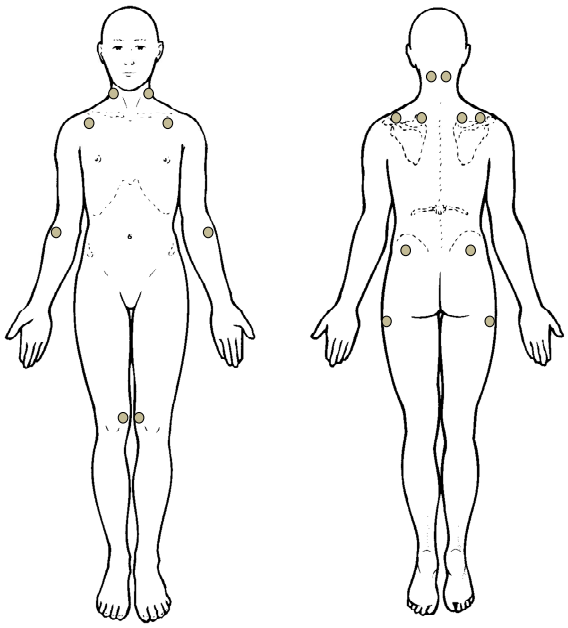


**FIGURE 2** Tender point assessment

Experimental Stage

Participants attended the laboratory a minimum of 48 hours after their initial assessment.

Participants filled out 5 questionnaires: Fear avoidance belief questionnaire (FABQ), Tampa scale of kinesiophobia, Oswestry disability index (ODI), Depression, anxiety and stress scale (DASS), and Pain catastrophising scale (PCS).

Height and weight measurements were taken of all participants. The order of PPT or VT measurements was randomly allocated by asking participants to choose a piece of paper from a bag written with either V or P. All measures were taken by one researcher blinded to the group allocation of participants.

*Vibration threshold testing*

Participants lay prone and a practice VT was obtained from the unaffected side on the plantar surface of the base of the first metatarsal using a vibrameter (Somedic AB, Sweden). The probe was placed perpendicular on the metatarsal so that the weight of the probe rested fully on the area. Vibration was slowly increased until the participant felt the onset. The stimulus was then increased before being reduced again until the participant could no longer feel the sensation. Once a consistent measure (within 10%) had been demonstrated, VT readings were taken from the same site on the affected side. Three vibration appearance values and 3 vibration disappearance values were taken. The participant was then asked to lie on their unaffected side and VT readings were taken from the lateral malleolus of the affected side.

*Pressure Pain Thresholds*

Participants lay prone and a practice PPT was taken from the unaffected leg with a tracker freedom wireless algometer (J Tech Medical, Salt Lake City, U.S.A.) over the gastrocnemius belly and tibial nerve to familiarise the participant to PPT.

PPTs were taken from the middle portion of the deltoid muscle on the unaffected side, the tibial nerve behind the knee, and gastrocnemius (a point marked one third of the distance between the knee crease to the top of the calcaneal tuberosity) on the affected side.

Participants lay on their affected side and the probe placed perpendicular to middle portion of deltoid with pressure applied at the rate indicated by the pacer (1kg/sec). Participants were asked to push a hand plate when the sensation of pressure changed to one of discomfort. The participant turned prone and the same procedure was repeated for the tibial

nerve behind the knee, before moving on to the gastrocnemius point. Two further readings were taken from each site, giving a total of three for each site.

*Treatment procedure*

All participants regardless of grouping had the same treatment procedure. Participants lay supine on the plinth with an ankle foot orthosis applied to both sides and the affected knee fully extended. The affected hip was flexed to the point of a change to symptoms, or if there was no change in symptoms, to the point where resistance prevented further movement. If symptoms were still not reproduced, medial rotation and adduction were added until symptoms occurred or resistance limited movement. The knee was then flexed until symptoms subsided (if present) and the treatment consisted of the knee being extended to the point of symptom onset or end range of resistance (if there were no symptoms) and then flexed again repeatedly (a knee joint mobilisation in SLR position). A grade III- to III+ mobilisation (large amplitude into tissue resistance [30, pg62] ) was performed. A treatment dose of 3 x 1 minute mobilisations was performed, with a 1 minute rest between mobilisations. The choice of treatment time has not been established to date for NDT, so was informed by clinical practice, and previously used by the researcher. [31]

PPT and VT were then retested as described above.

Analyses

*Vibration threshold*

The mean of three appearance and 3 disappearance values were calculated to give the final VT reading. This follows the method of limits [32,33] and has excellent repeatability in individuals with spinally referred leg pain.[34]

*Pressure pain threshold*

Three PPT readings were taken from each site. The first reading was discarded and the mean of the second and third measures used for the final reading of each site. This method was found to enhance the repeatability of PPT measures in individuals with spinally referred leg pain.[34]

Data Analysis

All comparable data was analysed to ensure normality using the Shapiro Wilk test. Baseline comparisons were made using Pearson's correlation coefficients. Baseline differences were analysed by one way ANOVA or for non-normally distributed data Kruskall Wallis, and for nominal data Chi square test was used. Differences between the 2 outcome measures, and between the 3 sub-groups were analysed using a 3 way mixed factorial ANOVA (time and site the within subject variables, and group the between subject variable) with subsequent covariate analysis to assess for any factors which may have influenced the outcomes. Post hoc testing was performed using Sidak corrected post hoc tests, unless indicated otherwise, and contrasts where appropriate. All p values were considered significant at $p<0.05$ level.

## RESULTS

Sixty seven participants were involved in the study; 13 were recruited from Physiotherapy waiting lists, and 54 from outside of the NHS. Table 1 gives the demographic details of all participants. There were no baseline differences in any of the variables between groups except for age and pain below the knee. Post hoc testing of age using Gabriel's pairwise test found no significant differences between the 3 sub-groups. For pain below the knee, the

somatic group, had a lower percentage of individuals with pain below the knee than radicular or radiculopathy groups.

| | | Diagnostic sub-groups | | | |
|---|---|---|---|---|---|
| | Total | Somatic | Radicular | Radiculopathy | *p* |
| N | 67 | 11 | 33 | 23 | |
| Age (years) | 52.9 (13.3) | 57.5 (10.6) | 48.5 (13.2) | 57 (13.1) | 0.027*[a] |
| Gender (% female) | 49.3 | 54.5 | 51.5 | 43.5 | 0.78[b] |
| Pain below knee (%) | 70.1 | 18.2 | 75.8 | 87 | 0.000[b] |
| Pain duration (years) | 2.7 (4.9) | 3.1 (5.9) | 3.1 (5.7) | 2 (2.8) | 0.422[a] |
| NHS Patients (%) | 19.4 | 25 | 21.2 | 13.04 | 0.58[b] |
| BMI | 27.1 (4.6) | 25.4 (3.6) | 27.2 (4.9) | 27.8 (4.6) | 0.36[a] |
| Disability (ODI) | 17.3 (10.1) | 16.3 (7.9) | 17.5 (8.1) | 17.4 (13.5) | 0.94[a] |
| Fear avoidance physical activity (FABQP) | 10.4 (4.9) | 11.6 (4.2) | 10.3 (4.8) | 10.2 (5.5) | 0.79[a] |
| Fear avoidance work (FABQW) | 9.2 (8.4) | 5.7 (7.2) | 9.2 (9) | 10.8 (7.9) | 0.26[a] |
| Pain Catastrophising (PCS) Total | 8.7 (8.9) | 5.8 (3.8) | 9.2 (8.9) | 9.4 (10.5) | 0.5[a] |
| PCS Rumination | 1 (5) | 1 (4) | 1 (5) | 2 (6) | 0.5[c] |
| PCS Magnification | 2 (3) | 2 (2) | 2 (3) | 2 (2) | 0.46[c] |
| PCS Helplessness | 2 (3) | 2 (2) | 2 (5) | 2 (4) | 0.71[c] |
| Depression (DASS21) | 1 (3) | 1 (3) | 1 (3) | 1 (6) | 0.72[c] |
| Anxiety (DASS21) | 1 (3) | 1 (2) | 2 (3) | 1 (3) | 0.69[c] |
| Stress (DASS21) | 4.8 (3.8) | 3.9 (3.2) | 5.3 (3.7) | 4.5 (4.2) | 0.54[a] |
| Kinesiophobia (Tampa) | 33 (10) | 34 (10) | 33 (10) | 35 (11) | 0.59[c] |

**TABLE 1** Baseline characteristics for the study participants

[a]One Way ANOVA, data given is means and standard deviations * post hoc testing revealed no sig diffs between groups (somatic v radicular $p = 0.114$, somatic v radiculopathy $p = 0.999$, radicular v radiculopathy $p = 0.051$).

[b]Chi Square Test

[c]Kruskall Wallis, data not normally distributed and data given is median and interquartile ranges

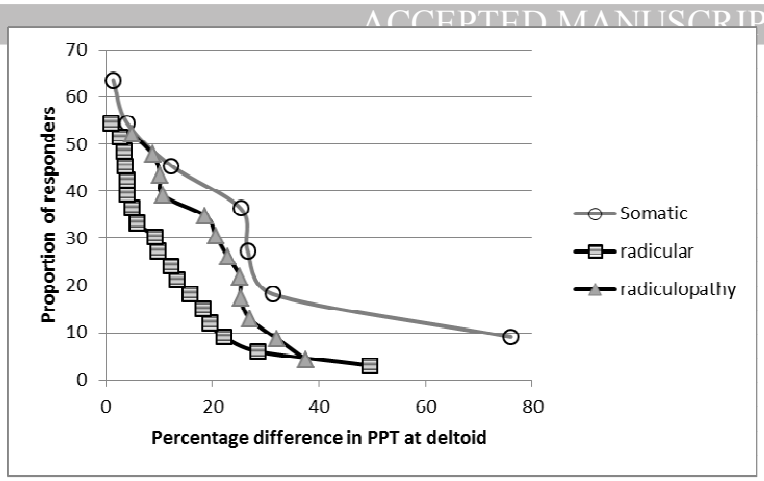
Key: BMI body mass index, ODI Oswestry disability scale, DASS disability anxiety and stress scale.

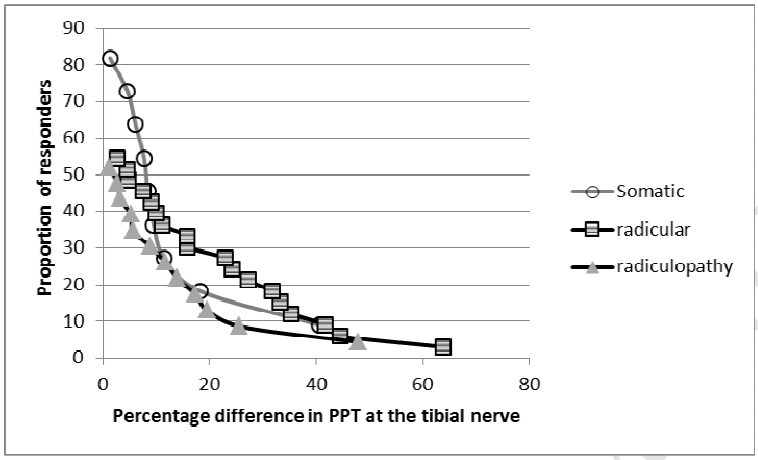
Pressure Pain Thresholds

Mean (SD) pre and post SLR treatment PPT readings and mean differences (SD) can be found in Table 2. Very small differences in PPT can be seen for all sites and sub-groups. Large standard deviations, suggesting marked variation in response to SLR treatment between individuals were found. A cumulative proportion of responders analysis was performed (Figure 3) to further analyse the data [30].

| Site | Deltoid | | | Tibial Nerve | | | Gastrocnemius | | |
|---|---|---|---|---|---|---|---|---|---|
| Group | Pre Rx | Post Rx | Mean Diffs | Pre Rx | Post Rx | Mean Diffs | Pre Rx | Post Rx | Mean Diffs |
| Somatic | 5.69 (2.19) | 6.27 (2.73) | 0.58 (2.45) | 6.25 (2.88) | 6.84 (3.02) | 0.59 (0.92) | 5.55 (2.10) | 6.19 (2.44) | 0.64 (1.80) |
| Radicular | 4.59 (2.33) | 4.4 (2.08) | -0.19 (0.97) | 4.62 (2.21) | 4.84 (2.25) | 0.22 (1.27) | 4.61 (2.07) | 4.63 (2.09) | 0.02 (0.83) |
| Radiculopathy | 4.58 (1.54) | 4.96 (1.98) | 0.38 (0.95) | 5.14 (2.02) | 4.93 (1.62) | -0.21 (1.26) | 5.02 (1.78) | 4.78 (1.94) | -0.24 (0.73) |

**TABLE 2** Mean (SD) PPT for each site and for each sub-group of individuals with spinally referred leg pain. Key: Rx = treatment



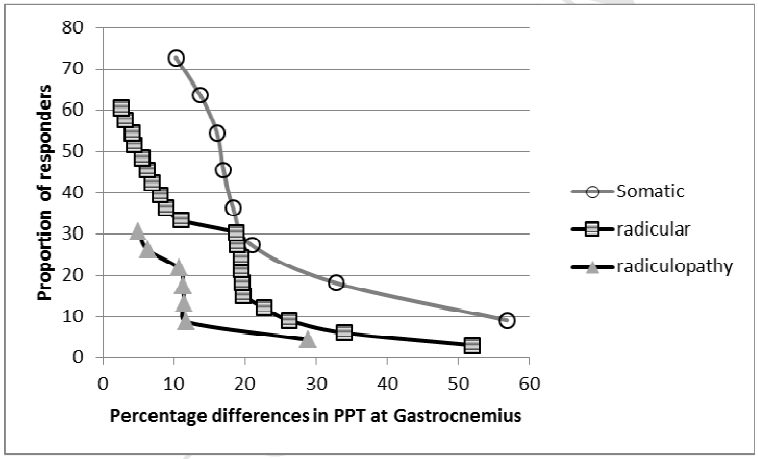




**FIGURE 3** Cumulative proportion of responders PPT (Kg) at deltoid (top), tibial nerve (middle) and gastrocnemius (bottom) site for each group

*Statistical Analysis*

All data were normally distributed (Shapiro Wilk p >0.05), apart from the tibial nerve pre-readings in the radicular group (p=0.009). Since only 1/18 readings reached statistical significance, and ANOVA is robust to alterations in normal distribution [35, pg 444], no transformations were carried out.

Mauchly's test of sphericity was not significant therefore sphericity was assumed. There was no main significant effect of group ($F(2, 64) = 2.77$, $p=0.07$), or time ($F(1, 64) = 2.46$, $p= 0.12$) or site ($F(2, 128) = 1.82$, $p= 0.16$), and no significant interaction effects for time v site ($F(2, 128) = 0.22$, $p= 0.8$) or time v group ($F(2, 64) = 1.92$, $p= 0.16$).
No significant correlations were found between the PPT readings and the psychosocial or disability factors, and no significant differences between groups at baseline, therefore no covariate analysis was performed.

Vibration Thresholds

Missing data occurred in some participants due to equipment failure and erroneous readings over 20µm [36] (see Table 3 and figure 4). In the case of the missing data due to elevated VT readings, all participants were male and between the ages of 64-69 years.

| Group | Site | N | Reason |
|---|---|---|---|
| Somatic | Both | 1 | Equipment failure |
| | 1st Metatarsal | 1 | VT>20µm |
| Radicular | Both | 1 | VT>20µm |
| | 1st Metatarsal | 1 | VT>20µm |
| Radiculopathy | Both | 1 | Equipment failure |
| | 1st Metatarsal | 1 | VT>20µm |

**TABLE 3** Missing vibration threshold data

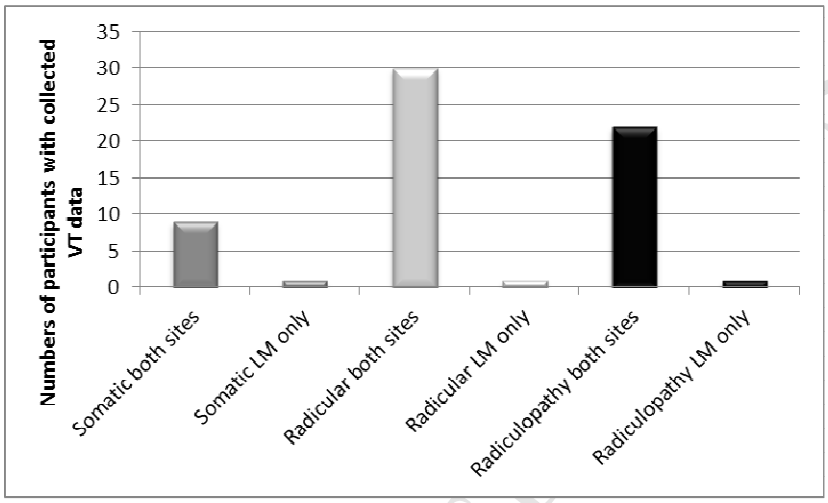



**FIGURE 4** Final numbers of participants with collected vibration threshold (VT) data

Key: LM vibration threshold from lateral malleolus

Figure 5 shows the mean differences (before and after) measures for each site. It can be seen that there was a tendency for a reduction in VT in both the somatic and radiculopathy groups after treatment, but a slight increase in the radicular group.

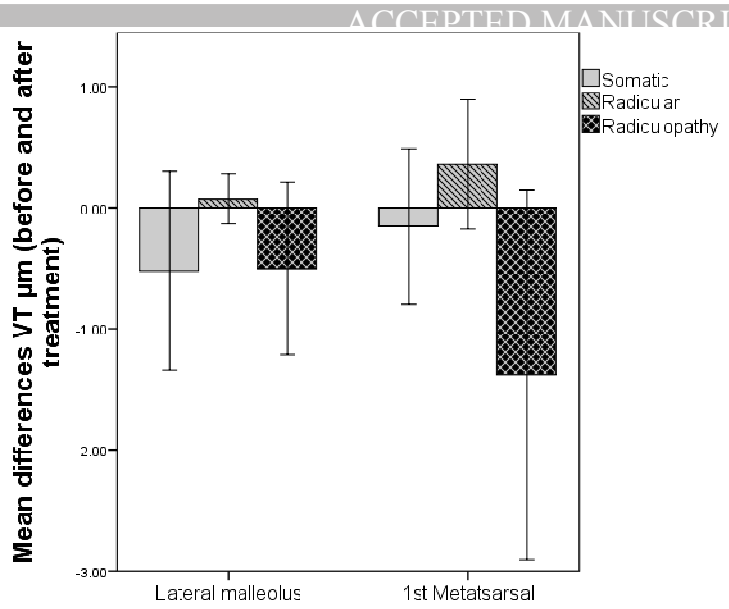



**FIGURE 5** Mean VT measures (µm) before and after treatment at the lateral malleolus and first metatarsal sites. The 95% confidence intervals demonstrate large variability in readings especially for the somatic and radiculopathy groups.

*Statistical Analysis*

All data were not normally distributed, (Shapiro Wilk test<0.05). A box-cox transformation ($VT^{a}$)-1/a (where a=0.1) successfully normalised all but one of the readings. Since ANOVA is robust to minor violations of normality, this transformation was considered successful.

There was a main effect for group ($F(2, 57) = 4.79$, $p= 0.012$). Sidak corrected post hoc tests indicated significantly higher VT for the radiculopathy compared to radicular group ($p=0.01$). There was a main significant effect for site ($F(1, 57) = 38.17$, $p<0.01$), but no other significant within subject effects ($p>0.05$).

Correlation analysis using Pearson's correlation (Table 4) showed significant strong correlations for VT with age. As age was strongly correlated with vibration thresholds, this interaction was entered into the analysis. No significant differences were seen for any

within or between subject analyses, indicating that the significantly higher VT in the radiculopathy group found in the first analysis was related to age.

| Variables | Correlation coefficient | P value | Confidence interval | $r^2$ |
|---|---|---|---|---|
| VTLM pre : age | 0.554 | 0.000 | 0.37-0.71 | 0.307 |
| VTLM post: age | 0.501 | 0.000 | 0.31-0.67 | 0.25 |
| VT1MT pre: age | 0.467 | 0.000 | 0.27-0.63 | 0.22 |
| VT1MT post: age | 0.446 | 0.001 | 0.22-0.63 | 0.199 |

**TABLE 4** Pearson's correlation between VT and age
Key: VTLM vibration threshold from lateral malleolus, VT1MT vibration thresholds 1st metatarsal.

There were no other significant correlations ($p>0.05$) between the psychosocial or disability factors and VT and no other baseline differences between groups therefore no further covariate analyses were performed.

Central Sensitisation

Only 2 participants were classified with CS, one within the radicular group and the other the radiculopathy group, therefore no meaningful analysis of this data could be attempted.

## DISCUSSION

Pressure Pain Thresholds

No significant main or interaction effects were found, indicating that the 3 x 1 minute SLR treatment was not effective at reducing PPT in any of the 3 groups. The cumulative responders analysis was performed (Figure 3) because it allows for a more comprehensive

analysis of the response to treatment between groups [30]. It has been suggested that a change in PPT over 15% may be clinically significant [37]. At the deltoid site, over 40% of individuals in the somatic and radiculopathy groups showed an increase in PPT over 15%, but only around 25% in the radicular group. This trend reversed at the tibial nerve site with around 35% of individuals in the radicular group having increases of over 15%, whereas in the somatic and radiculopathy groups this fell to around 20% of participants. At gastrocnemius, less than 10% of participants in the radiculopathy group improved over 15%, whereas 30% of participants in the radicular group and over 50% in the somatic group improved by over 15%. Overall this suggests that a more positive effect on pain may have occurred in the somatic group, which is not the group in which this treatment would normally be chosen. Silva et al.[10] also found no within subject differences in PPT after different durations of SLR treatment in individuals with sciatica, but significantly worse PPT in individuals with sciatica compared to a control group after 7 minutes of treatment. It is not known if longer treatment duration would have had such effects in the present study.

Some limitations in the study design could account for the results of the present study. Firstly, it may have been useful to have measured the PPT over the most painful site where most change may have been expected. Secondly, it is possible that changes to pain may not occur immediately post treatment, but may be more apparent some hours or even days later. [38,39] Thirdly, treatment consisted of 1 session of 3 minutes of treatment; it is not known if this time is sufficient to cause changes to pain, particularly in individuals with long-standing symptoms.

Vibration Thresholds

No significant differences were found in VT between the groups or before and after treatment. Whilst there was a trend for a decrease in VT post treatment in radiculopathy and

somatic groups and a slight increase in VT in the radicular group, these were mean differences, and individual variation meant that there were no significant differences overall.

No beneficial effects of the NDT can be claimed, but importantly, no detrimental effects were found, even in individuals with altered neurological integrity. It has been suggested that applying tensioner techniques in individuals with neuropathy may be detrimental to nerve function [6,7] . The results of this study do not support such conclusions. Whilst it could be argued that the risk of accepting the results of the study may be due to the sample size, it is important to consider the large variation in the effect of SLR treatment on VT between individuals, some showing decreases and others increases in VT post treatment, which may have washed out any treatment effects.

To the author's knowledge, only one study has looked at the effects of a neural mobilisation on VT [31.] The findings of this study revealed no significant differences in asymptomatic participants, including a sub-group of runners. Since runners may be predisposed to neuropathy [40, 41, 42], the current study supports these findings. Nee et al., [43] analysed adverse events in individuals after upper quadrant NDT. No differences in improvement occurred between those who reported an adverse event and those who did not. Whilst this study did not analyse changes to nerve conduction, it does suggest that adverse effects from NDT are short lived and not harmful.

Central Sensitisation and other factors

Only 2 participants were identified with CS, an unexpected finding considering the longevity of symptoms (mean 2.7 years) and the postulated relationship between chronic LBP and CS [26, 28, 44]. The method used to identify CS may not be sufficiently robust,

although this method is commonly used to identify CS in a number of conditions including fibromyalgia [45,46, 47]. Another explanation could be that individuals with this condition may be reluctant to volunteer for a study which may induce pain.

There were no correlations between PPT and VT and any of the psychological measures or disability scores. In addition, there were no significant differences in baseline measures between the groups. This suggests that these variables were not responsible for the outcome to the SLR treatment.

## CONCLUSION

A 3 x 1 minute SLR treatment does not improve PPT in individuals with spinally referred leg pain, however it does not detrimentally affect VT. This suggests that nerve conduction is not altered after NDT even in individuals with signs of nerve function loss. Future work is essential to analyse optimal treatment doses and follow up times for outcome measures.

## REFERENCES

1. Bogduk, N. On the definitions and physiology of back pain, referred pain, and radicular pain. Pain 2009; 147: 17-19. http://dx.doi.org/ 10.1016/j.pain.2009.08.020.

2. Cleland, JA, Childs, JD, Palmer, JA, Eberhart, S. Slump stretching in the management of non-radicular low back pain: A pilot clinical trial. Manual Therapy 2006; 11: 279-286. http://dx.doi.org/10.1016/j.math.2005.07.002

3. Schäfer, A, Hall, T, Müller, G, Briffa, K. Outcomes differ between subgroups of patients with low back and leg pain following neural manual therapy: a prospective cohort study. European Spine Journal 2011; 20: 482-490. http://dx.doi.org/ 10.1007/s00586-010-1632-2

4. Adel, SM. Efficacy of neural mobilization in treatment of low back pain dysfunctions. Journal of American Science 2011; 7(4): 566-573.

5. Nagrale, AV, Patil, SP, Ghandi, RA, Learman, K. Effect of slump stretching versus lumbar mobilization with exercises in subjects with non-radicular low back pain: a randomized clinical trial. Journal of Manual and Manipulative Therapy 2012; 20(1): 35-42. http://dx.doi.org/10.1179/2042618611Y.0000000015

6. Boyd, BS, Puttlitz, C, Jerylin, G, Topp, KS. Strain and excursion in the rat sciatic nerve during a modified straight leg raise are altered after traumatic nerve injury. Journal of Orthopaedic Research 2005; 23: 764-770. http://dx.doi.org/10.1016/j.orthres.2004.11.008

7. Dilley, A, Lynn, B, Pang, S. Pressure and stretch mechanosensitivity of peripheral nerve fibres following local inflammation of the nerve trunk. Pain 2005; 117: 462-472. http://dx.doi.org/ 10.1016/j.pain.2005.08.018

8. Martins, DF, Mazzardo-Martins, L, Gadotti, VM et al. Ankle joint mobilization reduces axonotmesis-induced neuropathic pain and glial activation in the spinal cord and enhances nerve regeneration in rats. Pain 2011; 152: 2653–2661. http://dx.doi.org/10.1016/j.pain.2011.08.014

9. Santos, FM, Silva, JT, Giardini, AC et al. Neural mobilization reverses behavioral and cellular changes that characterize neuropathic pain in rats. Molecular Pain 2012; 8: 57. http://dx.doi.org/10.1186/1744-8069-8-57

10. Silva LI, Rocha, BP, Antunes, JS et al. Evaluation of the pressure pain threshold after neural mobilization in individuals with sciatica European Journal of Physiotherapy 2013; 15(3): 146-150. http://dx.doi.org/10.3109/21679169.2013.831119

11. Sterling, M, Jull, G, Wright, A. Cervical mobilisation: concurrent effects on pain, sympathetic nervous system activity and motor activity. Manual Therapy 2001; 6:72-81. http://dx.doi.org/10.1054/math.2000.0378

12. Antonaci, F, Sand, T, Lucas, GA. Pressure algometry in healthy subjects:inter-examiner variability. Scandinavian Journal of Rehabilitation Medicine 1998; 30: 3-8. http://dx.doi.org/ 10.1080/165019773038.

13. Walton, D, Macdermid, J, Nielson, W, Teasell, R, Chiasson, M, Brown, L. Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. Journal of Orthopaedic and Sports Physical Therapy 2011; 41(9): 644-650. http://dx.doi.org/10.2519/jospt.2011.3666

14. Driscoll, P J, Glasby, MA, Lawson, GM. An in vivo study of peripheral nerves in continuity: biomechanical and physiological responses to elongation. Journal of Orthopaedic Research 2002; 20: 370-375. http://dx.doi.org/ 10.1016/S0736-0266(01)00104-8

15. Jou, IM, Lai, KA, Shen, CL, Yamano, Y. Changes in conduction, blood flow, histology and neurological status following acute nerve stretch injury induced by femoral lengthening. Journal of Orthopaedic Research 2000; 18: 149-155. http://dx.doi.org/ 10.1002/jor.1100180121

16. Kwan, MK., Wall, EJ., Massie, JB., Garfin, SR. Strain, stress and stretch of peripheral nerve: rabbit experiments in vitro and in vivo. Acta Orthopaedica Scandinavia 1992;63: 267-272.

17. Wall, E J, Massie, JB, Kwan, MK, Rydevik, BL, Myers, RR, Garfin, SR. Experimental Stretch Neuropathy - Changes in Nerve-Conduction under Tension. Journal of Bone and Joint Surgery 1992; 74B: 126-129.

18. Smith, SA, Massie, JB, Chestnut, R, Garfin, SR. Straight leg raising: anatomical effects on the spinal nerve root without and with fusion. Spine 1993; 18: 992-999.

19. Kobayashi, S, Takeno, K, Yayama, T et al. Pathomechanisms of sciatica in lumbar disc herniation: effect of periradicular adhesive tissue on electrophysiological values by an intraoperative straight leg raising test. Spine 2010; 35(22): 2004-2014. http://dx.doi.org/10.1097/BRS.0b013e3181d4164d

20. Chatani, K, Kawakami, M, Weinstein, J, Meller, S, Gebhart, GF. Characterization of Thermal Hyperalgesia, c-fos Expression, and Alterations in Neuropeptides After Mechanical Irrigation of the Dorsal Root Ganglion. Spine 1995; 20(3): 277-290.

21. Kawakami, M, Weinstein, J, Chatani, K, Spratt, KF, Meller, ST, Gebhart, GF Experimental lumbar radiculopathy. Behavioural and histologic changes in a model of radicular pain after spinal nerve root irritation with chromic gut ligatures in the rat. Spine 1994; 19(16): 1795-1802.

22. Freynhagen, R, Rolke, R, Baron, R, et al. Pseudoradicular and radicular low-back pain – A disease continuum rather than different entities? Answers from quantitative sensory testing. Pain 2008; 135: 65–74.http://dx.doi.org/10.1016/j.pain.2007.05.004

23. Heymans, MW, van Buuren, S, Knol, DL, Anema, JR, van Mechelen, W, de Vet, HCW. The prognosis of chronic low back pain is determined by changes in pain and disability in the initial period. The Spine Journal 2010; 10(10): 847–856. http://dx.doi.org/ 10.1017/S0007114509289069

24. Hill, J, Konstantinou, K, Egbewale, BE, Dunn, KM, Lewis, M, van der Windt, D. Clinical outcomes among low back pain consulters with referred leg pain in primary care. Spine 2011; 36(25): 2168-2175. http://dx.doi.org/ 10.1097/BRS.0b013e31820712bb

25. Haugen, AJ, Brox, JI, Grovle, L et al. Prognostic factors for non-success in patients with sciatica and disc herniation. BMC Musculoskeletal Disorders 2012; 13: 183 http://dx/doi/org 10.1186/1471-2474-13-183

26. Jensen, OK, Nielsen, CV, Stengaard-Pedersen, K. Low back pain may be caused by disturbed pain regulation: A cross-sectional study in low back pain patients using tender point examination. European Journal of Pain 2010; 14: 514-522. http://dx.doi.org/10.1016/j.ejpain.2009.09.002

27. Jull, G, Sterling, M, Kenardy, J, Beller, E. Does the presence of sensory hypersensitivity influence outcomes of physical rehabilitation for chronic whiplash? – A preliminary RCT. Pain 2007; 129: 28–34. http://dx.doi.org/ 10.1016/j.pain.2006.09.030

28. O'Neill, S, Manniche, C, Graven-Nielsen, T, Arendt-Nielsen, L. Generalized deep-tissue hyperalgesia in patients with chronic low-back pain. European Journal of Pain 2007; 11: 415-420. http://dx.doi.org/10.1016/j.ejpain.2006.05.009

29. Berglund, B, Harju, E-L, Kosek, E, Lindblom, U. Quantitative and qualitative perceptual analysis of cold dysesthesia and hyperalgesia in fibromyalgia. Pain 2002; 96: 177-187. http://dx.doi.org/10.1016/S0304-3959(01)00443-2

30. Farrar, JT, Dworkin, RH, Max, MB. Use of the cumulative proportion of responders analysis graph to present pain data over a range of cut-off points: making clinical trial data more understandable. Journal of Pain and Symptom Management 2006; 31(4): 369-377. http://dx.doi.org/10.1016/j.jpainsymman.2005.08.018

31. Ridehalgh, C, Greening, J, Petty, NJ. Effect of straight leg raise examination and treatment on vibration thresholds in the lower limb: a pilot study in asymptomatic subjects. Manual Therapy. 2005;10(2):136-43. http://dx.doi.org/10.1016/j.math.2004.08.008

32. Goldberg, JM, Lindblom, U. Standardised methods of determining vibratory perception thresholds for diagnosis and screening in neurological investigation Journal of Neurology, Neurosurgery and Psychiatry 1979; 42: 793-803. http://dx.doi.org/10.1136/jnnp.42.9.793

33. Halonen, P. Quantitative vibration perception thresholds in healthy subjects of working age. European Journal of Applied Physiology and Occupational Physiology 1986; 54: 647-655. http://dx.doi.org/10.1007/BF00943355

34. Ridehalgh, C, Moore, A, Hough, A. Repeatability of vibration thresholds and pressure pain thresholds in individuals with spinally referred leg pain Rendez-vous of hands and minds. Proceedings IFOMPT Quebec, September 2012

35. Field, A. 2013 Discovering Statistics Using IBM SPSS Statistics. 4th ed. London: Sage.

36. Hilz, MJ, Axelrod, FB, Hermann, K, Haertl, U, Duetsch, M, Neundorfer, B. Normative values of vibratory perception in 530 children, juveniles and adults aged 3-79 years. Journal of the Neurological Sciences 1998; 159: 219-225.

37. Moss, P, Sluka, KA, Wright, A. The initial effects of knee mobilisations on osteoarthritic hyperalgesia. Manual Therapy 2007; 12: 109-118. http://dx.doi.org/10.1016/j.math.2006.02.009

38. De-La-Llave-Rincon, AI, Ortega-Santiago, R, Ambite-Quesada, S, et al. Response of pain intensity to soft tissue mobilization and neurodynamic technique: a series of 18 patients with chronic carpal tunnel syndrome. Journal of Manipulative and Physiological Therapeutics 2012; 35 (6): 420-427. http://dx.doi.org/10.1016/j.jmpt.2012.06.002

39. Snodgrass, SJ, Rivett, DA, Sterling, M, Vincenzino, B. Dose optimization for spinal treatment effectiveness: A randomized controlled trial investigating the effects of high and low mobilization forces in patients with neck pain. Journal of Sports Physiotherapy 2014; 44: 141-152. http://dx.doi.org/10.1016/j.math.2014.01.006

40. Leach RE, Purnell MB. Peroneal nerve entrapment in runners. The American Journal of Sports Medicine 1989; 17(2) :287–91. http://dx/doi/org/10.1177/036354658901700224

41. Fabre, T, Piton, C, Andre, D, Lasseur, E, Durandeau, A. Peroneal nerve entrapment. Journal of Bone and Joint Surgery-American 1998; 80A: 47-53.

42. McCrory P, Bell S, Bradshaw C. Nerve entrapments of the lower leg, ankle and foot in sport. Sports Medicine 2002; 32(6):371–91.http://dx.doi.org/ 10.2165/00007256-200232060-00003

43. Nee, RJ, Vincenzino, B, Jull, GA, Cleland, JA Coppieters, MW. Neural tissue management provides immediate clinically relevant benefits without harmful effects for

patients with nerve-related neck and arm pain: a randomised trial. Journal of Physiotherapy 2012; 58, 23-31. http://dx.doi.org/ 10.1016/S1836-9553(12)70069-3

44. Giesecke, T, Gracely, RH, Grant, MA. Evidence of augmented central pain processing in idiopathic chronic low back pain. Arthritis and Rheumatism 2004; 50: 613-623. http://dx.doi.org/ 10.1002/art.20063

45. Desmeules, JA, Cedraschi, C, Rapiti, E, et al. Neurophysiologic Evidence for a Central Sensitization in Patients with Fibromyalgia. Arthritis and Rheumatism 2003; 48 (5): 1420–1429. http://dx.doi.org/ 10.1002/art.10893

46. Kosek, E, Ekholm, J, Hansson, P. Pressure pain thresholds in different tissues in one body region: the influence of skin sensitivity in pressure algometry. Scandinavian Journal of Rehabilitation Medicine 1999; 31: 89-93.

47. Nijs, J, Van Houdenhove, B, Oostendorp, RAB. Recognition of central sensitization in patients with musculoskeletal pain: Application of pain neurophysiology in manual therapy practice. Manual Therapy 2010; 15: 135-141.http:/dx.doi.org/ 10.1016/j.math.2009.12.001

## CAPTIONS TO ILLUSTRATIONS

Figure 1 Flow chart of sub-grouping procedure

Figure 2 Tender point assessment

Figure 3 Cumulative proportion of responders PPT (Kg) at deltoid (top), tibial nerve (middle) and gastrocnemius (bottom) site for each group

Figure 4 Mean VT measures (µm) before and after treatment at the lateral malleolus and first metatarsal sites. The 95% confidence intervals demonstrate large variability in readings especially for the somatic and radiculopathy groups.

Acknowledgements

Thanks to Kayleigh Morley for her work as research assistant on this project, and Chris Mercer for his feedback on drafts of the paper.

**Highlights**

- A straight leg raise tensioner was given to people with spinally referred leg pain
- Treatment duration was 3 x 1 minute
- Pressure pain thresholds and vibration thresholds were the outcome measures
- No statistical differences were found before and after treatment or between groups
- Psychosocial factors, disability and central sensitisation didn't alter outcomes