THE EFFECT OF MOBILISATION ON PRESSURE PAIN THRESHOLDS IN THE LUMBAR SPINE

Melanie Medley
Student number: 3552699
Masters of Health Science (Osteopathy)

School of Health Science
Faculty of Health, Engineering and Science
Victoria University

Supervisor: Gary Fryer

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ABSTRACT

Background and objectives: Mobilisation is a common technique used by manual therapists in the treatment of spinal pain, but there has been little investigation into its effect on pain in the lumbar region. The aim of this study is to determine the immediate effects of mobilisation on pressure pain thresholds (PPT) in the lumbar spine in an asymptomatic population.

Methods: Sixty-seven asymptomatic subjects (mean age=22, SD=2.3 yrs, 37 female, 30 male) were recruited from the Victoria University student population. Subjects were examined for the spinous process most tender on manual springing, which was marked with a skin pencil. An electric algometer was used to determine the PPT at this level. Subjects were guided to another room and were randomly assigned to either an extension mobilisation or a sham "functional" treatment. Following intervention, subjects returned to the testing room for re-measurement of PPT by an examiner who was blinded to the treatment intervention.

Results: Analysis of pre- and post- intervention PPT values showed that there was only a minimal increase in PPT in the mobilisation group (6.80 kPa) and a decrease in the sham group (-17.16). Paired t-tests indicated that there was no significant change following mobilisation (P=0.378) and the effect size was small (d=0.15). When the difference scores of the 2 groups were analysed with an independent t-test, a significant difference between the groups was found (P=0.04).

Conclusion: Extension mobilisation of the lumbar spine did not produce any significant improvement in PPT in an asymptomatic population. Further research on the effectiveness of mobilisation, as well as other manual interventions, for low back pain is recommended.

Key Words: Mobilisation, articulation, algometry, pressure pain thresholds, osteopathy

INTRODUCTION

Mobilisation is a technique used by practitioners in many different fields of manual medicine. Mobilisation, or articulation, as it is known in osteopathy is defined as a repetitive, passive movement of a joint (or joints) through its range(s) of movement, usually employing a lever and fulcrum to enhance the effect without the need to use force.[1] It is a gentle technique, which is claimed to restore or increase range of motion (ROM), stretch periarticular tissues (muscles, ligaments capsules), enhance lymphatic flow and joint nutrition, and relieve pain.[1-3]

The pain relieving effect of mobilisation in the lumbar spine is controversial. Hadler et al[4] and Cote et al[5] compared spinal manipulation with mobilisation for the treatment of low back pain. Hadler et al[4] found that subjects suffering from low back pain of 2-4 weeks duration who were treated with a single mobilisation lagged behind those treated with a manipulation in their rate of improvement. However, the mobilisation technique consisted of taking the participant into sidelying passive flexion only twice and then repeating this manoeuvre on the opposite side. This is not how osteopaths perform mobilisation techniques in the clinical setting. Osteopathic texts describe mobilisation as a repetitive passive movement that is continued until a change in the tissues is sensed[3,6]. This is not what occurred in the Hadler et al study; therefore, it is not a reliable reference on the effect of mobilisation on low back pain.

Cote et al[5] evaluated the effect of mobilisation and manipulation using pressure pain thresholds (PPT) in 30 adults with chronic mechanical low back pain. PPT values are determined using an algometer, a pressure gauge which registers the force applied to a tissue in kPa/sec. PPT is defined as the least stimulus intensity at which the subject perceives pain.[12] Measurements are taken pre and post treatment interventions to determine how they alter pain perception. Three points were selected on the symptomatic side (L5 spinous process, posterior sacroiliac ligament, gluteus muscle group), and were evaluated using a pressure algometer. The manipulation group received a rotational thrust, while the mobilisation group received one flexion mobilisation in a supine position, which was held for three seconds and then released. The PPT measurements were taken immediately after, 15 and 30 minutes after the intervention. No significant changes in PPT values were found at any of the selected points or between the manipulation and mobilisation groups. The lack of change in PPT may have been attributed to the selection of a pre-determined level, rather than sites which appeared tender or dysfunctional to palpation. Alternatively, a single manipulation or mobilisation technique (performed in a different manner to that which is commonly used by manual therapists) may not be adequate to produce a change in PPT values.[5]

Goodsell et al[7] however, observed significantly greater improvements in twenty-six subjects with low back pain immediately after the application of a posterior-anterior (PA) mobilisation to the lumbar spine. These researchers found a significant reduction in visual analogue scale (VAS) scores following the PA mobilisation, but no significant difference in ROM or PA stiffness.[7]

Mobilisation has been shown to be effective in both the thoracic and cervical spine. Fryer et al[8] compared the effect of manipulation and mobilisation on PPT in the thoracic spine of asymptomatic subjects. Springing of the thoracic spine was used to determine the spinal level most sensitive to pressure. Three PPT measurements were taken at that level pre- and post- intervention. Fryer et al[8] found that mobilisation increased PPTs to a greater extent than manipulation, although the increase in values for both mobilisation and manipulation were significant.[8]

Sterling et al[9] and Vicenzino et al[10] used PPT to evaluate tenderness at the cervical spine. Sterling et al demonstrated a significant difference in PPT values between a group of subjects treated with a unilateral grade III mobilisation and with both a sham treatment and control group. The mean increase in PPT for the treatment was 22.55 ± 2.4%. Sterling concluded that using a unilateral grade III (large amplitude, end range) mobilisation to the symptomatic side of C5/6 produced a hypoalgesic effect to mechanical nociception.[9] Utilising the same mobilisation technique as Sterling et al to the C5/6 segment, Vicenzino et al[10] recorded a 15%-25% increase in pain measures in patients suffering from lateral epicondylalgia, indicating that cervical mobilisation can elicit a decrease in pressure pain thresholds distant from the site of application.[10]

A systematic review[11] on the efficacy of spinal manipulation and mobilisation for low back pain in acute, chronic and mixed patients concluded there was moderate evidence that manipulation was more effective than mobilisation for the short term relief of acute low back pain. Manipulation and mobilisation were found to be effective when compared to other interventions for chronic LBP, such as general practice care and home exercise, and both techniques had similar or better outcomes than other interventions (McKenzie technique, soft tissue therapy) in mixed cases. The authors of the review recommended with confidence that the use of manipulation and/or mobilisation is a viable option for the treatment of low back pain.[11]

Pain is subjective and can be a difficult perception to measure. Pressure algometry has been found to be a reliable tool for the measurement of PPTs over bony landmarks.[8,12] An algometer is a pressure gauge, which registers the force (kPa) applied to a tissue or bony prominence allowing the PPT to be measured. PPT is defined as the least stimulus intensity at which the subject perceives pain.[12] The algometer has been used to assess the effect of therapeutic techniques and to document the PPT values of individual muscles.[5,12-14] Keating et al[12] examined PPT in different spinal regions in asymptomatic subjects and found good reproducibility (ICC >0.75) at the level of L4, but the reliability at this level was not as high as the cervical and thoracic regions. Mean PPT values were reported to increase in a caudal direction, from the cervical (255 kPa) to the lumbar region (445 kPa) .[12]

Studies investigating the hypoalgesic effects of mobilisation, have inappropriately utilised mobilisation as a placebo to investigate the therapeutic effects of manipulation,[4,5] or combined it with manipulation for the treatment of low back pain.[11] Only a few studies have investigated the effect of mobilisation without additional manual techniques to decrease pain levels.[7,15] The present study aimed to evaluate the PPTs of the lumbar spine in an asymptomatic population and observe how these thresholds change after the application of a mobilisation technique.

METHODS

Subjects

Sixty-seven asymptomatic participants (37 female, 30 male) aged between 18-34 years (mean=22, SD=2.3) were recruited from the Victoria University student population. Before participating, subjects were questioned on their eligibility to participate in the study and were excluded if they had current low back pain, any recent or previous lumbar pathology or trauma, or if they had received treatment to their lumbar spine in the last 3 days. Those who were eligible completed an informed consent form to continue in the study. Testing was performed in the Victoria University Osteopathic Clinic and ethics approval was received from the Victoria University Human Research Ethics Committee before commencement.

Materials

A hand-held electronic pressure algometer (Somedic Algometer Type 2, Sweden) was used pre- and post- intervention to determine the pressure pain thresholds (PPT) of participants (Figure 1). The algometer consists of a plastic handle, pressure transducer and LCD screen which records the amount and rate of pressure applied. A circular 2cm probe was used to increase stability and control of the algometer on the spinous process. A hand held button was also attached to the algometer. When this button is pushed, it immediately freezes the kPa value on the LCD screen at that time, which is then recorded. Calibration of the algometer was carried out according to operating instructions.

Figure 1: Somedic Algometer II

Measures

Posterior-anterior manual springing of the lumbar spinous processes was performed on the participant to determine the most tender level as described by the participant. This was then marked with a skin pencil. The algometer was positioned perpendicular to the marked spinous process and a downward pressure was applied at a constant rate of 40 kPa/second to record the PPT value (Figure 2). A PPT is defined as the least amount of force at which a subject perceives pain.[12] The LCD screen displayed the rate of applied pressure (the pressure and slope) and enabled the force to be applied at a constant rate. The pressure tip was stabilised between the Researcher's thumb and index finger to guide and stabilise the algometer tip on the correct spinous process. The participant was given a hand held button and was instructed to push the button when the sensation of pressure first became a sensation of pain. This immediately froze the pressure reading on the algometer, which was then removed and the results recorded. Three measurements were taken with a 10-second break between each. The mean of the three measurements was later calculated and used for analysis. This procedure for measuring PPT was based on the methods used by Fryer et al.[8]

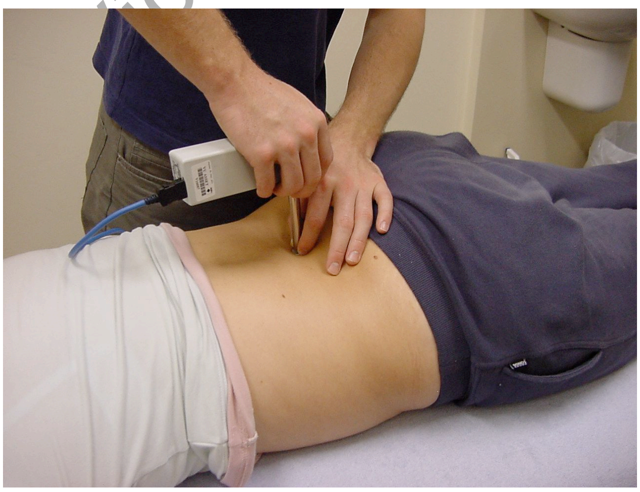

Figure 2: PPT measurement

Pilot study

Before commencement of the present study, a pilot study to assess the reliability of the application of the algometer was performed. Twenty volunteers were recruited from the Victoria University student population. Participants were instructed to lie prone on the treatment table with their lumbar spine exposed. The PPT measurements were taken as described previously. The participant was then instructed to leave the treatment room and return in approximately 1 minute to re-measure the PPT values. This time would mimic the time frame it would take for the participant to walk to another room, receive a 30 second treatment intervention and then return to the previous room, which is what occurred in the actual study. The mean difference between pre and post values was 5.83 kPa (SD= 44.21), and the error range was calculated as 50 kPa (mean difference + SD of the mean difference). Reliability statistics revealed an average Intraclass Correlation Coefficient of 0.94 and a significance value of p=0.000, indicating excellent repeatability.

Procedure

The participant lay prone on the treatment table with the lumbar spine exposed.

Researcher 1 palpated and applied posterior-anterior manual springing to each of the lumbar spinous processes and marked the most tender level reported by the participant with a skin pencil.

Researcher 2 recorded the PPT values over the marked spinous process. The participant was then directed to another room where Researcher 3, a qualified osteopath, randomly allocated the participant via lottery draw into an intervention group: mobilisation (n=37) or a "functional"/sham treatment (n=30). The appropriate intervention was then performed.

Following intervention, the participant was directed back to their initial room where Researcher 2 re-measured the PPT values as described previously. Both Researcher 1 and 2 were blinded to the treatment allocation of the subjects.

Intervention

Mobilisation (articulation)

Participants received an extension articulation technique in the side-lying position as described by Tucker and Deoora.[1] The participant lay on their side in a neutral position with their knees flexed to 50-60°. The practitioner stabilised the participant, by holding the participants' knees with their thighs. The practitioner then placed his hands around the waist palpating on either side of the spinous process. The participants' knees were then moved down and up, by the practitioner who accentuated the extension movement by applying an anterior force with his hands (Figure 3). This extension mobilisation was applied repeatedly for 30 seconds.

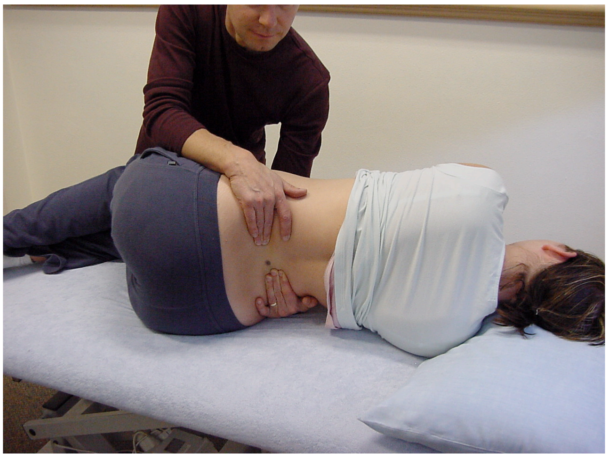

Figure 3: Lumbar mobilisation

Sham technique (placebo)

This intervention consisted of 30 seconds of a sham functional technique to the marked lumbar level. The participant was instructed to lie prone on the treatment table whilst the practitioner manoeuvred their lower limb into slight hip extension, to engage the 'barrier' (Figure 4). At no time throughout this treatment were any barriers or sense of "bind or ease" engaged, in order to produce an inert, sham (placebo) technique. Functional technique involves subtle leverages[6,16] and participants were informed that they should feel little movement and that if they experienced any pain to report this to the researcher. Subject expectation of a treatment effect may influence pain perception, and so a sham treatment was used to control for this bias and establish the effect of the treatment intervention. This type of sham technique was utilised, because the majority of our participants were knowledgeable of osteopathic techniques, and due to the subtle leverages involved in functional technique, subjects would have difficulty in determining whether it was performed incorrectly.

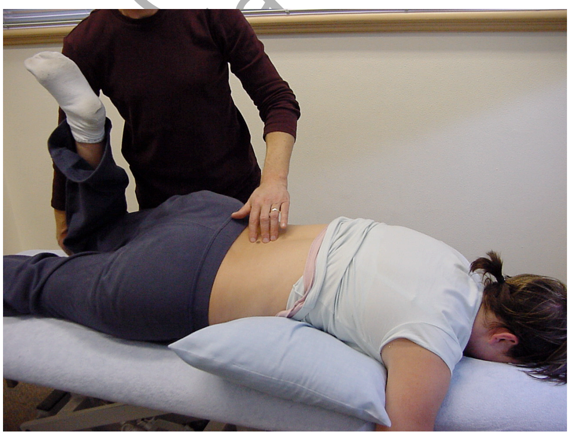

Figure 4: Sham 'functional' technique

Statistical Methods

All data was analysed using the computer statistical package SPSS version 12.0. Within-group changes in PPT measurements were analysed using paired t-tests for each of the intervention groups. An independent t-test was used to compare the mean differences in both groups to determine if there was any significant difference between the two interventions. Pre-post effect sizes (Cohen's d) were also calculated for both groups.

RESULTS

Analysis of pre- and post- intervention PPT values showed that there was only a minimal increase in PPT in the mobilisation group (6.80 kPa, SD=46.36) and a decline in PPT for participants in the functional/placebo group (-17.16, SD=45.02). Paired t-test indicated that there was no significant change following mobilisation (P=0.378), but a significant decrease in mean PPT occurred in the placebo group (P=0.046). Pre-post effect sizes (Cohens d) were calculated: mobilisation had a small effect size (d=0.15), whereas the functional/placebo group had a small to medium effect size (d=0.38). (Table 1)

When the different scores of the two groups were analysed with an independent t-test, a significant difference between the groups were found (P=0.04).

	Mobilisation	**Functional**
Pre-intervention	319.97 (107.97)	297.81 (113.14)
Post-intervention	326.77 (117.13)	280.66 (103.24)
Difference	6.80 (46.36)	-17.16 (45.02)
P value	0.378	0.046*
Effect size (Cohens d)	0.15	0.38

Table 1: PPT means, mean differences, P values and effect sizes
* indicates a significant value when P= 0.05

DISCUSSION

This study failed to demonstrate any significant change in the PPT values following a single application of lumbar mobilisation in asymptomatic participants, with only a small improvement of 6.80 kPa (SD=46.36). The placebo group, however, had a larger and significant decrease in mean PPT. Given that the error range of the measurement procedure was calculated at 50 kPa, as well as the small increase in PPT and a small effect size (d=0.15), this study demonstrated that mobilisation did not have a substantial effect on the pressure sensitivity of the spinous processes in these asymptomatic individuals.

The absence of a significant change in the mobilisation group, may be attributed to a number of factors. This study was conducted on an asymptomatic population; however the authors chose to investigate the most tender lumbar level in order to achieve more therapeutic results. Utilising a symptomatic population may have produced a greater change post-intervention, than what was achieved with an asymptomatic population.

Participants in this study were not screened for lumbar lordosis or range of motion. Osteopaths advocate direct techniques, such as mobilisation and manipulation, against a barrier to improve ranges of motion and decrease pain, and it is possible that participants whose lumbar lordosis was increased may not have gained improvement from an extension mobilisation. However, opting for a rotational mobilisation may have been more successful, because research has shown that rotational mobilisation of the lumbar spine produces movement in three planes (flexion, rotation & sidebending).[17] Lee[17] suggests that a rotational mobilisation may be able to restore lost movements of the lumbar spine in any of the three anatomical planes. As this study consisted of an asymptomatic population, employing a technique which theoretically affects three planes of movement instead of a technique that utilises only one plane may have resulted in a greater change in results. Cassidy et al[18] utilised a rotational cervical mobilisation in the form of muscle energy technique (MET) and compared it to manipulation in patients with neck pain. The authors concluded that manipulation and mobilisation were effective in reducing pain and increasing range of motion in subjects immediately post- intervention, however, manipulation achieved a greater effect.[18] Future research on the therapeutic effectiveness of rotational mobilisation in the lumbar spine is required.

Extension mobilisation has been shown to be effective in the thoracic spine. Fryer et al[8] found a 28.42 kPa increase immediately post-mobilisation, which was substantially greater than the 6.80 kPa increase in the lumbar spine in the present study. Because the methodology of these two studies is similar, biomechanical differences between the thoracic and lumbar spine in regard to the kyphotic and lordotic curvatures, may have attributed to the differing results recorded in each of these studies.

The present study consisted of one application of repeated mobilisation targeted at the level of the marked lumbar segment for 30 seconds, which commonly occurs in a single clinical treatment. It has been suggested by Cote et al[5] that one intervention application may not strongly affect PPT values. The authors state that in clinical practice manipulation and mobilisation are considered to be effective techniques for chronic low back pain, but the patient may require 10-12 manipulations for optimal results. Therefore a single application, as utilised in this study, may have had little effect on pain perception[5]. In clinical practice, the grade and duration of mobilisation on the lumbar spine is usually dependent on the condition being treated and the tissue response as monitored by the practitioner.[3,6] It is usually applied on more than one occasion over a longer period of time to provide a therapeutic effect, therefore one application of the technique as utilised in the present study may not have been sufficient to significantly alter the pain perception of participants.

Goodsell et al[7] performed posterior-anterior mobilisations to the lumbar spine in three 1-minute applications in subjects with low back pain. This produced a decrease in pain levels as shown on visual analogue scales by 28%.[7] Utilising this methodology may produce more significant results in future studies.

Participants were required to change rooms to receive the appropriate treatment intervention once their initial PPT measurement had been taken, and then return to their initial room once the intervention was completed. The movement of the participant from one room to another may have affected the results in either a positive or negative way due to the movement that occurs in the spine during walking. The authors believe that any change that may have occurred during this movement would have been minimal and would not have had a significant effect on the results. However, future research should focus on minimal movement of the participant, to purely measure the changes that occur from the intervention and not from any other variable.

The researchers in the present study believed the use of a sham functional technique was successful and the participants believed they were receiving an actual treatment; however, it cannot be certain this was the case, because there was no follow up study performed to determine this. The decrease in the PPT values of the placebo group post intervention was surprising, as our pilot study investigating the reliability and reproducibility of the algometer, showed an Intraclass Correlation Coefficient (ICC) value of 0.94. Other studies which have evaluated the reliability of electric algometers have achieved ICC values between 0.64-0.96 (moderate to excellent reliability).[8,9,12-14] The decrease in PPT values in the present study may be the effect of an increased subject awareness of the specified spinal level to which the intervention was applied to. The sham functional technique consisted of constant light palpation over the spinous process and the application of subtle leverages to that level for 30 seconds. As expected, there appeared to be no therapeutic effect of this sham treatment, but the subject awareness of the spinous process sensitivity may have heightened due to constant palpation leading to a decrease in PPT values post intervention. It is also possible that subject bias played a role, if the participants in this group believed they were not receiving actual treatment, but, given the subtle leverages employed with functional technique, it is unlikely that all 30 participants were aware of the sham. It is possible that repeated evaluation of the spinous processes caused them to become sensitive to the pressure of the algometer, but this is again unlikely because this did not occur in the pilot study. The results of the pilot study showed a small increase of 5.83 kPa. If participants were prone to becoming sensitive to the evaluation of the spinous process by the algometer, you would expect this value to have decreased in the pilot study. In future research, a control group should be utilised to compare and analyse if any changes that occur are due to the placebo intervention or the method and the use of the algometer itself.

Nussbaum and Downes[14] found that PPT measurements were reliable within the same day and over 3 consecutive days, although this study tested the biceps brachii and not the spinous processes.[14] Most studies utilising the algometer refer to its reliability in the form of ICC values.[8,9,12-14] No study found, refers to the error range associated with its use and how this may affect the reliability and the clinical significance of the results found. Our study recorded an error range of 50 kPa, which is large compared to the pre-post changes.

High repeatability of the algometer was achieved by following the conditions described by Downes and Nussbaum.[14] The authors state that higher reliability of the algometer is achieved when test sites are marked, when the site is flat and bony (as opposed to soft tissues), when one practitioner performs all the testing and when the timing of the force applied is standardised (40 kPa/sec). The algometer reliability trial demonstrated that the procedure was highly repeatable (ICC=0.94), which was consistent with Keating et al[12] who obtained an ICC value of 0.84 in the lumbar spine. Despite this, the standard deviations were relatively large, as was the resultant error range (50kPa). This is possibly due to the fact that pain is subjective and a hard perception to measure. However, the standard deviations found in the present study were lower than those calculated in the Keating et al study (standard deviation of 182 kPa at L4 compared to 117 kPa in the present study).[12]

The mechanism by which spinal manipulative therapy (encompassing both spinal manipulation and mobilisation) produces an hypoalgesic effect is poorly understood.[8,19-21] The central nervous system (CNS) contains modulatory circuits that regulate pain perception.[22] It has been proposed that spinal manipulative therapy may produce hypoalgesia by activating these pathways.[19] The first of these inhibitory pathways is located in the dorsal horn of the spinal cord, where both large diameter non-nociceptive neurons and small diameter nociceptive neurons synapse. It is believed that when a stimulus activates the large diameter afferents over the area of injury, it modulates pain by "closing the gate" on the passage of noxious information. This is termed the gate control theory of pain modulation.[22] Fryer proposed that any technique that produces movement of the joint and stretching of the joint capsule, such as manipulation or mobilisation, will stimulate joint proprioceptors and potentially be capable of inhibiting pain via this theory.[19]

The second is the peri-aqueductal grey (PAG) region of the midbrain. It stimulates nor-adrenergic descending pathways that inhibit the release of Substance P (a neuropeptide which is released in response to peripheral noxious mechanical stimulation) which in turn inhibits the pain response.[20,22] Experiments on rats have shown that stimulation of the dorsal PAG causes analgesia with associated sympathoexcitation. Wright et al[20] investigated the sympathetic reaction following mobilisation to determine if the dorsal PAG played a role in SMT induced hypoalgesia. They found that cervical posterior-anterior mobilisation produced an initial sympathoexcitory effect, which is compatible with the concept that SMT may exert its effects by activating the dPAG pathway.[20]

Opioid receptors within the CNS indicate that pain inhibitory pathways may be stimulated by opioid peptides. β endorphins in particular are released to the PAG and to nor-adrenergic nuclei in the brainstem.[22] Vernon et al[21] measured the β-endorphin levels in the blood pre- and post-cervical manipulation, finding a statistically significant increase in plasma levels 5 minutes post- manipulation, supporting this view.[21]

Further research on the hypoalgesic effect of lumbar mobilisation is warranted due to the conflicting evidence in the literature.[4,5,11,15] It is recommended that future research should use symptomatic participants. Researchers should examine the effectiveness of this technique over a longer period of time to determine the potential for long term relief of symptoms, and evaluate the effect of multiple treatment applications over an extended time frame, such as weekly treatments for 4 weeks as performed in the clinical setting to determine the effectiveness of mobilisation in the treatment of low back pain.

CONCLUSION

Extension mobilisation of the lumbar spine did not show any significant improvement in pressure pain thresholds in an asymptomatic population. This may have been attributed to the use of an asymptomatic population, not screening for lumbar lordoses or segmental restriction of extension, performing only one application of the treatment intervention and the reliability of the algometer. The effectiveness of mobilisation as a therapeutic technique is controversial; therefore, further research is necessary to determine the hypoalgesic effect of this technique in a symptomatic population.

References

1. Tucker C, Deoora T. *Fundamental Osteopathic Techniques*. Melbourne: Research Publications; 1995.
2. Greenman PE. *Principles of manual medicine*. 2nd ed: William & Wilkins; 1996.
3. Ward R. American Osteopathic Association. *Foundations for Osteopathic Medicine*. Williams & Wilkins; 1997.
4. Hadler N, Curtis P, Gillings D, Stinnett S. A Benefit of Spinal Manipulation as Adjunctive Therapy for Acute Low-Back Pain: A Stratified Controlled Trial. *Spine*. 1987;12(7):703-706.
5. Côté P, Mior S, Vernon H. The Short Term Effect of a Spinal Manipulation on Pain/Pressure Threshold in Patients with Chronic Mechanical Low Back Pain. *J Manipulative Physiol Ther.* 1994;17(6):364-368.
6. Hartman L S. Handbook of Osteopathic Technique. 2nd ed. London: Chapman & Hall; 1985.
7. Goodsell M, Lee M, Latimer J. Short-Term Effects of Lumbar Posteroanterior Mobilisation in Individuals with Low-Back Pain. *J Manipulative Physiol Ther*. 2000;23(5):332-342.
8. Fryer G, Carub J, McIver S. The effect of manipulation and mobilisation on pressure pain thresholds in the thoracic spine. *J Osteopathic Med*. 2004;7(1):8-14
9. Sterling M, Jull G, Wright A. Cervical mobilisation: concurrent effects on pain, sympathetic nervous system activity and motor activity. *Man Ther*. 2001;6(2):72-81
10. Vicenzino B, Collins D, Benson H, Wright A. An investigation of the interrelationship between manipulative therapy-induced hypoalgesia and sympathoexcitation. *J Manipulative Physiol Ther*. 1998;21(7):448-453.
11. Bronfort G, Hass M, Evans, R, Bouter L. Efficacy of spinal manipulation and mobilisation for low back pain and neck pain: a systematic review and best evidence synthesis. *The Spine J*. 2004;4:335-356

12. Keating L, Lubke C, Powell V, Young TR, Souvlis T, Jull GA. Mid-thoracic tenderness: a comparison of pressure pain threshold between spinal regions, in asymptomatic subjects. *Man Ther*. 2001;6:34-39
13. Vanderween L, Oostendorp RAB, Vaes P, Duquet W. Pressure algometry in manual therapy. *Man Ther*. 1996;1:258-265
14. Nussbaum EL, Downes L. Reliability of clinical pressure-pain algometric measurements obtained on consecutive days. *Phys Ther*. 1998;78:160-169
15. Hanrahan S, Van Lunen B, Tamburello M, Walker M. Short-Term Effects of Joint Mobilizations on Acute Mechanical Low Back Dysfunction in Collegiate Athletes. *J Ath Train*. 2005;40(2):88-93
16. Chaitow L. *Positional Release Techniques.* 2nd ed. London: Churchill Livingstone; 2002.
17. Lee R. Kinematics of rotational mobilisation of the lumbar spine. *Clin Biomech*. 2001;16:481-488.
18. Cassidy J, Lopes A, Yong-Hing K. The Immediate Effect of Manipulation versus Mobilisation on Pain and Range of Motion in the Cervical Spine: A Randomised Controlled Trial. *J Manipulative Physiol Ther.* 1992;15(9):570-575
19. Fryer G. Intervertebral dysfunction: a discussion of the manipulable spinal lesion. *J Osteopathic Med*. 2003;6(2):64-73
20. Wright A. Hypoalgesia post-manipulative therapy: a review of a potential neurophysiological mechanism. *Man Ther*. 1995:1:11-16
21. Vernon H, Howley T, Annett R. Spinal Manipulation and Beta-Endorphin: A Controlled Study of the Effect of a Spinal Manipulation on Plasma Beta-Endorphin Levels in Normal Males. *J Manipulative Physiol Ther*. 1986;9(2):115-123
22. Kandel ER, Schwartz JH, Jessell TM. *Principles of Neural Science.* 4th ed. New York: McGraw-Hill; 2000.