The Biomechanical and Analgesic Effects of Lumbar Mobilisations

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Abstract

A common treatment used by physiotherapists for patients with low back pain (LBP) is mobilisations. The aim of applying mobilisations is to increase range of movement (ROM) and reduce pain and stiffness. Therapists choose a specific dose of mobilisation for each patient, which includes a decision on the duration of applied force, commonly up to 3 minutes. Little research has been done to determine the biomechanical and analgesic effects of different durations of treatment. There is tentative evidence that increased duration beyond 3 minutes leads to an increase in range of movement and decrease in pain. This research set out to establish the biomechanical and analgesic effects of longer durations of lumbar mobilisations than commonly used in clinical practice. Only the immediate effects of a single treatment dose have been assessed to date.

Three studies were conducted. Firstly a reliability study (n=20) was undertaken to ensure the reliability of pressure pain thresholds (PPT), ROM, and stiffness measurements of the lumbar spine. Two methods of stiffness measurement were identified from the literature; in this study measurements were simultaneously collected using both methods to allow comparison. Excellent reliability PPT, good reliability for ROM and moderate reliability for both stiffness measurements were established. Standard error of measurement (SEM) and Minimal Detectable change (MDC) statistics were calculated to enable identification of participants who responded to treatment in the later studies.

A single-arm trial (n=17) was conducted to determine the immediate effects of 3 and 6 minutes of lumbar spine mobilisations on ROM, stiffness and pain (PPT) and verbal rating scales (VRS) of pain in participants with LBP. For verbal rating of pain on movement there was a significant difference between durations, with a significant reduction in pain immediately after 6 minutes of treatment, but not after 3 minutes of treatment. There was a significant increase in PPT ($p<.01$) immediately following both durations of treatment. The difference between 3 and 6 minutes of treatment on PPT failed to reach significance. These findings suggest that 3 minutes of mobilisation treatment were not sufficient to create a significant change in PPT. The changes in PPT were evident at sites suggesting both a local and segmental treatment effect. There was dissociation between PPT's and VRS. There was no significant change in ROM ($p=0.42$) or stiffness ($p=0.11$- $p=0.99$) following either duration of treatment; therefore these measures were not included in the final study.

Finally a randomised placebo controlled trial (n=72) was conducted to establish the immediate and short-term (24 hours after treatment) analgesic effects of different duration of lumbar mobilisation in participants with LBP. Two groups (short and long duration) were included in the study. Participants in the short duration treatment group received measurements of pain (PPT and verbal rating of pain) before and after 2 minutes of sham mobilisation and again after 1 minute of mobilisations. Participants in the long duration treatment group received measurements of pain before and after 2 minutes of mobilisation and again after an additional 4 minutes of mobilisations. In both treatment groups pain measures were also taken 24-hours after treatment. Analysis of treatment responders demonstrated that significantly more participants receiving longer duration of treatment experienced a reduction in PPT local to the site of treatment. There was no overall difference between treatment groups. Verbal rating of pain on movement was significantly reduced after treatment but the difference between treatment groups failed to reach significance. There was dissociation between patients rating of pain and PPT, suggesting that the different measures are mediated by different underlying neurobiological mechanisms.

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List of figures

List of tables

List of appendices

Glossary of terms

GRPC	global rating of received change
ICC	Intraclass correlation coefficient
PA	posteroanterior
PAG	periaqueductal gray
LBP	low back pain
MDC	minimal detectable change
MRI	magnetic resonance imaging
N	Newton
PPT	pressure pain threshold
RCT	randomised controlled trial
ROM	range of movement
SEM	standard error of measurement
SD	standard deviation
SPS	Spinal physiotherapy simulator
SAM	Stiffness assessment machine
SPAM	Spinal PosteroAnterior mobiliser
VAS	visual analogue scale
VRS	verbal rating scale

Acknowledgements

It can take a long time to write a PhD thesis. I would here like to take a little more time to thank those people that have supported me throughout this lengthy process.

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In order to undertake this thesis, it required data. I collected a lot of data. None of this would have been possible without the participants and I would like to thank them all. Whilst the data collecting process has not always run smoothly it has been, at times, a reminder of why I became involved with the profession 19 years ago to improve peoples wellbeing. Thank you to Emmanuel Defever for his assistance with the collection of data and subsequently Liz Cheek for her patience and advice with the statistical analysis.

I am dedicating this thesis to my family. My children, Zak, Edward and Ella (now 9,10 & 12 years), who have lost such significant time from their mother, but gained a valuable head start with statistics. Andrew, my husband has continued to support me, believed in me and given me the strength to carry on whilst taking care of the child care and cooking duties over the last 8 years. Finally to my parents, albeit with a sense of sadness that my mother was not able to see me complete this goal.

Declaration

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the Author. The thesis has not been previously submitted to this or any other university for a degree, and does not incorporate any material already submitted for a degree.

Signed . . . . . .
Dated . . . . . .

Chapter 1.

Introduction to the thesis

The overall aim of this thesis was to investigate the immediate and short-term effect of duration of lumbar mobilisation treatment on ROM, stiffness and pain in participants with non-specific chronic LBP.

LBP has been defined as pain between the costal margin and the gluteal fold, which may occur with or without leg pain (Krismer and van Tulder, 2007). Reports on the prevalence of LBP from the UK have indicated that approximately 17.3 million people, more than one third of the adult population are affected (Savigny et al., 2009). It is estimated that 1-in-15 people in the UK seek advice for their LBP (NICE, 2009a). The overall cost of healthcare for treating people with LBP is estimated to exceed £500 million per year in the private sector and over £1000 million in the National Health Service (NICE, 2009b). Healthcare professionals such as physiotherapists, osteopaths and chiropractors frequently use spinal manual therapy (SMT) to treat low back pain (Bronfort et al., 2004). Systematic reviews of the literature have suggested that manual therapy may be effective in the treatment of patients with spinal pain (Cleland et al., 2005; Bronfort et al., 2004; Gross et al., 2002).

Manual therapy is a term used to encompass physical techniques applied by the therapist to patients and includes mobilisation and manipulation. Mobilisation refers to low velocity repetitive oscillations of a joint, which can be passive or combined with active movements (Maitland et al., 2005). Manipulation refers to a high velocity thrust, which is applied to a joint over a short amplitude and is often associated with an audible crack (Maitland, 2005). One commonly used mobilisation technique is a posteroanterior (PA) mobilisation. When used on the spine it involves sustained, or repeated, oscillatory pressure that can be applied through the spinous or transverse process of the vertebra with the patient lying prone (Maitland, 2005). It is the dosage and effects of this PA mobilisation of the spine that forms the basis of this thesis.

Physiotherapists often apply mobilisations aiming to increase range of movement, reduce stiffness and/or decrease pain (Schmidt et al., 2008). Although the literature discusses possible biomechanical effects of mobilisation there is limited evidence to demonstrate that they have an effect on spinal range of movement (ROM) or stiffness. Mobilisations have been found to have an immediate hypoalgesic effect in patients with neck pain (Sterling et al., 2001; Vicenzino et al., 1998 and 1996; Vicenzino,1995). Although an immediate hypoalgesic effect has also been demonstrated in response to

lumbar mobilisation this evidence is confined to asymptomatic participants (Pentelka et al., 2012; Krouwel et al., 2010; Willett et al., 2010).

Clinically mobilisations are performed for varying amounts of time. The maximum duration of treatment advocated in one session would be 3 sets of 60 seconds of mobilisation (Maitland et al., 2005). However there is some evidence that suggests that a longer duration of treatment may be indicated (Pentelka et al., 2012; Sluka and Wright, 2001):

Pressure pain thresholds (PPT) have been used to measure the immediate hypoalgesic effects of mobilisations (Pentelka et al., 2012; Willett et al., 2010; Sterling et al., 2001; Vicenzino et al., 1998 and1996; Vicenzino, 1995). However, no studies have demonstrated a relationship between changes in PPT following mobilisations and patient reported changes in pain such as pain on movement.

The literature pertaining to mobilisations and their effects and the influence of mobilisation treatment duration is considered in chapter 2. The studies in (chapter 6) of this thesis investigated the effects of mobilisations on ROM, stiffness and pain. The evidence pertaining to the methods of measurements of ROM, stiffness and pain that were employed in this thesis are considered in chapter 3. Chapter 4 outlines the preliminary work for this thesis and chapter 5 reports on a study which investigated the reliability of these measurements (n=20).

Chapter 6 outlines a single-arm trial (n=17) which investigated the immediate effects of different durations of mobilisation treatment (3 and 6 minutes) on ROM, stiffness and pain in participants with chronic non-specific LBP. This single-arm trial was conducted as a preliminary investigation and served to focus a randomised placebo-controlled trial (n=72) which investigated the immediate and short-term analgesic effects of different durations of lumbar mobilisation treatment in participants with chronic non-specific LBP (chapter 7). Chapter 8 summarises the overall findings of the studies in this thesis, highlights areas for future work and outlines the original contribution to knowledge.

The author of this thesis is a senior lecturer at the University of Brighton and a course leader of an MSc in neuromusculoskeletal physiotherapy. The author is an experienced physiotherapist in both the NHS and private sectors and an active member of the Musculoskeletal Association of Chartered Physiotherapists. The use of mobilisations has been of interest to the author since first applying mobilisation treatment to patients as a physiotherapy student. She has published several peer-reviewed articles investigating the dosage of mobilisation treatment.

Chapter Two

Mobilisations

This chapter initially describes mobilisations, their dosage and use in clinical practice. A review of the literature pertaining to the effects of a mobilisation on range of movement (ROM), stiffness and pain follows. This chapter continues by considering the potential analgesic mechanisms through which mobilisation may extol a hypoalgesic effect. Because this thesis aimed to investigate the influence of one component of treatment dose, duration of mobilisation treatment, this chapter is completed by consideration of the influence of treatment duration.

2.1. Literature Search

A literature search was conducted which consisted of an extensive search of the following databases: Ovid, Medline, CINAHL, Pubmed, EMBASE, Science Direct, ProQuest and Web of Science. The search strategy used a combination of the following sub headings (MeSH) and key words

Spin* OR lumbar AND:

- Motion (mh) OR range of motion (mh) OR movement
- mobilis* OR mobiliz*
- stiff*
- pain OR hypoalgesia

The reference lists were hand searched. Iterative supplementary searches literature were conducted to explore specific aspects of the literature for example pressure algomet* OR pressure pain threshold, verbal rating scale OR visual analogue scale, placebo, pain gate (see Figure 2.1). Additional literature was considered throughout the course of this PhD that was not included in the thesis such as that on mobilis* AND muscle OR proprioception and creep OR hysteresis.

All available literature written in English was searched without restriction to human subjects or publication date. The reference list of retrieved article was hand searched. RSS feeds were set up, using the search terms detailed, to alert the researcher to new publications.

LITERATURE SEARCH

Lumbar Mobilisations / Manipulation

Mobilisations (effects of a single treatment dose)

Mobilisation	n<15 **IDENTIFIED**	→ Peripheral	n=3 **EVALUATED**	→ n=3 **REFERENCED**
		→ Cervical	n=6 **EVALUATED**	→ n=6 **REFERENCED**
		→ Lumbar	n=4 **EVALUATED**	→ n=4 **REFERENCED**
Manipulation	n<120 **IDENTIFIED**	→ Clinical prediction rules	n<15 **EVALUATED**	→ n=3 **REFERENCED**

Note: Those papers investigating the effects on muscle and proprioception not identified.

As part of multimodal care package

Mobilisation	n<15 **IDENTIFIED**	→ Systematic reviews	n=5 **EVALUATED**	→ n=0 **REFERENCED**

Measurements

Pain

PPT	n=40 **IDENTIFIED**	→ Reliability Papers	n=12 **EVALUATED**	→ n=8 **REFERENCED**
		→ Dermatome zones	n=3 **EVALUATED**	→ n=3 **REFERENCED**
VRS /VAS	n>10 **IDENTIFIED**	→ MCID	n=10 **EVALUATED**	→ n=3 **REFERENCED**
Questionnaires	n>35 **IDENTIFIED**	→ McGill	n=8 **EVALUATED**	→ n=4 **REFERENCED**
		→ SOPA	n=6 **EVALUATED**	→ n=3 **REFERENCED**
		→ Oswestry	n=9 **EVALUATED**	→ n=3 **REFERENCED**
		→ GHQ	n=4 **EVALUATED**	→ n=1 **REFERENCED**
Lumbar range of movement	n=20 **IDENTIFIED**	→ 3D Measurement	n=10 **EVALUATED**	→ n=8 **REFERENCED**
Stiffness	n>120 **IDENTIFIED**	→ Human, lumbar spine	n>20 **EVALUATED**	→ n=18 **REFERENCED**
Force measurement	n>15 **IDENTIFIED**	→ Used in stiffness mesaurment	n>8 **EVALUATED**	→ n=6 **REFERENCED**

Analgesic mechanisms

Descending inhibition	n>30 **IDENTIFIED**	→ Landmark/Mobilisation related	n=15 **EVALUATED**	→ n=10 **REFERENCED**
Pain gate	n>6 **IDENTIFIED**	→ Landmark/Mobilisation related	n=6 **EVALUATED**	→ n=6 **REFERENCED**
Opioid/serotonergic	n>30 **IDENTIFIED**	→ Landmark/Mobilisation related	n=15 **EVALUATED**	→ n=2 **REFERENCED**
Placebo/expectations	n>30 **IDENTIFIED**	→ Landmark/Mobilisation related	n=10 **EVALUATED**	→ n=4 **REFERENCED**

Statistics

Reliability	n>10 **IDENTIFIED**	→	n=10 **EVALUATED**	→ n=5 **REFERENCED**
MDC/MCID	n>10 **IDENTIFIED**	→	n=7 **EVALUATED**	→ n=3 **REFERENCED**
Responders analysis	n<7 **IDENTIFIED**	→	n=5 **EVALUATED**	→ n=2 **REFERENCED**

Miscellaneous

Creep and hysteresis	n>20 **IDENTIFIED**	→	n=10 **EVALUATED**	→ n=0 **REFERENCED**
Risk factors for LBP	n>30 **IDENTIFIED**	→	n=10 **EVALUATED**	→ n=0 **REFERENCED**
Epidemiology of LBP	n>30 **IDENTIFIED**	→	n=10 **EVALUATED**	→ n=0 **REFERENCED**
Treatment of LBP	n>30 **IDENTIFIED**	→	n=20 **EVALUATED**	→ n=0 **REFERENCED**

Figure 2.1. Literature Search — papers identified, evaluated and referenced.

2.2. Physiotherapy treatment of low back pain

Approximately 9% of patients suffering from LBP visit a physiotherapist (Office of population census and surveys 1997), resulting in an estimated 1.6 million adults receiving physiotherapy for LBP each year. In 1998 it was estimated that 37% (£600 million) of the total LBP healthcare cost was spent on physiotherapy and other allied professions (Maniadakis and Gray 2000). The National Institute of Clinical Excellence systematically reviewed the literature on LBP in order to produce national guidelines and recommendation for clinicians in the UK. The resulting recommendations were that patients should be offered a tailored treatment programme of exercise or acupuncture or mobilisations and for patients where these interventions have not been successful, a combined physical and psychological treatment programme was recommended to include a cognitive behavioral approach and exercise. It concluded that physiotherapy provides a cost effective treatment for recurrent and persistent LBP (Savigny et al., 2009).

When a patient is referred to the physiotherapy department for treatment of their LBP the physiotherapist takes a subjective history from the patient. This involves mapping the area of patients' symptoms, understanding what aggravates or eases their symptoms, gaining a history of the present and past episodes of symptoms and gaining a thorough account of their general health and past medical history (Petty, 2011). The physiotherapist also asks special questions about features that may indicate serious pathology (if these sign and symptoms are present the patient would be referred to another appropriate health professional) (Greenhalgh and Selfe, 2006). It is also important that during the subjective history taking the physiotherapist gains an insight into the patient's functional limitations and perceptions of the problem and physical or psychological factors that may affect recovery (Petty, 2011).

A physical examination follows which is tailored to the patient's individual problem, based on the information gained in the subjective examination (Petty, 2011). A physical examination of the lumbar spine normally includes an assessment of lumbar physiological and accessory movement (physiological movements are those that the patient can perform themselves such as bending to their toes and leaning backwards. Accessory movements are gliding movements that occur at the joint during physiological movement but cannot be performed by the patient in isolation, requiring an external force such as that applied by a physiotherapist (Maitland et al., 2005). Other test may be performed which preferentially assess the muscles and nerves that may give rise to pain in the pattern described by the patient (Petty, 2011)

Once the complete examination has been performed the therapist determines whether the patient is suitable for physiotherapy treatment or requires referral for

further investigation or alternative treatment. The therapist then devises a treatment plan based on the examination and the patient's goals. Treatment options vary, exercise and advice are incorporated into most treatment plans, but other specific treatments such as electrotherapy, graded return to activity and spinal manual therapy may be included.

2.3. The use of mobilisations in the treatment of low back pain

One technique commonly used in the treatment of back pain is a posteroanterior (PA) mobilisation. This involves the application of low velocity force, directed from posterior to anterior (posteroanterior (PA)), through the spinous process (central PA) or transverse process (unilateral PA) of the vertebra (Maitland et al., 2005), (Figure 2.2).

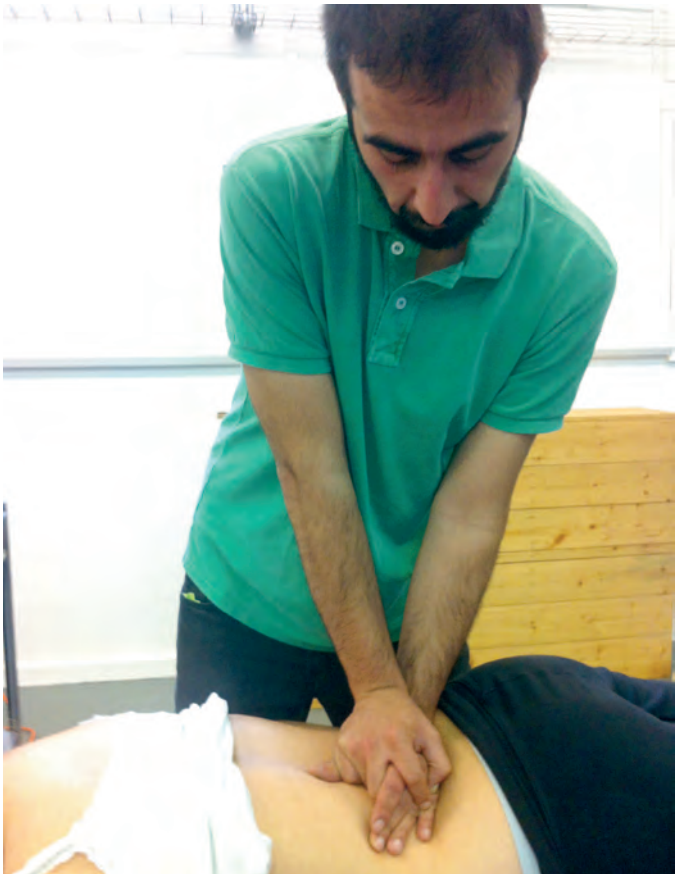


Figure 2.2: Central posteroanterior (PA) mobilisation of the spine.

During the application of a central PA mobilisation, movement occurs throughout the whole thoracolumbar region (Lee et al., 1996). This is made up of rotation of the pelvis (Chansirinukor et al., 2001) and the thoracic cage (Chansirinukor et al., 2003), compression of the skin and soft tissue (Lee, 1990) and movement of the spinal joints (Kulig et al., 2004; Powers et al., 2003; Lee and Evans, 2000 and 1997; Lee and Svensson, 1993; Lee and Evans, 1991).

Physiotherapists apply mobilisations in order to increase range of movement and/or reduce perceived stiffness or pain. Different treatment doses are selected based on perceived clinical need. Some of the factors that therapists may take into account when deciding on treatment include how acute the symptoms are, the nature of the condition, the severity and irritability of the symptoms and the relationship between pain and stiffness as assessed on clinical examination (Maitland, 2005).

Treatment dose describes the variation in different components of treatment applied and is designed to create the optimum treatment effect. The different components of treatment are presented and examples provided in Table 2.1.

Table 2.1. Components of a treatment dose.

Components of a mobilisation treatment dose	
Position of person and joints	For example the patient may lie prone with the lumbar spine positioned in extension, flexion, lateral flexion, rotation or in a combination of these positions (McCarthy, 2010).
Level of treatment	Normally applied to the most symptomatic level as determined by the physical examination (Maitland, 2005).
Direction of mobilisation force	The inclination of the applied mobilisation, eg caudad, cephalad, medial or lateral (McCarthy, 2010).
Grade	Includes a description of the region of resistance reached and amplitude of mobilisation. For example, grade III- is a large amplitude mobilisation in the first third of resistance and grade IV+ is a small amplitude mobilisation in the last third of resistance (Petty, 2011).
Rate	Commonly applied at a rate of 1-2Hz. 1-2 mobilisation cycles per minute (Souvlis et al., 2004). Can be quasi-static (Petty, 2011).
Rhythm	May be slow and smooth or staccato (Petty, 2011).
Duration	How long the treatment is applied for. Typically up to 3 sets of 30-60 seconds (Maitland, 2005).
Symptom reproduction	Treatment may be applied short of reproduction of symptoms, or to the point of partial or full reproduction of symptoms (Petty, 2011).

Examples of typical treatment doses, incorporating the components outlined in Table 2.1, are:

- In prone, lumbar extension, central PA to L4 III- slow and smooth, 1 x 30 seconds, to the first point of pain reproduction.
- In left side lying, lumbar right lateral flexion, transverse to L3 IV+ staccato, 3 x 60 seconds, to the point of full reproduction of symptoms.

Clinical decision making and studies investigating the mechanisms of pain relief through mobilisations are somewhat inhibited by lack of evidence regarding the optimum dose of mobilisation treatment. Two studies included in this thesis (chapter 6 and 7) did not only investigate the effects of mobilisations, but also the influence of duration of treatment, the evidence related to applying different durations of treatment is considered in section 2.11, page 21.

2.4. The biomechanical and analgesic effects of mobilisations

The effects of mobilisations can be broadly divided into biomechanical effects and neurophysiological effects. The biomechanical effects are those that change the mechanics of the spine, resulting in changes in ROM or spinal stiffness. The neurophysiological effects of mobilisation treatment are the effects on muscle activity (Krekoukias et al., 2009; Sterling et al., 2001), proprioception (Cho et al., 2012), and pain. This thesis focuses on the effects of mobilisation treatment on ROM, stiffness and pain and therefore this section reviews the current evidence regarding the effects of mobilisations on these variables.

2.5. The effects of mobilisation treatment on ROM in asymptomatic participants

Therapists apply mobilisation treatment, aiming to restore normal ROM in patients with limited range (Schmid et al., 2008), although the evidence supporting this practice is sparse. The effect of PA mobilisations on lumbar sagittal mobility has been investigated in both asymptomatic (Stamos-Papastamos et al., 2011; Petty, 1995; McCollam and Benson, 1993), and symptomatic participants (Powers et al., 2008; Chiradenjant et al., 2003 and 2002; Goodsell et al., 2000).

The studies performed on asymptomatic participants have reported contradictory results. Differences in the number of levels treated, duration of treatment and the demographics of the participants may explain the contradiction (Table 2.2). Petty, (1995) applied an oscillatory PA mobilisation on one vertebral level (L3) for two minutes on three consecutive days and found no significant effect on sagittal mobility. Stamos- Papastamos et al., (2011), employed a similar treatment dose of 3 minutes applied to L4; again no significant changes in ROM were found. Conversely McCollam and Benson, (1993) measured ROM in 130 participants after 3 x 1 minute bouts of grade IV+ PA mobilisations to L3, L4 and L5, (resulting in

treatment being applied to three levels and a total duration of 9 minutes) and found a significant increase in lumbar extension.

Another difference between the studies was the differences in the population groups used. In the study by McCollam and Benson, (1993) participants consisted of 18-51 year old males who were engaged in active military service, in contrast to the younger exclusively female (18-32 years) population used by Petty, (1995). There may well be age and gender differences in the effect of mobilisations on ROM, furthermore the level of physical training in the military population may influence the effects of treatment (20% of participants were reported to have been on a 25 mile road march during the course of the study). Although statistically significant differences were reported by McCollam and Benson, (1993) this amounted to a 7.1% increase in extension, equivalent to a 2-degree change, which may not represent a clinically meaningful or clinically detectable change. Moreover McCollam and Benson, (1993) did not comment on the measurement reliability of the inclinometer which is likely to have a greater measurement error than the electromagnetic tracking device employed by Stamos-Papastamos et al., (2011) and Petty, (1995).

Another factor that may explain the differences between these studies was that Petty, (1995) preconditioned the lumbar spine with 5 repetitions of flexion and extension. These repeated physiological movements may have had an effect on the tissues similar to the treatment effect from mobilisations; Lee and Evans, (1992) demonstrated that the response to PA loading of the spine stabilised after the first 2 cycles of loading, therefore the preconditioning implemented by Petty, (1995) may have resulted in the greatest tissue changes occurring prior to baseline measurements.

2.6. The effects of mobilisation treatment on ROM in symptomatic participants

It could be proposed that mobilisations might produce a greater increase in ROM in symptomatic subjects, many of whom complain of a decreased ROM associated with their symptoms. However there is limited evidence to support this (see Table 2.2). In a same-subject control study, Goodsell et al., (2000) investigated the effects of applying a mobilisation treatment to 26 patients with non-specific LBP and reported no significant difference in extension ROM between the control and intervention groups. However the control intervention was applied immediately before or after the mobilisation according to randomisation, thereby not allowing a washout period between interventions. The strength of this study would have been improved if patients had returned on a different occasion for the second intervention. In a much larger study Chiradejnant et al., (2002) found that PA mobilisations did not change ROM in 120 participants suffering from LBP. These

Reference	Study design/ conditions	Symptoms	Age years	Subjects	Measurement	Number of measurement repetitions	Duration of treatment	Grade or force applied	Spinal level treated	Frequency	Result
McCollam and Benson, 1993	Parallel group Mobilisation + Control (no contact)	none	18-51	130 Male Asymptomatic 65 control 65 intervention	Inclinometer	Measurement taken from 3rd rep	9 mins (3 mins at each level)	Described as "grade IV+"	L3, L4 and L5	Therapist selected	Significant increase (p<.05) in extension (7.1%)
Petty, 1995	Crossover Mobilisation + Control (no contact)	none	18-32	18 Asymptomatic female	Spine motion analyser	5 precondition movements. Mean of 3	2 min	Mean 92.5N	L3	4.5Hz	No change
Stamos-Papastomos et al, 2011	Same-subject repeated measures crossover design. Manipulation group and Mobilisation group	none	Mean 24 SD 5	16 men 16 women	Fastrak	Mean of 6	3 x 1 min	Grade IV+	L4	2Hz	No change
Goodsell et al., 2000	Crossover Mobilisation + Control (no contact)	0.5-60 months Mean 8.1 (SD18) months	16-69 Mean 39 SD15	26 LBP 13 men 13 women	Inclinometer Fingertip to floor	Inclinometer – 1 measure Finger to floor – mean of 2	3 x 1 min	60-250N Mean 137	Most symptomatic level	Therapist selected	No significant change 2-3% change
Chiradenjnant et al., 2002	Parallel group: Mobilisations to randomly slected v symptomatic level	220.7 +/- 616.2 days	12-72 Mean 41 SD14	120 LBP 71 female 49 male	Inclinometer Fingertip to floor	1 repetition	2 x 1 min	As determined by therapist	Central PA Symptomatic v randomly selected.	Therapist selected	No change
Chiradenjnant et al., 2003	Parallel group: Mobilisations to randomly slected v symptomatic level	Resting pain > 2/10	Mean 67 SD 16	140 LBP 71 male 69 female	Inclinometer Fingertip to floor	1 repetition	2 x 1 min	As determined by therapist	Symptom-atic	Therapist selected	No change
Powers et al., 2008	Parallel group: Mobilisation v press-up exercise	< 3 months with pain on and reduced extension.	18-45 mean 30 SD 8	30 LBP 19 female 11 male	Kinematic MRI	1 repetition	3 x 40 sec at symptomatic level. 2 x 40 at other Lumbar levels	'Up to grade IV'. Short of symptom reproduction	All	1-2Hz	Increase 3.6 (SD 5) degrees. Side effect of time p<.01, but no sig group or group/ time interaction.

Table 2.2: The effect of mobilisation on ROM

findings were confirmed in a later study applying 2 x 1 minutes of mobilisations to 140 participants with non-specific LBP (Chiradejnant et al., 2003). The measurement tools used in these studies were fingertip to floor method for flexion and an inclinometer for extension. The reliability of these methods could be questioned, however when the use of these tools is carefully standardised, reliability can be good. Chiradenjnant et al., (2003) reported an intraclass correlation coefficient (ICC) of 0.95 for fingertip to floor measurements and Pearson's r of 0.75 for inclinometer measurements.

Only one study involving symptomatic participants has reported a significant increase in extension range of movement; Powers et al., (2008) used MRI to measure range of extension in prone after mobilisations or press up exercises in 30 patients with non-specific LBP. Three x 40 second sets of mobilisations were applied to the most symptomatic level and 2 x 40 second sets were applied to each of the other lumbar vertebral levels. A significant increase in extension range was observed but there was no difference between groups. Similar to the study in asymptomatic participants that reported significant findings (McCollam and Benson, 1993), Powers et al., (2008) employed a total treatment duration of 7 minutes. This was 5 minutes more than that used by Chiradejnant et al., (2003) and may explain the difference in results. Powers et al., (2008) sought to assess the difference between extension exercises and mobilisations so did not include a control group and therefore the significant change could be due to natural variation or non-specific effects of treatment such as placebo. Furthermore the mean difference in range, post mobilisation, was 3.6 degrees (standard deviation (SD) 5.1.) The authors reported excellent reliability with this method with a standard error of mean (SEM) of 0.66 degrees suggesting the change was not a result of measurement error. However the clinical relevance of a change of 3.6 degrees is perhaps questionable. Moreover all lumbar levels were treated which may not replicate clinical practice where treatment may only be applied to the most symptomatic level (Chiradenjnant et al., 2003 and 2002). Another explanation for the contradictory findings reported by Powers et al., (2008) is the inclusion criteria of increased pain on extension, and reduced range of extension. These criteria may have resulted in the selection of participants who were most likely to respond to mobilisation treatment.

In summary, studies report that mobilisations do not change ROM when applied to asymptomatic or symptomatic populations. The exceptions to this are two studies which applied mobilisations to more lumbar levels, resulting in longer treatment duration. Further research is warranted in order to establish whether either of these variables is responsible for the observed treatment effect. A single-arm trial (chapter 6) and randomised-placebo controlled trial (chapter

7) included in this thesis, aimed to determine the influence of one of these factors, treatment duration, on range of movement.

The following sections consider the evidence that patients suffering from LBP have stiffer lumbar spines than asymptomatic individuals. In addition evidence is examined regarding the effect of mobilisation treatment on lumbar stiffness.

2.7. Lumbar spine stiffness in patients with LBP

Clinicians may apply treatment aiming to reduce perceived stiffness, although there is limited evidence that patients with LBP have stiffer spines than asymptomatic individuals; with only a small pilot study reporting increased stiffness in 2 participants with low back pain compared to 6 control subjects (Shirley and Lee, 1993). However, there is evidence to suggest that a relationship between pain and stiffness exists. Latimer et al., (1996b) found stiffness was significantly reduced (by a mean of 8%) in patients after participants symptoms had resolved by 80%, no significant change was seen in a non LBP group over the same time period. The patients in the Latimer et al., (1996b) study had a mean duration of symptoms of 18.1 days. The point at which their symptoms had reduced by 80% ranged from 2-105 days (mean 22.64).

2.8. The effects of mobilisation treatment on lumbar stiffness.

Physiotherapists frequently use mobilisations to reduce lumbar stiffness, as perceived in the physical examination. However, there is a paucity of evidence to support this reasoning as there are few studies examining the effectiveness of mobilisation treatment in reducing lumbar stiffness. This section therefore considers the effects of lumbar mobilisation treatment on stiffness (also see Table 2.3).

Therapist reliability at perceiving spinal stiffness is poor (van Trijffel et al., 2005), so mechanical devices have been built to measure spinal stiffness. However the use of this equipment is largely confined to laboratories, subsequently limiting widespread usage. To overcome these difficulties Ferreira et al., (2009) measured stiffness on an 11-point scale using a portable stiffness spring reference device. One hundred and ninety one LBP patients were divided into three groups, a general exercise group, a motor control exercise group and a group receiving mobilisations. A significant decrease in stiffness was found immediately following treatment (mean 1.2 point decrease on an 11-point scale); however there was no difference between groups and since no control group was included, differences may have been due to natural resolution over the eight-week intervention period (stiffness was shown to decrease significantly (by 8%) in a group of patients whose symptoms had resolved by 80% (Latimer et al., 1996b)). Furthermore, the methodology, comparing stiffness against a spring is not comparable to the

Reference	Design	Participants	Technique	Dose	Stiffness measurement	Result
Goodsell et al., 2000	Crossover. Treatment and control (no contact)	26 with LBP	PA mobilisation to the most symptomatic level	3x60secs Rx force 60-250N (mean 137N)	Displacement method using mechanically driven indenter	No significant change in stiffness ($p>.05$)
Allison et al., 2001	Single-arm trial	24 asymptomatic	Central PA to L3	2 minutes Rx mean force 146N 1.5Hz	Displacement method using mechanically driven indenter	No significant change in stiffness $p=.17$
Lee et al., 2005b	Parallel groups: 1. LBP participants 2. Asymptomatic participants	19 with LBP 20 asymptomatic	PA mobilisation to the most symptomatic level	Grade III for 30 secs. 1.2Hz (SD 0.6)	Three-point bending method	Significant reduction in stiffness ($p<.05$)
Ferreira et al., 2009	Parallel groups: 1. General exercise 2. Motor control exercise 3. Mobilisation / manipulation	191 with LBP 71 received mobilisations / manipulation	Mobilisation or manipulation chosen by therapist	Varied	Stiffness measured of 11-point scale using a spring reference device	Sig main effect of time ($p<.05$) No significant difference between groups ($p>.05$).
Stamos-Papastamos et al., 2011	Same-subject repeated measures crossover design. Manipulation group and mobilisation group	32 asymptomatic	Central PA to L4	3x60 Grade IV+ 2Hz	Three-point bending method	No sig effect of condition ($p=.18$)

Table 2.3. The immediate effects of a single mobilisation treatment dose on stiffness.
Rx = treatment; sig = significant; SD = standard deviation; Mob = mobilisation; PA = posterioranterior; N = Newtons.

stiffness assessment carried out by physiotherapists who assess resistance to the application of manually applied force.

Other studies investigating the effects of treatment have used instrumented three-point bending and displacement methods of measuring stiffness (these methods are fully considered in section 3.2, page 28). Using the displacement method, Allison et al., (2001) reported no change in stiffness immediately following 2 minutes of PA mobilisations applied to L3 in asymptomatic participants.

It could be argued that a significant decrease in stiffness may not be found in an asymptomatic population who do not suffer from spinal stiffness. However studies in symptomatic populations reported similar results; using the same (displacement) method of stiffness measurement Goodsell et al., (2000) found no significant change in stiffness following 3 x 1 minutes of PA mobilisation in patients with LBP. The dose of treatment employed by Goodsell et al., (2000)

replicated those used in clinical practice as it was applied to the symptomatic level using rates and forces that were determined to be appropriate by the therapist. One limitation of this study was that a large range of forces was used (60-250N) and some may not have been sufficiently large to alter stiffness. However, post hoc analysis suggested that this was not a factor as there was no correlation between treatment force and changes in stiffness.

Contradictory findings were reported by Lee and colleagues (Lee et al., 2005b). who reported a significant reduction in three-point bending stiffness following lumbar PA mobilisation treatment in both 19 participants with LBP and in 20 asymptomatic participants. This study did not included a placebo or control group and thus should be interpreted with caution.

These contradictory results may be due to the different method of stiffness measurement. Lee et al., (2005a) used the three-point bending method of stiffness testing which was designed to account for the geometry of participants' spines. However, the three-point bending method has been used to assess the effects of lumbar mobilisations more recently (Stamos-Papastamos et al., 2011) and no significant effect on stiffness was observed (the different methods of stiffness measurement are considered in section 3.2, page 28).

In conclusion, despite reducing stiffness being a common aim of treatment, there are few studies investigating the effects of mobilisations on stiffness. One study has demonstrated a change in stiffness following mobilisations, using the less widely employed three-point bending method of stiffness measurement (Lee et al., 2005b), but did not compare the effects against placebo or control intervention. The maximum treatment duration used in these studies was 3 minutes. There is some indication from studies measuring the effects of mobilisations on ROM that a longer duration of treatment may result in a greater biomechanical treatment effect (Powers et al., 2008; McCollam and Benson, 1993). Therefore a single-arm trial (chapter 6) included in this thesis aimed to evaluate the effects of mobilisation treatment duration on stiffness using both displacement and three-point bending methods of stiffness measurement. This section has considered the biomechanical effects of mobilisations on ROM and stiffness. Mobilisations are also thought to have an analgesic effect. The following section considers the effects of mobilisations on pain and the possible underlying analgesic mechanisms.

2.9.The effect of mobilisations on pain measures

Mobilisations are often applied to patients with the aim of reducing pain and thus a number of studies have investigated the effects of mobilisation on pain. Many of these studies have been conducted in asymptomatic participants and therefore

use experimental measures of pain, such as pressure pain thresholds (PPTs), to determine whether a hypoalgesic effect has occurred. The measurement of PPTs involves using an algometer to apply pressure to pre-determined points and asking participants to indicate when the sensation changes from pressure to pain. In addition to PPTs, studies performed in symptomatic participants may also include patient reported measures such as pain rating scales.

2.9.1. Changes in PPT following mobilisation treatment

No studies have investigated the immediate effects of a single mobilisation treatment dose in patients with LBP. However, a number of studies have investigated the immediate effects of a single mobilisation treatment dose to other regions and in the lumbar spine in asymptomatic participants (Table 2.4). These studies have all reported a hypoalgesic response to mobilisation of the cervical spine (Sterling et al., 2001; Vicenzino et al., 1998 and 1996; Vicenzino, 1995), elbow (Paungmali et al., 2003; Vicenzino et al., 2001), knee (Moss et al., 2007), ankle (Yeo and Wright, 2011) and lumbar spine (Pentelka et al., 2012; Krouwel et al., 2010; Willett et al., 2010). The studies in the cervical spine, elbow, knee and ankle have been conducted with symptomatic subjects. Two studies have reported contradictory results, finding that mobilisations had no significant effect on PPT – Soon et al., (2010) in asymptomatic participants and Sterling et al., (2010) in patients with whiplash of at least 3 months duration. Sterling et al., (2010) proposed that the difference in results could be explained by mobilisations having a different effect in participants with different musculoskeletal conditions. However another possible reason for the difference reported by Sterling et al., (2010) is the duration of the participants' symptoms; all of the other studies utilising symptomatic participants (Table 2.4) recruited participants with a mean symptom duration of less than 3 months. Whether the effects on PPT would be the same in a population with more chronic symptoms remains unknown and thus the studies in chapter 6 and 7 of this thesis investigated the effects of mobilisations in participants with chronic low back pain.

The studies shown in Table 2.4 all investigated the immediate effects of mobilisation. Although a few studies have investigated within- and between-session changes in pain (Cook et al., 2012; Tuttle, 2005; Hahne et al., 2004). These were pragmatic studies which included a number of manual therapy treatments and home exercises and did not provide further information about the longevity of mobilisation effects in isolation. There is no evidence on the longer-term effects of a single mobilisation treatment dose. Two studies included in this thesis (a single-arm trial and a randomised-placebo controlled trial (RCT)) have investigated the immediate effects of mobilisations in participants with chronic LBP. In addition the RCT investigated the effects 24 hours after treatment (chapter 6 and 7).

Reference	Design	Subjects	Technique	Dose	Reliability	Patient reported pain scores Mean (SD)	PPT
Vicenzino et al., 1995	Within-subjects Placebo (sham mob), control (no contact). Crossover	24 asymptomatic Mean age 19.8	Grade III Lateral glide to C5/C6	3x30s	None reported	None	Sig main effect of condition (p<.05) No effect size reported
Vicenzino et al., 1996	Within-subjects Placebo (sham mob), control (no contact). Crossover	15 with lateral epicondylalgia Mean age 44 Mean duration of symptoms 8 months (SD 2, range 2-36)	Grade III Lateral glide to C5/C6	3x30s non-noxious	None reported	Sig main effect of condition (p<.05) on VAS and PFGS VAS (of worst pain in 24 hours) Mean decrease in mob group 1.9 (0.5) cm	Sig main effect of condition (p<.05) Mean increase in mob group 45kPa / 25%
Vicenzino et al., 1998	Within-subjects Placebo (sham mob), control (no contact). Crossover	24 unilatateral epicondylalgia. Mean age 49. Mean duration of symptoms 6.2 months (SD 5.1, range 1.5-24)	Grade III Lateral glide to C5/C6	3x30s	None reported	Sig main effect of condition (p<.05) on PFGS	Sig main effect of condition (p<.01) Mean increase in mob group 75.74 (SD 12.69) kPa /30%
Sterling et al., 2001	Within-subjects Placebo (sham mob), control (no contact). Crossover	30 with C5/6 dysfunction.	Grade III Unilateral PA to C5/C6	3x30s	PPT left C5/6 ICC 0.91. SEM 1.62 PPT right C5/6 ICC 0.92. SEM 1.41	Sig main effect of condition (p<.05) on VAS at rest (post hoc > difference b/w mob and control) VAS decrease in resting pain 0.34 (0.02) No effect of pain on rotation to symptomatic side (p>.05)	Sig main effect of condition (p<.01) Mean increase in mob group 22.5 (SD 2.4)%.
Vicenzino et al., 2001	Within-subjects Placebo (sham mob), control (no contact). Crossover	24 unilateral epicondylalgi Mean duration of symptoms 8.33 months (SD 1.71, range 2-36)	lateral glide MWM with patient gripping.	6 reps	PPT ICC 0.95: SEM 7.08kPa	PFGS – Sig increase in mob compared to placebo (*p*<.05)	Sig increase mob compared to placebo (*p*<.01). Sig increase of mob compared to control (*p*.049). Mean increase in mob group 10.26%
Chiradejnant et al., 2002	Parallel group: Mobs at random v symptomatic level	120 LBP patients (n=60 in each group)	PA symptomatic level pragmatic grade	3x60s	None reported	Current pain intensity VAS de-screase by 1.34 (SD 1.27)	None
Paungmali et al., 2003	Within-subjects Placebo (sham mob), control (no contact). Crossover	34 unilateral lateral epicondylalgia	lateral glide MWM with patient gripping.	10x 6s holds	ICC 0.90. SEM 9.4kPa	PFGS – significant increase following mob (*p*<.05)	Significant condition x time interaction effect (*p*<.05) PPT 281.4 (142.6) kPa increased to 300.8 (115.2) kPa with Rx.

Table 2.4. The immediate effects of a single treatment dose on PPT and patient reported pain measures. kPa = kilopascals; Rx = treatment; PFGS = Pressure free grip strength; TPT = thermal pain threshold; sig = significant; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SD = standard deviation; Mob = mobilisation; MWM = mobilisation with movement; AP = anteroposterior; para =paravertebral muscle; derm = dermatome; s=seconds.
Note: table continues …

Reference	Design	Subjects	Technique	Dose	Reliability	Patient reported pain scores	PPT
Willett et al., 2010	Within same-subject repeated measures	30 asymptomatic Mean age 30 years	200N peak force PA L5	3x60s	ICC 0.89-0.96 SEM 0.17-0.25	None	Sig main effect of mobilisation (p<.01), Mean percentage change (actual change kg/cm^2) L5 para 19.15 (1.18) L5 derm 17.33 (0.85) L2 derm 14.96 (0.85) 1st interossei 10.89 (0.51)
Krouwel et al., 2010	Within same-subject repeated measures	30 asymptomatic Mean age 26 years	200N peak force PA L3	3x60s	ICC 0.84-0.94 SEM 0.16-0.18	None	Sig main effect of mobilisation (p<.05), Mean percentage change (actual change kg/cm^2) L3 para18.73 (1.01) L3 derm 17.93 (0.82) S1 derm 10.53 (0.53) Deltoid 19.06 (0.73)
Sterling et al., 2010	Parallel group: Mobs or Control (manual contact)	39 whiplash associated disorder (grade II). 18-65 years Duration of symptoms greater than 3 months	Non noxious Lateral glide C5-6.	3x60s	None reported	None	No significant difference between Rx and control (p=.49). Percentage change C6 24.1 (7.3) Median nerve 11.3 (4.7) Tibialis anterior 7.8 (4.8)
Soon et al., 2010	Within-subjects, Placebo (sham mob), control (no contact). Crossover	24 asymptomatic	Grade III unilateral PA Left C5/6	3x60s	PPT L/R articular pillar C5/6 ICC 0.97 (CI 0.87) SEM 16.13 kPa	None	No significant effect. (p=.846)
Yeo and Wright., 2011	Within-subjects, Placebo (sham mob), control (no contact). Crossover	13 subjects with recent ankle inversion injury	AP mobilisation on talus. Short of pain	3x60s	None reported	VAS no significant effect (p=.37)	PPT increased by 17.17% Significant increase in Rx group. (p<.01)
Pentelka et al., 2012	Within subjects repeated measures	19 asymptomatic	PA L4 mean peak force 243N (SD 25)	5x30s 5x60s	ICC 0.78-0.86 SEM 0.7-1.91 Minimal detecTable change 1.94-2.93	None	Sig main effect of mobilisation (p<.01). Mean percentage change (actual change kg/cm2) L4 para 56 (2.8), L4 derm 41 (1.4) S1 derm 41 (1.5), Deltoid 46 (1.6)

Table 2.4. (Continued) The immediate effects of a single treatment dose on PPT and patient reported pain measures. kPa = kilopascals; Rx = treatment; PFGS = Pressure free grip strength; TPT = thermal pain threshold; sig = significant; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SD = standard deviation; Mob = mobilisation; MWM = mobilisation with movement; AP = anteroposterior; para =paravertebral muscle; derm = dermatome; s=seconds.

2.9.2. Changes in patient reported pain measures following mobilisation treatment

Although there is strong evidence that mobilisations result in decreased PPT, this change may not be relevant to patients, as it may not relate to a change in their symptoms. In order to explore the effect of mobilisation on pain some studies have measured changes in visual analogue scale (VAS) scores after mobilisation treatment. For example Goodsell et al., (2000) investigated the effect of mobilisations on clinical measures of pain (VAS and patient reported pain relief scale) during either active physiological flexion or extension (whichever was worse). This was a randomised controlled same-subject design, where participants received a control intervention, consisting of lying prone for 3 minutes, immediately before or after treatment. Pain on flexion decreased by 41% following a mobilisation treatment, and a subsequently applied control intervention resulted in a further decrease of 15%. Whereas, when the control intervention was applied first there was a 7% decrease in pain on flexion followed by a further 11% decrease with the mobilisation treatment. Mobilisations resulted in pain on extension decreasing by 19% and the subsequent control intervention produced a further 18% decrease in pain. When the control intervention was applied first this produced a 6% decrease in pain on extension and the subsequent mobilisation a 33% decrease. These results represent a significant decrease in pain on worst movement, which was significantly greater with mobilisation than control intervention. However, the differences between the treatment and control group should be interpreted with caution as the two conditions were applied consecutively, with no wash out period; therefore, the temporal effects of the previous intervention may have affected the results.

Chiradejnant et al., (2002) investigated the effects of 2 x 1 minute of mobilisations in 120 patients with LBP and reported a significant reduction in current pain intensity (measured using a numeric rating scale) but no change in the pain associated with movement. The mean change in scores on an 11-point scale was 1.34 (SD 1.27), equivalent to a 31% decrease. In a randomised placebo control study, Sterling et al., (2001) found that cervical mobilisations resulted in a significant decrease in VAS at rest, however the magnitude of change was small (mean 0.34cm, SD 0.02) and a change in VAS of this magnitude is not thought to be clinically meaningful (Rowbotham et al., 2001). Furthermore there was no difference between the treatment and placebo groups so the changes may have resulted from non-specific effects of treatment. There was no change in VAS on active physiological rotation. The lack of change in pain on rotation may have been because this was the movement tested in all subjects irrespective of whether it was their most symptomatic movement. Importantly, Sterling et al., (2001) also found a significant reduction in PPT but these were not correlated with VAS scores. The relationship between PPT and patient reported measures of pain was explored further in the studies in the current thesis (chapters 6 and 7).

In summary, most studies report an increase in PPT immediately following a mobilisation treatment, however the longer-term effects have not been investigated. There is some evidence to suggest that patients experience an immediate reduction in resting pain following mobilisations, but conflicting evidence regarding the effect of mobilisations on pain during movement. There is limited evidence on the relationship between PPT and VRS of pain. This was explored in chapters 6 and 7 of this thesis.

2.10. Mechanisms of analgesia

Although it has been established that mobilisation results in a decrease in pain (Sterling et al., 2001; Vicenzino et al., 1998 and 1996), the underlying mechanisms are largely unknown (Coronado et al., 2012). This section outlines the analgesic mechanisms and considers which of these may be responsible for the pain relief resulting from mobilisation treatment. The interpretation of studies on the hypoalgesic and analgesic response to mobilisation often draws on the understanding gained through animal studies. Thus the evidence from animal and human studies will be considered alongside the potential analgesic mechanisms through which mobilisations may elicit a pain relieving response.

2.10.1. The pain gate theory

Pain is transmitted by thin myelinated A delta and unmyelinated C-fibres to the dorsal horn of the spinal cord. Nociceptive information is then conveyed via the midbrain and thalamus to the cerebral cortex, where it is perceived. Melzack and Wall (1965) described the pain gate theory as a mechanism whereby large diameter, fast conducting fibres (A beta fibres) inhibit small diameter, slower conducting fibres (A delta and C-fibres) in the substantia gelatinosa in the dorsal horn of the spinal cord, thereby reducing the nociceptive information reaching the brain. The pain gate mechanism may be stimulated by PA mobilisations (Souvlis et al., 2004; Wyke and Polacek, 1975). PA mobilisations produce movement of joints, muscles, nerves and skin and in doing so, activate cutaneous, articular, muscular and neurovascular afferents (Souvlis et al., 2004). This provokes discharge by mechanoreceptors, which is conveyed to the spinal cord by large diameter afferents (A beta fibres), where they reduce the input from nociceptors, thus reducing the awareness of pain (Wyke and Polacek 1975).

In order to explore whether the pain gate was responsible for the pain relief resulting from manual therapy treatment in a human population, George et al., (2006) and Bialosky et al., (2009) used quantitative sensory testing to establish the effect of a high velocity thrust (manipulation) on A and C fibre activity and found lessening of C nerve fibre mediated temporal summation (a measure of dorsal horn excitability) following treatment. This hypoalgesia was evident in the

lumbar innervated but not cervical innervated areas suggesting a local mechanism mediated by the dorsal horn of the spinal cord. However, the effects of low velocity PA mobilisations are not necessarily the same as the effects of manipulation.

One study in rats found the analgesia resulting from mobilisations may be mediated at spinal cord level; Malisza et al., (2003) investigated the effect of knee joint mobilisations in rats and found a decrease in activity (using functional MRI) in the areas of the spinal cord associated with pain, suggesting that the analgesic response from mobilisations, may at least in part, be mediated at the level of the spinal cord. These studies provide speculative evidence to support the theory that the pain gate mechanism may be a mechanism involved in the analgesia resulting from mobilisations. In addition to stimulating the pain gate mechanism, mobilisations are thought to provide a powerful input to the central nervous system via afferent neurons which may cause descending modulation of pain (Souvlis et al., 2004).

2.10.2. Descending modulation of pain

Electrical stimulation of various regions of the brain (in both rats and humans) has been shown to induce analgesia and has confirmed that descending systems contribute to pain modulation (Souvlis et al., 2004; Sluka and Rees, 1997; Hosobuchi et al., 1977; Mayer and Liebeskind, 1974; Reynolds, 1969). Much of this work has focused on the Periaqueductal Gray (PAG) of the midbrain and the Nucleus Raphe Magnus (Sluka and Rees, 1997). The effect of stimulation of the PAG have been found to create strong analgesic responses; in a landmark study Reynolds (1969) highlighted the importance of the PAG area in the control of nociception by observing that analgesia could be produced by electrical stimulation of the PAG of the midbrain in rats. This analgesia was sufficient to allow surgery without an anaesthetic and with no aversive reactions in the rats. A later study (Hosobuchi et al., 1977) found that stimulating the central gray area in humans with intractable pain resulted in pain relief, suggesting that the PAG area of the brain is also important in mediating an analgesic response in humans.

Lovick et al., (1991) found that descending pain inhibitory systems, and particularly the PAG area, play an important integrative role for behavioural response to pain, stress and other stimuli by co-ordinating responses of a number of systems including the nociceptive system, autonomic nervous system and the motor system. Stimulation of the dorsal PAG in rats resulted in mechanical hypoalgesic, sympathetic excitation and increased muscle activity. This response in rats has been compared to the effects of mobilisation treatments in humans and has been considered as evidence regarding the brain

regions responsible for pain relief resulting from mobilisations (Sterling et al., 2001, Wright et al., 1995). This comparison arises from studies investigating the effects of mobilisations on the human cervical spine (Sterling et al., 2001; Vicenzino, 1995; Vicenzino et al., 1996) that have reported concurrent sympathetic excitation and mechanical hypoalgesia. The measures of sympathetic nervous system used in these studies were skin temperature and skin conductance which are indirect measures of sympathetic nervous system activity. These measures may be considered to lack validity and are subject to influence from psychological factors (Arena and Hobbs, 1995). Furthermore the reliability of SNS measures was not reported in any of the aforementioned studies. If the validity and reliability of these SNS measures were established any effect observed post mobilisation would remain indirect evidence of stimulation of the dorsal PAG.

In summary, there is some indirect evidence that that the analgesic response to mobilisations may at least in part be mediated by the dorsal PAG.

2.10.3. Opioid analgesia

Another mechanism of pain relief is endogenous opioid analgesia. This does not appear to be a mechanism involved with mobilisation induced analgesia as studies in humans have also found that the hypoalgesia resulting from mobilisations is not reversed by systemic administration of the opioid antagonist naloxone (Paungmali et al., 2004; Vicenzino et al., 2000).

2.10.4. The extent of the hypoalgesic effect of PA mobilisation treatment

In order to provide insight into the potential mechanisms evoking an analgesic response resulting from mobilisations, some studies have measured PPT at sites chosen to establish the extent (local, segmental or systemic) of the analgesic effect (Pentelka et al., 2012; Krouwel et al., 2010; Willett et al., 2010). These studies have reported widespread changes in PPT following lumbar mobilisation in asymptomatic participants. However some studies reported changes local to the site of treatment were significantly greater than those in distant locations (Pentelka et al., 2012; Willett et al., 2010), suggesting that more than one analgesic mechanism is stimulated. The widespread changes are indicative of modulation of pain within the central nervous system, whereas the local changes may indicate modulation at spinal cord level. This suggests that mobilisation-induced hypoalgesia is mediated by an interaction between spinal cord and central mechanisms. These studies were all conducted with asymptomatic populations and it is not known whether the extent of the analgesic effect would differ in a symptomatic population; this remains an area for further investigation which is considered in chapter 6 and 7 of this thesis.

2.11. The effects of different durations of mobilisation treatment

The focus of two studies in this thesis, a single arm trial (chapter 6) and an RCT (chapter 7), was on the effect of different durations of mobilisations treatment. Clinically, PA mobilisations are performed for varying amounts of time. The conventional duration of treatment applied in one session would normally be up to 60 seconds of mobilisations repeated 3 times (3 x 60 seconds), resulting in a total of 3 minutes of mobilisations (Petty, 2011). However evidence has indicated that longer treatment duration may have an increased analgesic effect (Pentelka et al., 2011; Sluka and Wright, 2001).

In a placebo-controlled study, Sluka and Wright, (2001) compared the effects of applying 3, 9 and 15 minutes of mobilisation on rats knees and found that only 9 and 15 minutes produced a significant increase in mechanical withdrawal thresholds (indicating an analgesic effect). No significant findings were found with placebo (manual contact only) or control (no contact) groups (Sluka and Wright, 2001). This study indicated that, in rats, duration of mobilisation treatment is important in producing an analgesic effect.

Studies investigating the analgesic effect of PA mobilisations, utilising human participants, typically employ treatment durations of 1.5 to 3 minutes. Only two studies to date have investigated treatment duration in a human population; Souvlis et al., (2001) compared 3 x 30 seconds, 6 x 30 seconds and 3 x 60 seconds of mobilisations to the cervical spine, on SNS measures, and reported that the largest changes from baseline were provided by 3 x 60 secs followed by 3 x 30 secs. These results may suggest that the number of sets of treatment is more important than the total duration of treatment. However no pain measures were included and the relevance of isolated changes in SNS measures is questionable. One recent study has investigated longer durations of mobilisation applied to the lumbar spine in asymptomatic participants; Pentelka et al., (2012) applied 5 sets of mobilisations of 30 and 60 seconds duration (resulting in a total treatment duration of 2.5 and 5 minutes). PPT measurements were taken between each set of mobilisation. A significant effect was observed after the first set of mobilisations – PPT increased gradually over the following sets, reaching further significance following the 4th set of mobilisations. These timings suggest that applying more sets of mobilisations resulted in a greater hypoalgesic effect. However the study was designed to compare the effects of 30 and 60 second sets of mobilisations and did not include a control group. There was no difference between 30 and 60 second set durations.

In summary, the duration of PA mobilisation treatment used by physiotherapists at present is not highly evidence based. Evidence suggests that a greater analgesic

effect may be produced by longer durations of treatment than those commonly employed in clinical practice. To date no studies have investigated the effect of longer duration of treatment on lumbar spine ROM or stiffness. The overall aim of this thesis was therefore to investigate the effects of mobilisation treatment duration on ROM, stiffness and pain, and thus the following chapter considers the measurement of these variables.

Chapter 3

Methods of measurement of pain and lumbar spine range of movement and stiffness

The studies included in this thesis investigated the effects of PA mobilisation on lumbar spine range of movement (ROM), stiffness and pain. In this chapter consideration is given to the methods of measurement of lumbar spine ROM and the two methods of stiffness measurement found in the literature. The use of pressure algometry, to measure pressure pain thresholds (PPT) and VRS (verbal rating scale), a patient reported measure of pain, are also explored.

3.1. Measurement of lumbar spine ROM

Historically measurements of spinal ROM were made using biplanar radiography which involved taking lateral and antero-posterior radiographs and identifying the change in position of anatomical landmarks on each vertebra in both views (Pearcy, 1985). This continues to be considered a valid measure of actual spinal motion. However it requires a skilled operator, can only be used in a radiology department, involves exposing subjects to radiation and is costly. Currently most studies measuring spinal ROM involve taking measurements at the skin surface. However it is accepted that skin movement will contribute an error to surface measurements and that these measures may overestimate the actual motion of the spine. The advantages of systems that measure movement at the skins surface are that they can be widely used in situ without exposing participants to radiation.

There are a number of measurement tools that enable measurement of lumbar ROM at the skins surface; some simple measures of lumbar spine movement such as fingertip to floor and inclinometer readings (protractors that measure the change in angle or tilt of the spine) have been used extensively but these are limited to measuring sagittal plane movement. Electrogoniometers have also received widespread use but only measure movement in two dimensions. Other surface measurements that have been widely employed are three dimensional measurement methods such as inertial measurement systems and electromagnetic tracking devices. The reliability of electromagnetic tracking devices in measuring spinal ROM has been considered in the following section.

3.1.1. Reliability of ROM measurements of the lumbar spine using electromagnetic tracking systems

When considering the ROM and comparing it to that reported in other studies, it is essential to consider the system that was used. Even studies using a similar or the same system may yield different ranges of lumbar movement (Table 3.1). In those

using the same system the method of sensor fixation may be different. For example, some studies use the velcro straps provided by the manufacturer, whilst others have designed fixing plates which are attached to the skin with double sided sticky tape and are said to minimise the influence of skin movement (Mannion and Troke, 1999). The participants themselves will create a variation, due to within participant variation and between participant differences (such as age and gender). The difficulties in comparing measurements using different systems were highlighted in a study by Mannion and Troke, (1999); the range of lumbar rotation measured using two electromagnetic tracking systems (Fastrak and CA6000 Spine Motion Analyser) was compared and the two systems were found to yield different results. The greatest difference was observed in the range of rotation; the mean range recorded was 11.3 degrees with the CA spine motion analyser and 34 degrees when using Fastrak. So therefore caution should be applied when comparing measurements reported in studies using different devices (Table 3.1).

Despite the variations in measurements obtained, when using the same device, with the same methods of fixation, reliability of measurements can be good. Using the Fastrak electromagnetic tracking device, Lee and Wong, (2002) reported a co-efficient of multiple determination of 0.98 for 3 ROM measurements conducted at 5 minutes intervals. Also using Fastrak to measure lumbar ROM, Mannion and Troke, (1999) reported within-day intraclass correlation coefficients (ICC's) of 0.82-0.99 and between-day ICC's of 0.72-0.81.

Reference	Method	Gender	Age (years) Mean (SD)	Flexion degrees Mean (SD)	Extension degrees Mean (SD)	Lateral flexion degrees Mean (SD)	Rotation degrees Mean (SD)
Hindle et al., 1990	3 space Isotrak	40 male 40 female	10 in each: 20-29 30-39 40-49 >50	73.8 in males 66.7 in females	21.5 in males 24.1 in females	48.5 in males 54.1 in females	27.1 in males 30.8 in females
Peach et al., 1998	3 space Isotrak	17 male 7 female	22 (3.4) 20.4 (0.5)	71.6 (8.6) flexion / extension		30.8 (5)	16.6 (4.7)
Mannion and Troke, 1999	CA6000	5 male 6 female	22-43	64.5 (12.4)	22.8 (7.9)	45.7 (6.7)	11.3 (4.3)
Mannion and Troke, 1999	Fastrak	5 male 6 female	22-43	56.4 (7.9)	19.7 (8.3)	53.4 (6.3)	34 (6.5)
Stamos-Papastomos et al., 2011	Fastrak	16 male 16 female	25.5 (4.5)	54.11 (11.12)	22.8 (10)	Not reported	Not reported
Ha et al., 2013	Fastrak	12 male 14 female	28.2 (7.4)	56.9 (7.8)	26.7 (9.6)	26.1 (7.1)	14.8 (3.8)
Ha et al., 2013	Xsens	12 male 14 female	28.2 (7.4)	56.6 (8.9)	26.2 (7.7)	27.3 (7.2)	14.2 (3.6)
Lee et al., 2003	Gyroscope	15 male 4 female	22 (5)	48.6 not reported	18.7 not reported	16.3 not reported	8.9 not reported

Table 3.1. Studies measuring range of lumbar movement using three dimensional measurement methods. SD= standard deviation

In summary due to skin movement electromagnetic tracking devices may overestimate lumbar range of movement. However, the advantages of these systems have led to their widespread usage. When using the same device and fixation method, electromagnetic tracking devices provide a reliable way of measuring lumbar ROM. Because electromagnetic tracking devices have been found to be reliable and able to monitor three-dimensional movements an electromagnetic tracking device was chosen to measure the effects of mobilisations on lumbar spine ROM in a single-arm trial included in this thesis (chapter 6).

3.2. Measurement of lumbar spine stiffness

In addition to measuring lumbar ROM, studies in this thesis measured stiffness of the lumbar spine. One of the techniques used during the examination of patients with LBP is the application of PA mobilisation to the spine. When applying a PA force to the spine, the therapist makes an assessment of spinal stiffness, which is the resistance of the spine to deformation. The ability of the therapist to discriminate the spinal levels that are stiff and those that are not and the inter-therapist and intra therapist reliability of this assessment is poor (Snodgrass et al., 2009; Binkley et al., 1995; Maher and Adams, 1994). For this reason researchers have developed instrumented methods of measuring stiffness that measure the force applied and the corresponding displacement or movement of the lumbar spine. This section considers the different methods of measuring stiffness that have been developed. The second part of this section considers the stiffness values that have been reported using these systems and the factors that may influence the stiffness values obtained.

3.2.1. The displacement method of spinal stiffness measurement

Several systems have been employed which measure stiffness by calculating the amount of displacement in response to the force applied (Table 3.2). These constitute the majority of the studies using instrumented measurement of stiffness. The first device designed to measure stiffness using this displacement method was the spinal physiotherapy simulator (SPS), developed by Lee and Svensson, (1990). The SPS system consists of a load cell mounted on an indenter, through which pressure is applied to the spine. Movement of the indenter is controlled by a variable speed motor to allow oscillations to be applied at varying (standardised) speeds (Lee and Svensson, 1990). To allow measurement of stiffness in Newtons per millimetre (N/mm), the load cell measures the force, while a linear inclinometer measures vertical displacement of the tissues under the indenter. Lee and Svensson, (1990) established the reliability and validity of the SPS in making stiffness measurements by testing an elastic beam with a known stiffness value. The SPS was found to underestimate stiffness by less than 1% of the true value. The test re-test reliability was good, resulting in an ICC of 0.88.

The same research group developed a similar, portable version of the SPS, (called the Stiffness Assessment Machine (SAM) (Latimer et al., 1996a). The reliability of this system was established using repeated measures (taken 5 minutes apart) performed at the most symptomatic vertebral level in patients with LBP. Excellent reliability was found as an ICC of 0.96 (95% confidence interval of 0.91-0.98) was reported (Latimer et al., 1996b). Validity was not as good as with the non-portable device as when testing the elastic beam it was found to underestimate stiffness by less than 2.5% (1.5% greater error then the SPS). Although validity of these systems has been reported, one requisite of validity testing is that it is performed in light of the measure's intended use (Streiner and Norman, 2008). Testing against a beam, as was the case with these systems, is likely to be a less complex task than testing of stiffness in the lumbar spine, where error may be greater, and thus validity of spinal stiffness measurements may not be as good.

A different research group (Edmonston et al., 1998) developed a third, similar device, called the Spinal Postero Anterior Mobiliser (SPAM). Like previous devices it consists of a mechanically driven load cell. This group reported excellent reliability of spinal stiffness measurements (ICC of 0.98 and standard error of measurement (SEM) of 0.52N/mm).

More recently an American Chiropractic research group developed another system using similar technology and calculation methods (Owens et al., 2007a). As with the previous systems a load cell was mounted on the indenter, but in this system an electromagnetic sensor was mounted on top of the load cell in order to measure displacement. Reliability testing of this system resulted in an ICC of 0.74 and a SEM of 1.62N/mm (Owens et al., 2007a). In contrast to the other systems, where the indenter is mechanically driven, in this system the therapist applied the force manually using the indenter. The disadvantage of this is that there will be variations in the way the therapist applies the force on different occasions; for example even with considerable effort to standardise application, rate and angulation of force may be inconsistent. However the hand held indenter does not require the complex and expensive mechanical devices used by Edmonston et al., (1998) and Latimer et al., (1996a).

Reference	Participants details (age, gender, symptoms)	Method	Indenter head	Breathing /plinth	Amount of force Newtons	Frequency (hertz)	Preconditioning
Viner et al., 1991	5 females- asymptomatic 18-21 years	SPS	Unpadded indenter head 720mm^2	Unreported	Unreported	Unreported	Unreported
Lee and Evans, 1992	28 asymptomatic 14 males, 14 female 19-23 years (mean 20.9, SD 4.5)	SPS and linear potenti-ometers	Indenter head 720mm^2 with 'thin soft padding'	Mattress on floor	Max 150N	1-2Hz	Not stated
Lee and Svensson, 1993	12 asymptomatic 4 males, 8 female 26-35 years (mean 28.1, SD 3)	SPS + Linear poten-tiometers	Unpadded indenter head 720mm^2	Unpadded FRC	Max 100N	1Hz or 0.5Hz or static	Several preconditioning cycles
Lee and Liver-sidge, 1994	19 asymptomatic, 7 male, 12 female 18-40 years (mean 26.3 SD 7.6)	SPS	Unpadded indenter head 720mm^2	FRC	Max 120N	Quasistatic (for 10secs) And 0.5Hz	3 slow loading cycles
Lee et al.,1994	10 asymptomatic. 5 male, 5 female. Mean age 29.2 years	SPS	Unpadded indenter head 720mm^2	Unpadded FRC	Max 120N	0.2Hz	3 cycles
Latimer et al., 1996a	22 with LBP, 12 male, 10 female 19-58 years (mean 27.4 SD 9.4)	Portable SAM	Unpadded indenter head 720mm^2	FRC	Max 105N	0.5Hz	'several' preliminary cycles
Latimer et al., 1996b	25 with LBP, 10 male, 15 female 25 asymptomatic.	Portable SAM	Unpadded indenter head 720mm^2	Unreported	Un-reported	0.5Hz	5 preliminary cycles.
Viner et al., 1997	42 asymptomatic 20-45 years 'balance of genders'	SPS	Unpadded indenter head 720mm^2	Unpadded FRC	Max 100N	0.5Hz	'a few oscillations of force'
Edmonston et al., 1998	12 asymptomatic 7 male, 5 female Mean 28.8 years (SD 3.4)	SPAM	Padded (4mm dense foam) indenter head 300mm^2	Thin padded FRC	Up to 80N used for analysis	Sustained load was applied for 10 secs.	Preload of 30N and sustained for a few seconds.

Table 3.2. Differences in methodology of studies using instrumented measurement of lumbar spine stiffness.
SPS =Spinal Physiotherapy Simulator, SAM = Stiffness Assessment Machine, SPAM= Spinal Postero Anterior Mobiliser, ASIS=anterior superior iliac spine, FRC =forced residual capacity, Hz = hertz, mm = millimetres, N = Newtons, SD = standard deviation, LBP= low back pain.

Reference	Participants	Method	Indenter head	Breathing /plinth	Amount of force Newtons	Frequency (hertz)	Preconditioning
Goodsell et al., 2000	26 with LBP, 13 male, 13 female 16-69 years (mean 39.4, SD 15)	SPS check system	Unpadded indenter head 720mm^2	Unpadded FRC	60-230N (mean 137N)	0.5Hz	2 cycles
Chansirinukor et al., 2001	37 asymptomatic 19 male, 18 female 18-40 years (mean 23.7, SD 4.7)	SPS	Unpadded indenter head 720mm^2	Unpadded FRC	Max 120N	0.05Hz	4 cycles 0-120N
Shirley et al., 2002	18 asymptomatic 12 female, 6 male Mean age 28 (SD 7)	Portable SPS	Unpadded indenter head 720mm^2	FRC	30-90 used for analysis	0.5Hz	4 cycles 0-120N
Chiradenjant et al., 2003	41 asymptomatic 12 male, 29 female 18-35 years (mean 22.3, SD 4.7)	SPS	Unpadded indenter head 720mm^2	Padded plinth	Max 125N	1Hz	4 cycles 0-125N
Chansirinukor et al., 2003	41 asymptomatic 20 male, 21 female 18-37 years (mean 24.5, SD 5.4)	SPS	Unpadded indenter head 720mm^2	FRC Hard plinth	Max 120N	Unreported	3 cycles / 0-120N
Lee et al., 2005b	20 asymptomatic 12 male, 8 female Mean age 20 (SD 2)	Three-point bending	Applied by therapist using pisiform	Not mentioned	Mean 178 (SD 30) 141-273N	Grade III for 30 secs. 1.2Hz (SD 0.6)	Mobilisation for 30 seconds
Owens et al., 2007a	36 with LBP 22 male, 14 female Mean age 49.1 (SD 14.2)	Manually applied System	Indenter (2cm diameter) 314mm^2	FRC Hard plinth	Max 80N	1Hz	First cycle excluded from analysis
Owens et al., 2007b	192 with LBP 89 female 103 male. Mean age 40 (SD 9.4)	Manually applied System.	Indenter (2cm diameter) 314mm^2	Exhale to comfortable level. Hard plinth	Max 80N	Loading 1.16secs (SD 0.39). Unloading 0.5secs (SD 0.2)	First cycle excluded from analysis

Table 3.2. (continued) Differences in methodology of studies using instrumented measurement of lumbar spine stiffness. SPS =Spinal Physiotherapy Simulator, SAM SPAM= Spinal Postero Anterior Mobiliser, ASIS=anterior superior iliac spine, FRC =forced residual capacity, LBP = low back pain. Hz = hertz, mm = millimetres, N = Newtons, SD = standard deviation.

All the above methods measure vertical displacement of the indenter while the load cell measures the applied force. This is where the main potential limitation arises. It is widely recognised that these systems do not purely measure intervertebral movement at the point of application (Lee and Evans, 2000 and 1997; Lee et al., 1996), but the displacement measurement is made up of regional spinal movement, compression of the plinth padding, abdomen and thoracic cage, rotation of the pelvis and displacement of the overlying soft tissues (Chansirinukor et al., 2003 and 2001; Kulig et al., 1994). Gliding at the zygapophyseal joints adjacent to the point of application is thought to be a small contributor to the overall movement (Kulig et al., 2004; Powers et al., 2003; Lee and Evans, 2000; Lee and Evans, 1997; Lee and Svensson, 1993). Therefore if the aim is to purely measure the resistance to spinal joint movement then there is certainly potential error with the use of this method. However if the aim is to measure what a physiotherapist perceives when applying a PA mobilisation (including compression of soft tissue, the abdomen and the plinth) during assessment and reassessment of stiffness in patients then this may be considered to be a valid measure, i.e., a measurement that is a good measure of what it intends to measure (Streiner and Norman, 1989).

3.2.2. Three-point bending method of stiffness measurement

In order to minimise the contribution from soft tissue and plinth compression to stiffness measurements, Lee et al., (2005a) developed the three-point bending model of measuring lumbar stiffness, involving measurement of movement of the whole lumbar spine. Participants were asked to lie on a plinth mounted on a force plate and electromagnetic sensors were placed on the sacrum and T 8/9. An equation was developed to calculate stiffness that used the force measured and the corresponding change in angle of the spine. This equation assumed an engineering three-point bending beam model, where the lumbar spine is theoretically supported at the rib cage and pelvis, both of which are constrained from vertical movement but free to rotate. Using engineering equations for beam bending a stiffness value was calculated linking the PA force, the rotation of the sensors and the measurements of the ‘beam length’, in this case the distance between the sensors and the point of force application. With this system a therapist applied the PA force (as opposed to the load cell developed by Latimer et al., 1996a). One disadvantage of this system, like the system used by Owens et al., (2007a,b) is that it introduces operator error into the application of force.

The difference between stiffness measurement methods, displacement and three-point bending methods of stiffness measurement are displayed in Table 3.2. In addition to the different measurement systems other experimental variables can influence stiffness measurement; these have been considered in the following section.

3.2.3. Experimental variables influencing stiffness measurements

As discussed the manual application of force introduces potential error in stiffness measurement that might not be evident with motor driven indenters. The following variables, which are also less controllable with manual application of force, have been shown to influence stiffness measurements: peak force (Latimer et al., 1998), rate of application (Lee and Liversidge, 1994; Lee and Svensson, 1993) and angle of application (Allison et al., 1998).

There are a number of other experimental factors that can affect stiffness measurements (see Table 3.2). These include differences in the amount of plinth padding and size of the indenter head – both of which have been found to significantly affect stiffness measurements (Latimer et al., 1997). There are also within- and between-subject factors that can affect stiffness. These include body composition (Owens et al., 2007b; Lee et al., 1998; Viner et al., 1997) and the spinal level tested (Chansirinukor et al., 2003; Lee and Liversidge, 1994). Methodologically, the amount of preconditioning (applying loading cycles prior to data collection to stabilise the response of the tissues) and the range of force used in stiffness calculations may influence measurements (for differences in these between studies see Table 3.3). The calculation of stiffness values is considered in the following section.

3.2.4. Stiffness calculations using the displacement method of measurement

All of the above systems calculate stiffness from a force displacement graph, on which the application of a PA force can be depicted. The initial part of the force displacement graph (Figure 3.1) is generally recognised as non-linear and represents small forces producing a relatively large displacement (Lee and Evans, 1992, 1994). Typically the tissues become gradually stiffer until a more linear part of the force displacement graph is reached.

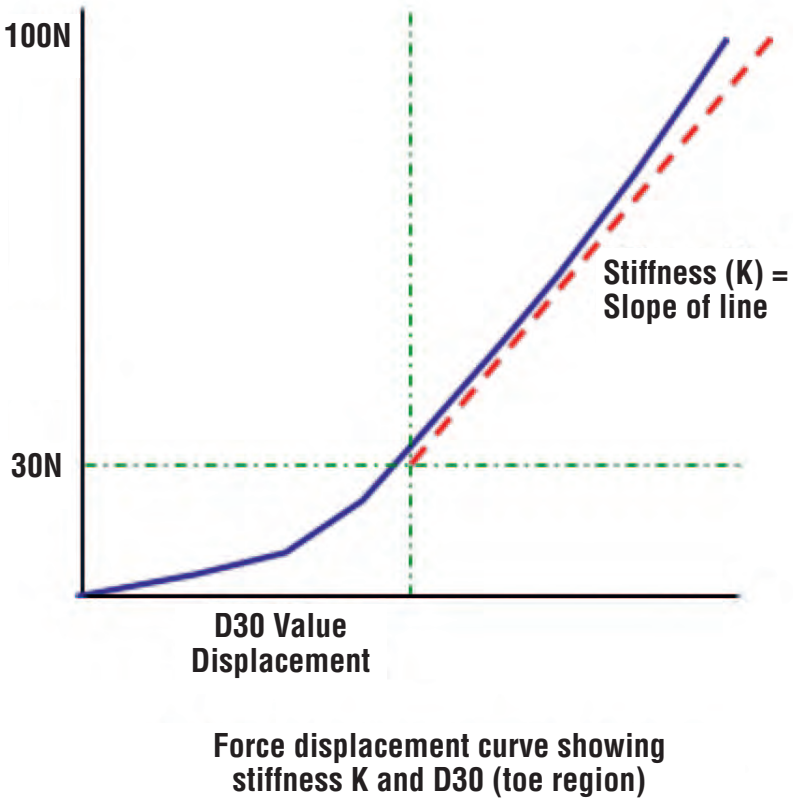


Figure 3.1. Force displacement graph of PA pressure applied to the lumbar spine.

The toe region of the force displacement curve (Figure 3.1) is thought to occur when collagen fibres are uncurling. Stiffness increases and the curve becomes more linear once the collagen fibres are straight (Lee and Evans, 1994). Compression of soft tissues overlying the spinous process is also thought to contribute to the toe region (Lee and Svensson, 1993). Latimer et al., (1996b) examined the force displacement graphs produced from the application of a PA mobilisation to the lumbar spine in 22 participants and found that the non-linear region representing the low stiffness part of the curve occurred during the application of the first 30 Newtons (N) of force.

When calculating stiffness most studies have fitted the slope of a regression line to the linear region of the force displacement chart (Table 3.3); this represents the stiffness coefficient K (Figure 3.1). Some studies have also looked at the displacement (in millimetres) during the non-linear portion of the force displacement curve up to 30N (D30). Like the majority of studies, in this thesis stiffness was calculated by linear regression of the loading phase between 30-100N on the force-displacement curve.

Table 3.3. Method of stiffness calculation for the lumbar spine at different spinal levels and with different angles of force application. K =stiffness expressed in Newtons per milimetre (N/mm), D = displacement expressed in millimetres; The range of D and K are stated for example D5-30 is the displacement that occurs between 5 and 30 Newtons of applied force. Ceph=cephlad, Caud =caudad. **Note**: continues on next page.

Reference	**Method of calculation (loading cycles used in analysis)**	**Spinal level / angle of force (degrees)**	**Stiffness Mean (standard deviation)**	
Lee et al., 1994.	Mean of 5 cycles. greater than 50N	L3	K= 13.4 (3.13) N/mm	
Latimer et al.,1996a.	Cycles 2-5 D30 also calculated.	L2: 5.5° ceph L3: 5.5° caud L4: 4.5° caud L5: 16° caud	K= L2 (n=2): 12.78 N/mm K= L3 (n=1): 17.46 N/mm K= L4 (n=4): 15.94 N/mm K= L5 (n=15): 15.14 N/mm	
Latimer et al.,1996b.	Cycles 2-5 K: 30-100 D 0.5-30		LBP: K: 14.96 (2.74) N/mm D: 4.50 mm (1.43)	Non LBP: K: 14.84 (3.46) N/mm D: 4.88 (1.14) mm
Latimer et al., 1997.	K: 30-90	L3	L3: 14.87 (3.21) N/mm rigid plinth 12.01 N/mm (2.51) padded plinth	
Viner et al., 1997.	D5-30 K: 30-100	L1: 6° ceph L2: 3° ceph L3: 1° caud L4: 5° caud L5: 14° caud S1: 19° ceph	<u>D5-30 mm</u> L1: 1.77 (0.98) L2: 1.92 (1.04) L3: 2.09 (1.09) L4: 2.31 (1.47) L5: 2.61 (1.49) S1: 2.38 (1.21)	<u>K 30-100 N/mm</u> L1: 14.05 (2.97) L2: 14.17 (2.54) L3: 14.48 (3.02) L4: 15.50 (3.30) L5: 16.41 (3.77) S1: 16.95 (3.67)
Lee et al., 1998.	K: 30-100	L1: 4.5° caud L4: 12.50ceph	L1: 10.4 N/mm L4: 13.3 N/mm	
Goodsell et al., 2000.	Cycles 2-5. D30 and K (30-90N) calculated	L2: 5.5° ceph L3: 5.5° caud L4: 4.5° caud L5: 16° caud Most symptomatic	Mean of stiffness measurement at all levels reported K= 15.11 (4.7) D30: 5.01 (1.1)	
Chansirinukor et al., 2001.	Slope of least regression line: 30-100N	L2: 3° ceph L3: 1° caud L4: 5° caud L5:14° caud	K= L3: 8.93 N/mm K= L5: 11.02 N/mm No gender difference Other values not reported	
Caling and Lee, 2001.	Two cycles collected. First cycle used for analysis.	3 direction L3: 11° caud, 1° caud, 9° ceph L5: 24° caud, 14° caud, 4° caud	<u>D5-30 mm</u> L3: 11° caud: 3.9, 1° caud: 3.5, 9° ceph: 3.9 L5: 24° caud: 5.4, 14° caud: 5.3, 4° caud: 4.8	<u>K:30-100 N/mm</u> L3: 110 caud: 14.1 10 caud: 15.8 90 ceph: 13.5 L5: 240 caud: 16.4 140 caud: 16.1 40 caud: 15.2

Reference	Method of calculation (loading cycles used in analysis)	Spinal level / angle of force (degrees)	Stiffness Mean (standard deviation)
Shirley et al., 2002.	D30 -2-30N Within test: cycles 1-5 Between tests: mean of cycles 2-5	L4	D30: 5.97 (0.37) mm K: 13.218(0.71) N/mm
Owens et al., 2007a.	Cycles 2-5 Slope of force displacement 55-75N	L1-L5 Straight PA	L1: 11.18 N/mm L2: 11.38 N/mm L3: 11.09 N/mm L4: 11.37 N/mm L5: 11.87 N/mm Standard deviations not reported
Owens et al., 2007b.	Cycles 2-5 Slope of force displacement 55-75N (In subjects unable to tolerate 80N (20N range from 5N less than max force)	L1-L5 Straight PA	L1: 10.25 N/mm L2: 10.45 N/mm L3: 10.82 N/mm L4: 10.81 N/mm L5: 11.12 N/mm Standard deviations not reported

Table 3.3. (continued) Method of stiffness calculation for the lumbar spine at different spinal levels and with different angles of force application. K = stiffness expressed in Newtons per millimetre (N/mm), D = displacement expressed in millimetres; The range of D and K are stated for example D5-30 is the displacement that occurs between 5 and 30 Newtons of applied force. Ceph = cephlad, Caud = caudad.

This section has considered the methodological and patient variables, which can affect stiffness measurements. The different methods of spinal stiffness measurement were explored. However there was little comparison between stiffness methods in the literature so it was not possible to clarify the best method for measuring spinal stiffness. After initial pilot work (section 4.4) identified the need for experimental comparison of these methods both three-point bending and displacement methods have been employed and the results compared during the studies in chapter 5 and 6 of this thesis. As described, both three-point bending and displacement methods of stiffness measurement involve the measurement of applied force. The following section considers the different systems used to measure force when investigating spinal stiffness.

3.3. Measurement of forces

Spinal stiffness is the extent to which the spine resists deformation in response to an applied force and thus stiffness measurement involves the measurement of applied force. In previous studies, the force has been applied and thus measured using a load cell (Owens et al., 2007 a,b; Lee and Svennson, 1990; Latimer et al., 1996a), or applied by a therapist and measured indirectly through force plates (Lee et al., 2005a; Harms et al., 1995). The studies in this thesis used indirect measurements of applied force and thus these have been considered in further detail below.

The first system employed to indirectly measure applied force, indirectly measured the change in force when a mobilisation was performed by a therapist standing on a force platform (Matyas and Bach, 1985). Applied force was calculated using the equation F+G –W =ma, where F is the reaction to the force applied by the therapist to the patient, G is the ground reaction force, W is the weight of the therapist and 'a' is the acceleration of the centre of gravity of the therapist. It has been argued that because therapists use acceleration of the upper body when applying force, the change may not represent that applied to the patient (Harms et al., 1995). However, Petty and Messenger, (1996) argued that the average acceleration of the therapist over time must be zero, otherwise the therapist would acquire a net positive or negative velocity; for this reason, acceleration was considered to be zero or so small it could be ignored. The influence of acceleration has been investigated experimentally by sampling data from the force plates over 20 oscillations and it was found that total acceleration was virtually zero (Matyas and Bach, 1995). However, although measuring acceleration over a period of time was zero, it will not be zero at the instant of measurement and therefore other systems have been developed to overcome this error.

To overcome the problems with acceleration, Harms et al., (1995) developed a plinth with force transducers mounted in the frame plinth. Lee et al., (1990) described an alternative technique where the plinth is mounted on a force plate; this was the method of force measurement employed in the studies contained in this thesis.

3.4 Measurement of pain

In addition to investigating the effects of lumbar mobilisations on lumbar spine ROM and stiffness, the researcher also sought to examine the analgesic effects of lumbar mobilisations. Therefore the following section considers the measurement of pain.

3.4.1. Pressure algometry

The studies in this thesis (chapters 5-7) included a number of pain related measures used to assess the hypoalgesic effects of mobilisations. One of the pain related measures was pressure pain threshold (PPT). Pressure algometry has been used extensively to quantify people's pain experience. Algometers are used to measure pressure pain threshold and involve the application of pressure to the skin. Perceived pain is quantified by determining the point at which the sensation of pressure changes to one of pain or discomfort. Algometry has been used to measure soft tissue tenderness (Nussbaum and Downes, 1998), to quantify trigger points (Delaney and McKee, 1993), to assess the effects of treatment regimens (Dhondt et al., 1999; Fryer et al., 2004; Willett et al., 2010) and to assess

the relationship between PPT and disability in patients with LBP (Farasyn, 2005). There are two main types of algometer, non-electronic ones and electronic ones. The electronic ones often have the advantage of including functions which are designed to enhance the reliability of measures, such as patient control switches and indicators of force application rate.

Pressure algometry tests the response of nociceptors in both deep and superficial tissues. Kosek et al., (1999) compared PPT before and after the application of a local anaesthetic cream and a control cream and reported that PPT were significantly lower when the control cream was applied. This demonstrated that cutaneous receptors contribute to the pain experienced during pressure algometry. However blunt pressure, as produced with a pressure algometer, is also thought to activate nociceptors in deep tissue (Treede et al., 2002). It has been suggested that in order to maximise the contribution from deep tissues, probe sizes of $1cm^2$ and above should be used as they deform both the epidermis and deeper tissue; rounded or padded tips minimize deformation of the epidermis and it is thought that this may result in preferential activation of nociceptors in deeper tissues (Treede et al., 2002). For the studies in this thesis a $1cm^2$ padded probe was used for all testing sites so both deep and superficial nociceptors are likely to have contributed to the discomfort experienced by participants.

3.4.2. Reliability of pressure pain threshold measurements

PPT can be measured at various locations. The choice of testing location may depend on the aims of testing. However readings taken at different sites cannot be compared due to large inter-site variations in PPT readings (Fischer, 1987). In contrast, testing the contralateral side on the same muscles has been shown to have excellent intra-subject reliability (Fischer, 1987). It can be seen in Table 3.4, that the reliability of repeated PPT measures has consistently been shown to be very good. It is important to note that there are often methodological explanations for the studies reporting lower ICC's for example the lower values (0.64-0.96) reported by Vanderween et al., (1996) can be explained as in this study testing sites were not marked, therefore in addition to the reliability of PPT measures, these figures are also a measure of the examiner's ability to return to the same testing point. All PPT sites used in the studies reported in this thesis were marked to allow accurate repositioning of the algometer.

Debate in the literature has focused on the optimum number of repetitions required to achieve the most reliable result. Some authors have advocated taking 3 measurements and discarding the first (Nussbaum and Downes, 1998). However careful inspection of their data does not support this conclusion; Nussbaum and Downes, (1998) examined which combination of 3 trials produced the most

reliable results. The first trial alone produced ICC's of 0.74-0.78, which were lower than those produced by the mean of 1 and 2, 1,2 and 3 *and* 2 and 3. All of these combinations produced ICC's of 0.8; an alternative conclusion from these figures could be that the use of the first trial alone produces less reliable results than any other combination of the 3 trials.

Research has suggested that the mean of 2 measurements may be sufficient to achieve good reliability. Ohrbach and Gale (1989) investigated the reliability of 5 measurements taken 4-5 minutes apart and found that more than 2 measurements was not justified. This is in agreement with Chesterton et al., (2003) who calculated the mean of 2 PPT measurements taken 10-15 seconds apart and a further 2 PPT taken every 10 minutes thereafter, resulting in 14 readings over 1 hour. There was no significant difference between repeated measures.

The instructions given to participants may be important in the reliability of PPT measurements. Most of the published work seems to have used the term 'pressure to pain' for example Fischer et al., (1987) and Chesterton et al., (2003) used the instruction 'say stop immediately when a discernible sensation of pain distinct from pressure or discomfort is felt'. However, other authors noted that participants found this point difficult to determine and altered the standard instructions for example Dhondt et al., (1999) used the phrase 'the moment the applied force becomes unpleasant', Buchanan and Midgley, (1987) described the sensation as 'barely perceptible pain' and Delaney and McKee, (1993) asked participants to say yes when they 'first felt discomfort'.

In summary the evidence suggests that reliability is improved when more than one PPT measure is taken. It appears that there is no justification in terms of enhanced reliability for using the mean of more than 2 measures. The literature review highlighted the importance of the number of repeated PPT measures and the testing instructions. These methodological factors were investigated during preliminary work for this thesis (section 4.4).

Reference	Participants	Testers	Algometer	Loading rate	Sites	Number of readings	Sessions	Reliability ICC
Antonaci et al (1998)	15 males, 6 females	2	1cm^2 tip. Plunger with force gauge. Pain threshold meter	2 kg/s	Deltoid Median finger 13 points head and neck	Mean of 3	3 (2-3 mins apart). Other examiner same day	Inter 0.75 Intra-examiner 0.84
Delaney and McKee 1993	25 males 25 females	2	Pressure threshold meter 1cm^2 tip	1kg/s	2 sites in trapezius	2 repetitions	5 mins apart	Inter-rater 0.82-0.92 Intra-rater 0.8-0.91
Jones et al. 2007	19 females	1	Somedic 2cm^2 head	Not stated	8 sites in upper limb and torso	3 trials, several mins between measures	On 4 consecutive days	Intra-day 0.92-0.98
Potter et al 2006	5 males 5 females	1	Pressure threshold meter 1cm^2 tip	1kg/s	4 muscles bilaterally Paraspinal, trapezius, glut max	2 (5 minutes apart)	3 different days	Intra-day 0.91 Inter-day 0.87 SEM (approx. 3kg/cm^2)
Persson et al 2004	24 females	2	Somedic 2cm^2 head	Not stated	14 points in trapezius and deltoid	4 measures at 10 minute intervals	Day 1,3,28,30	ICC 0.7 - 0.94
Ohrbach and Gale 1989	5 males 5 females	1	Force transducer 0.5cm^2 tip, amplified by polygraph driver	0.4kg/ cm^2	15 sites over temporalis and Masseter	5 trials At 4-5min intervals	At 2 sites Every week for 4 weeks and 8 weeks later	Reliability coefficients 0.83-0.91 for 5 trials
Vanderween et al 1996	15 males 15 females	1	Pressure threshold meter 1cm^2 tip	1Kg/s	28 sites (14 on each side)	2	2 reps at 5 min intervals	Intra-rater 0.64-0.96
Ylinen et al 2007	20 females	1	Force five Wagner. 1cm^2 tip	10N/s	5 places in neck muscles	2 measures 30 secs apart	Repeated 24hrs later	ICC 0.78-0.93
Nussbaum and Downes 1998	35	2	Fischer algometer 1cm^2 tip	5kg/cm^2	Biceps muscle belly	3 trials 10secs b/w trials 3 trials 20 mins later	3 days	1st trial ICC .74-0.73 Trial 1,2; 1,2,3 and 2+3 ICC all >0.8

Table 3.4. Reliability of Pressure pain threshold measurement (loading rate is expressed in kilograms per second (kg/s) or Newtons per second (5N/s). RA = Rheumatoid Arthritis.

3.4.3. Verbal Rating Scale (VRS) of pain measurements.

When assessing a patient in clinical practice and monitoring changes in patients' symptoms within- and between-treatment sessions physiotherapists use reassessment asterisks. These are clinical tests that reproduce the patient's symptoms. For example resting pain levels and reproduction of pain during active physiological movement may be used as reassessment asterisks. Patients may be asked to score their pain on a verbal rating scale (VRS). An 11-point verbal rating scale is often used, 0 being no pain and 10 being the most pain imaginable. VRS are often used to establish the effects of treatment, for example patients may be asked to rate their pain on movement before and immediately after a mobilisation treatment. This scale is often used by therapists in clinical practice and thus was utilised in the studies included in this thesis.

3.5. Questionnaires

The studies in this thesis (chapters 6 and 7) examined the analgesic effects of lumbar mobilisation treatment utilising a symptomatic population. Analgesia was measured using PPT and participants' VRS of pain. However, pain is a multidimensional experience and is based on factors such as physiology, personality, previous life experiences and family and cultural factors. In order to gain an understanding of their pain experience participants were asked to complete a number of questionnaires on their first attendance (see appendix 7 for full questionnaires).

To capture multiple aspects of participants' pain experience, questionnaires were used to measure participants' description of the pain, the disability resulting from the pain, the impact of the pain and their levels of anxiety/depression (as emotions have been shown to influence pain processing in the central nervous system (Atlas and Wager, 2012)). The questionnaires utilised in the studies in this thesis have been considered below. This includes details of their psychometric properties. For the purposes of the studies in this thesis only one measurement will be taken and thus validity of these questionnaires is of greatest importance.

3.5.1. Measures to describe pain

The McGill Pain Questionnaire (MPQ) is a tool for quantifying dimensions of pain and is able to discriminate between different pain problems (Melzack, 1983). It is sensitive in detecting differences between analgesic methods (Melzack, 1975) and has good test-rest reliability (Grafton et al., 2005). The questionnaire contains different categories which represent different dimensions of pain, these are sensory, effective and evaluative perceptions of a person's pain (Strong, 1999). Participants are required to choose words describing the pain experience, different words in each subclass represent the intensity of the pain (Melzack, 1983).

3.5.2. Measurement of the response to pain

The survey of pain attitudes (SOPA) had adequate construct and discriminant validity for patients with LBP (Strong et al., 1992). The SOPA is also reported to have good internal consistency and test-retest reliability (Jensen et al., 2000). It consists of subgroups of questions designed to measure the multidimensional nature of pain beliefs and has been shown to correlate well with the areas that they aim to measure (Tait and Chibnall, 1998). The SOPA assesses 7 different pain dimensions which allow patients to be grouped into categories representing differences in their pain attitudes and clinical status (Tait and Chibnall, 1998). These categories are:

Control	The extent to which patients believe they can control their pain.
Disability	The extent to which they are disabled by pain.
Exercise	Beliefs that they are damaging themselves through exercise and activity.
Emotion	The extent to which their emotions affect their pain.
Medication	Their beliefs that the use of medications is appropriate.
Solicitude	Their expectation that their family should help and take care of them more.
Medical cure	Expectations of a medical cure.

3.5.3. Measurement of the impact of the pain

The Oswestry disability questionnaire (ODQ) was designed to measure disability in patients with LBP, it assesses the person's functional status, their activity levels and how the pain is affecting their lifestyle by asking them about the amount to which pain affects their daily activities. It includes nine functional categories and a pain intensity scale. Each functional category consists of six statements that describe their difficulties in different functional activities. Fisher and Johnston, (1997) compared patients' responses to the ODQ to their performance on a number of functional tasks and concluded that there is some evidence of criterion related and factorial validity and good face validity. Vianin, (2008) reported good construct validity when compared to other measures of back pain disability. The ODQ has been shown to have reasonable internal consistency (Strong, 1994).

3.5.4. Measurement of depression / anxiety

The general health questionnaire (GHQ) is a tool for measuring minor psychopathology (Gibbons et al., 2004), it measures two elements of depression; the ability to continue functioning as normal and symptoms of emotional distress. It includes four subscales; somatic, emotional, social dysfunction and depression.

In a study validating the GHQ against an interview it was correlated with measures of anxiety and depression and demonstrated high sensitivity and specificity when compared to an interview (Gibbons et al., 2004).

3.5.5 Demographic questionnaire

A demographic questionnaire (Appendix 7) was utilised in order to gain information about factors which may influence prognosis of recovery from LBP. These included cultural and social factors, the type and effectiveness of any previous treatment participants had received, and the type and the amount exercise participants were engaged in on a regular basis.

3.5.6 Nicotine and alcohol dependency questionnaires

Nicotine and alcohol questionnaire were utilised as these substances may influence the analgesic mechanisms (Heatherton et al., 1991) through which mobilisation are mediated.

3.6. Summary of the literature review and overview of studies

In summary there is limited evidence demonstrating that longer duration of mobilisation treatment influences lumbar ROM (Powers et al., 2008; McCollam and Benson, 1993), and only one study (Lee et al., 2005b) demonstrating that mobilisation treatment results in a significant effect on lumbar stiffness.

There is evidence to suggest that mobilisations produce an analgesic effect (Sterling et al., 2010), however this has not been established in a population with low back pain. Furthermore, the optimum treatment dose has not been established, although some research in an asymptomatic population suggests that longer durations of mobilisation treatment may have a greater analgesic effect (Pentelka et al., 2012). Only the immediate effects of lumbar mobilisation have been investigated. This review identified the need to investigate the mid to long-term effects of mobilisations.

The relationship between experimental pain such as pressure pain thresholds (PPT) and patient reported measures such as verbal rating scales of pain or global perceived effect has not been established.

This literature review confirmed that electromagnetic tracking devices were highly reliable and suitable for use on large numbers of participants. Therefore an electromagnetic tracking system was employed in two of the studies in this thesis (chapter 5 and 6) in order to obtain both ROM and stiffness measurements. A lack of experimental comparison between the displacement and three-point bending methods of stiffness measurement was evident and thus the best method

for stiffness measurement was not identified. These two methods of stiffness measurement are compared in chapters 5 and 6.

PPT are used widely to measure pain and were applied in the studies in this thesis. In order to replicate pain measures taken in clinical practice and develop an understanding of participants' perception of changes in their symptoms, VRS of pain were also employed in these studies.

Review of the literature resulted in a number of research questions which underpin a series of studies outlined in the following section. The overall aim of the thesis was to establish whether longer durations of lumbar mobilisation treatment resulted in greater effects on ROM, stiffness and pain in participants with chronic non-specific LBP. Figure 3.2 provides an overview of the studies in this thesis.

3.7. The research questions addressed in the studies in this thesis

- What is the test-retest reliability and measurement error of ROM (using an electromagnetic tracking device), stiffness (using three-point bending and displacement methods) and PPT measurements?

- Which is the most valid and reliable method for measuring the effects of mobilisation on lumbar stiffness?

- What are the immediate effects of lumbar mobilisations on pain, stiffness and ROM in patients with chronic non-specific LBP?

- What are the short-term effects of lumbar mobilisations on pain, stiffness and ROM in patients with chronic non-specific LBP?

- What is the effect of a longer duration of mobilisation treatment on ROM, stiffness and pain in patients with chronic non-specific low back pain?

- What is the relationship between PPT and VRS of pain?

Chapter 4

Pilot work

Reliability and validity of fastrak measurements (page 47)

Validation of sychronisation of force and motion measurements (page 49)

Study to calibrate the algometer (page 50)

Study to assess the procedure and data analysis for ROM, stiffness and PPT measurements (page 50)

Development of a hand held indenter for displacement method of stiffness measurement (page 61)

↓

Chapter 5 (page 65)

The reliability of pressure pain thresholds, physiological range of movement, and stiffness measurements of the lumbar spine.

What is the reliability of ROM (using an electromagnetic tracking device), stiffness (using three-point bending and displacement methods) and PPT measurements?

↓

Chapter 6 (page 95)

A single arm trial investigating the immediate effects of 3 and 6 minutes of lumbar mobilisation treatment on physiological range of movement, stiffness and pain.

What are the immediate effects of lumbar mobilisations on pain, stifffness and ROM in patients with chronic non-specific LBP?

↓

Chapter 7 (page 127)

The effects of duration of lumbar mobilisations on pressure pain thresholds and patient reported pain measures. A placebo controlled trial

What are the immediate and short term analgesic effects of different durations of mobilisation treatment in patients with chronic non-specific low back pain?

Chapter 4.

Preliminary studies

This chapter outlines the preliminary work that informed the protocols used in the main studies of this thesis. The calibration procedures, reliability (which reflects the amount of measurement error) and validity (accuracy) testing of the equipment are detailed. The experimental procedures employed in later studies required synchronisation of two pieces of equipment; therefore this chapter also includes details of a pilot study that was conducted to establish the accuracy of this synchronisation. The development of a standardised protocol for ROM, stiffness and PPT testing is also detailed. The preliminary work was as follows:

4.1. Study to establish the validity and reliability of Fastrak

4.2. Study to establish the synchronisation of force and motion measurements

4.3. Study to calibrate the algometer

4.4. Study to assess the procedure and assessment of the quality of the data for range of movement (ROM), stiffness and pressure pain threshold (PPT) measurements.

4.5. Development of a hand held indenter for stiffness measurements.

4.1. Study to establish the validity and reliability of Fastrak

Studies in this thesis used the Fastrak electromagnetic tracking system to measure both ROM and stiffness. The manufacturers of the Fastrak (electromagnetic tracking) system (3SPACE Fastrak, Polhemus Inc. Colchester, VT, USA) claim that it has excellent accuracy (0.8mm for sensor position and 0.15 degrees for sensor orientation). However, the system used in the studies for this thesis had been in use in the University laboratory for a number of years and thus could have developed an error over time. This study was performed in order to establish the reliability and validity of the measurements recorded by this particular Fastrak system prior to the main studies in this thesis. This was intended to be a preliminary procedure as a more involved study establishing the reliability of Fastrak in measuring lumbar spine ROM was conducted and is reported on in chapter 5.

4.1.1. Pilot study aim

This study was designed to test the validity and test-retest reliability of Fastrak in the measurement of various goniometer angles.

4.1.2. Equipment

The 'Fastrak' electromagnetic tracking system (3SPACE Fastrak, Polhemus Inc. Colchester, VT, USA). This system uses a stationary source to generate an electromagnetic field. The position of the electromagnetic sensors (with dimensions 28.3mm by 22.9mm by 15.2mm) was tracked in three dimensions in relation to the source.

4.1.3. Methods

The Fastrak sensors were mounted on a goniometer using double-sided sticky tape. The Fastrak recording was initiated with the goniometer positioned at 0 degrees. After several seconds the goniometer was moved to a position of 20 degrees, after a further few seconds it was moved to a position of 40, then 60 then 80 degrees with a pause of several seconds between angles. This was repeated on 3 occasions at 5 minute intervals. The angles recorded by the Fastrak electromagnetic system were compared to the angles set on the goniometer.

4.1.4. Data analysis

Scatter graphs were used to determine the time at which each angle was maintained. The mean and standard deviation of 2 seconds of data was calculated for each angle.

4.1.5. Results

There were minor differences between the Fastrak and goniometer angles (Table 4.1). The range of differences between the angle recorded by the Fastrak and the position on the goniometer was 0 - 0.54 degrees.

	Fastrak angles with goniometer positioned at 20 / 40 / 60 and 80 degrees			
Occasion	**20° (mean)**	**40° (mean)**	**60° (mean)**	**80° (mean)**
1	19.56 (0.04)	39.65 (0.05)	59.60 (0.11)	79.77 (0.05)
2	20.00 (0.06)	40.18 (0.05)	60.02 (0.07)	79.95 (0.05)
3	19.81 (0.06)	39.82 (0.08)	59.87 (0.08)	79.84 (0.07)

Table 4.1. Comparison of Fastrak and goniometry measurements. The goniometer was positioned at 20 /40 /60 and 80 degrees. Data are mean and standard deviations (SD) of Fastrak angles over a 2 second period on 3 occasions.

4.1.6. Discussion

The small discrepancies between the goniometer and Fastrak angles were of expected magnitude and may have been due to errors in positioning the goniometer or inaccuracies in Fastrak measurements. The measurement error shown in this pilot study was considered to be small and unproblematic for the studies in this thesis. The validity of using this device to measure spinal ROM maybe different, due to errors from factors such as slippage of the sensors on the skin, skin movement and variability in participants' movement. The following chapter in this thesis (chapter 5) investigated the reliability of Fastrak in measuring lumbar ROM using skin-mounted sensors.

4.2. Study to establish the synchronisation of force and motion measurements

Two studies in this thesis (chapter 5 and 6) included measurement of lumbar spine stiffness. Stiffness measurements required calculations using simultaneously collected force and motion data. This required synchronisation of these measurements. Earlier work in the laboratory had indicated that there was a phase difference in the synchronised data collection (due to Fastrak losing time). It was important to investigate this phase difference to establish whether it would cause errors in the calculation of stiffness. A longer period of data collection would result in a greater phase difference; the maximum period of data collection proposed for future work was 1 minute.

4.2.1. Pilot study aim

The aim of this study was to establish the phase difference between data from the force plates and motion data from Fastrak over a 1-minute period.

4.2.2. Instrumentation and measurements

Motion was measured using Fastrak (section 4.1.2) electromagnetic tracking system. Force was measured using non-conductive ground reaction force plates (AMTI OR6-7 – Advanced Mechanical Technology Inc., Watertown, MA, USA). The force and motion data was synchronised using a TG200 function generator, (Thurlby Thandar Instruments Ltd., Cambridgeshire, England).

4.2.3. Method

The Fastrak sensors were attached to a modified plinth (mounted on the force plates) approximately 10cms apart using double-sided sticky tape. Data collection was started. After 1 minute of data collection (of force and motion data) the researcher depressed the padding on the plinth between the sensors in a cyclical manner.

4.2.4. Data analysis

The differences between the onset of change in force observed from the force plate data and onset of movement from the Fastrak data was calculated. This represented the phase difference after 1 minute of data collection.

4.2.5. Results and discussion

Over the 1 minute data collection period, there was a 0.1 second phase difference between the force plate and Fastrak measurements. This was considered to be insignificant as it was not of a magnitude that would affect the results.

4.3. Study to calibrate the algometer

PPT have been employed previously to investigate the effects of mobilisations (Pentelka et al., 2012; Sterling et al., 2010). The studies in this thesis used an electronic algometer (Tracker computerised algometry system, JTECH medical industries, Salt Lake City, Utah) to measure PPT. The algometer was zeroed as part of the start-up procedure in the software. If a zero value was not recorded further testing could not be conducted. In addition the manufacturers recommend re-calibration against known weights every 6 months. The algometer readings were checked against 0.5kg, 1kg, 2kg, 2.5kg and 5kg weights. This procedure was repeated on a six-monthly basis through the course of the studies for this thesis.

4.4. Study to assess the procedure and data analysis for ROM, stiffness and PPT measurements

Following the calibration of the equipment detailed in sections 4.1-4.3, the protocol for the main studies was evaluated and the data scrutinised. This involved measurements of PPT, lumbar ROM and stiffness.

The electromagnetic sensors were used for measurement of lumbar ROM and stiffness. For this reason the sensors would need to be placed to enable measurement of any movement in the entire lumbar region. This required identification of the first lumbar vertebra (L1) and the sacrum (the bottom of the lumbar region). The fixation method of these sensors was also evaluated. Standardised instructions for ROM measurements were also assessed for clarity.

The measurement of PPT was designed to determine the extent of the analgesic effect (local, systemic or segmental). In order to achieve this PPT testing sites needed to be identified local to the site of treatment, at a point in the upper quadrant, distant from the site of treatment and because later studies included in this thesis applied mobilisation treatment to participants' most symptomatic vertebral level, it was necessary to determine PPT testing sites in each of the lower limb dermatomes. The spinous process and paravertebral muscles and

deltoid muscle met the criteria for being local and distant from the site of treatment respectively, and have been sites used in previous research (Persson et al., 2004; Dhondt et al., 1999; Antonaci et al., 1998).

Identifying sites in each dermatome was more challenging as dermatome maps vary between texts. This originates from two early studies demarcating the dermatomes by Foerster (1933) and Haymaker and Woodhall (1953) the difference in these maps occurred due to differences in the authors' understanding of the embryology of dermatomes (Butler, 2000). Furthermore there is variation in dermatome positions between individuals and overlap of adjacent dermatomes within one individual (Butler, 2000). Nitta et al., (1993) determined distinctive or signature zones within each lower limb dermatome (areas of most overlap of sensory loss and least involvement when adjacent segments were blocked) by mapping the area of sensory impairment in patients receiving spinal nerve blocks at L4, L5 and S1 levels. Sites in these signature zones were used for testing in each lower limb dermatome.

Ensuring exact repositioning of the algometer tip and ensuring application at 90 degrees to the testing sites are two methodological factors important in maximising the reliability of measurements (Vanderween et al., 1996). Repositioning the algometer tip is easier within sessions as the sites can be marked. However, it creates a greater challenge when taking measurements on different occasions. For this study, once the optimum sites for testing were established, it was necessary to develop a protocol that enabled relocation of the same anatomical site on different sized individuals, whilst allowing the researcher to apply the force at 90 degrees to the point of application, and maintaining a comfortable position for participants.

4.4.1. Pilot study aim

The aim of this study was to develop the PPT, lumbar ROM and stiffness procedure for the main studies in this thesis.

4.4.2. Ethics approval

This pilot work was approved by the Faculty of Health and Social Science Research Ethics and Governance Committee (FREGC) (Appendix 2).

4.4.3. Participants

Two asymptomatic participants were recruited via word of mouth. Potential participants were sent a participant information sheet and list of inclusion and exclusion criteria and asked to contact the principal researcher again if they wished to take part, at which point an appointment was made for them to attend the human movement laboratory, Robert Dodd Annex, Eastbourne.

4.4.4. Inclusion and exclusion criteria

Potential participants were required to be between 18-70 years of age.

Potential participants for this study were excluded if they had a history of back pain as it may have affected the reliability of readings. To prevent potential soreness or damage to their spine participants with conditions that may have affected their spine and associated structures were excluded from the study. This resulted in the following exclusion criteria:

- Spinal congenital abnormality
- History of spinal fracture
- History of malignancy
- Bone disease (osteoporosis, osteomyelitis, tuberculosis, Paget's)
- Inflammatory arthritis (rheumatoid arthritis, ankylosing spondylitis, gout)
- Congenital generalised hypermobility (Ehlers-Danlos syndrome)
- Advanced degenerative changes

Participants with the following precautions to mobilisations were also excluded:

- History of steroid therapy
- Pregnancy
- Current anticoagulant medication

4.4.5. Confidentiality

All participant information was kept confidential and only made available to the study investigator and supervisors. Both participants were allocated with a code; to ensure anonymity and all data was stored under that code, the key to which was kept on a password protected computer. To fulfil the requirements of the Data Protection Act 1998 all personal data was destroyed at the end of the study. Anonymised data will be kept for 10 years following completion of the study.

4.4.6. Instrumentation and measurements

Range of Movement was measured using Fastrak (section 4.1.2, page 48).

Lumbar spinal stiffness was measured using three-point bending (force/angle) method. This required force and Fastrak motion sensor data measurements to be taken simultaneously during PA loading. Fastrak was used to measure the change in the curvature of the spine (angular rotation). For force measurements, a lightly padded wooden plinth was mounted on non-conductive ground reaction force plates (AMTI OR6-7 – Advanced Mechanical Technology Inc., Watertown, MA, USA). The force plates indirectly measured the force applied by the therapist

(Lee, 2005a). The researcher stood on a wooden platform with a lean bar (Figure 4.1) during the stiffness testing procedure to ensure that only the therapist's mobilising force was measured by the force plates. The force and motion data was synchronised using a TG200 function generator, (Thurlby Thandar Instruments Ltd., Cambridgeshire, England).

Figure 4.1. Plinth mounted on force plates and lean bar

Pain Pressure Thresholds were measured using an electronic pressure algometer (Tracker computerised algometry system, JTECH medical industries, Salt Lake City, Utah) fitted with a 1cm^2 tip. The algometer had two features designed to aid reliability. Firstly an on-screen dial to facilitate the researcher in standardising the rate of application at 1kg/cm^2/sec (see Figure 4.2); standardisation of the rate of application has been shown to vary results (List, 1991; Jensen et al., 1986). Secondly, a patient control switch, which enabled the participants to freeze the recording at the point 'that the sensation of pressure changes to pain'. The patient control switch prevented a time delay between the participant communicating the point of change and the researcher recording a measurement, PPT readings were automatically saved when the patient control switch was pressed.

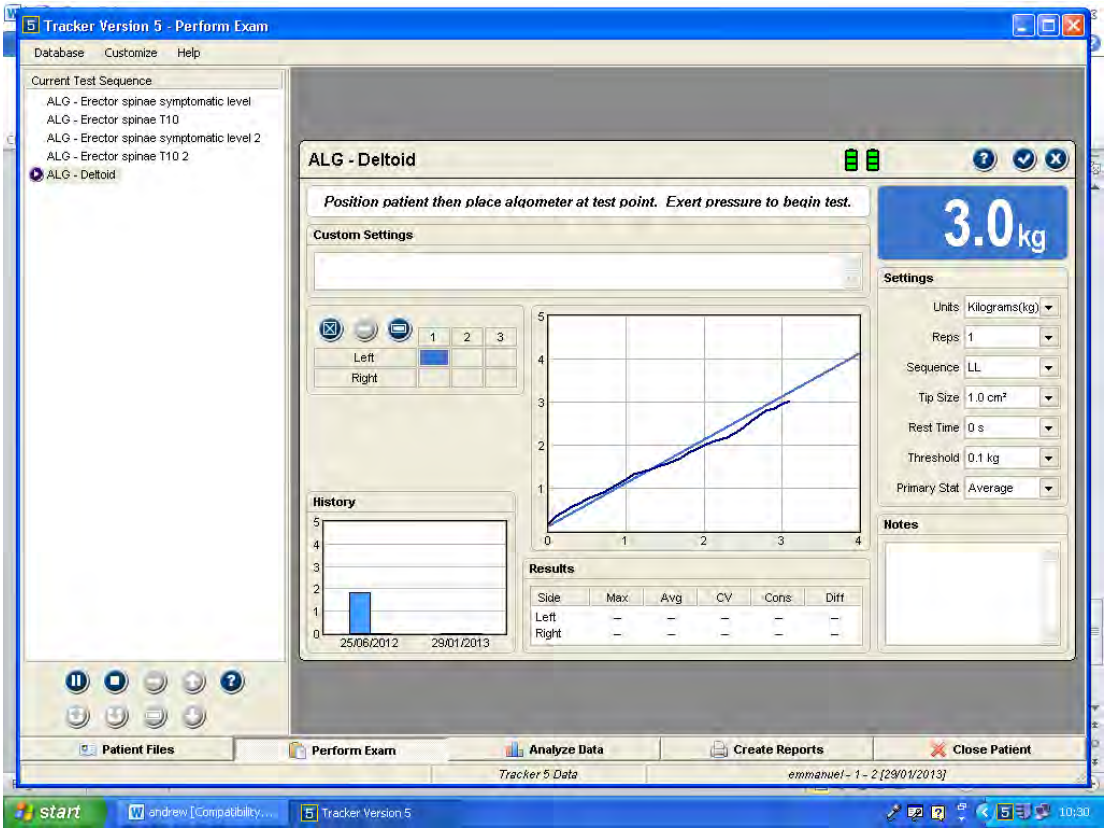


Figure 4.2. Algometer software with on screen scale to indicate rate of application.

4.4.7. Procedure

To allow measurement of lumbar range of movement and stiffness, the Fastrak sensors (section 4.1.2) were mounted on thin plastic plates (103 x 48 x 1mm) in a fixation method previous found to be reliable (Ha, 2010) and positioned on the sacrum and L1 spinous process (Figure 4.3) using the following procedure: The skin on the participants' back was cleaned using an alcohol wipe. The sacral base was located through palpation and marked with a temporary marker pen. From the sacral base, the researcher counted up the vertebra to L1, in order to count up to L1 the tip of L5 was palpated in the lumbosacral depression, the researcher then moved up one spinous process to L4. The L4 and L5 were cross-referenced by palpating the iliac crests. Oliver and Middleditch, (2004) found that in 60% of participants the iliac crests were level with the L4/5 interspace, but in 20% of individuals they were level with the vertebral body of L4 and in the remaining 20% they were level with the body of L5; because of this anatomical variation once the researcher had counted up from L4 to L1, L1 was cross-referenced by palpating the 12th rib and following the rib posteriorly to ascertain the T12 spinous process. The plastic plates were attached to the skin overlying the 1st lumbar vertebra and sacral base with double-sided tape. The bottom edge of the superior plastic plate was aligned with the spinous process of L1 and the top of the inferior plate was aligned with the base of the sacrum (Figure 4.3).

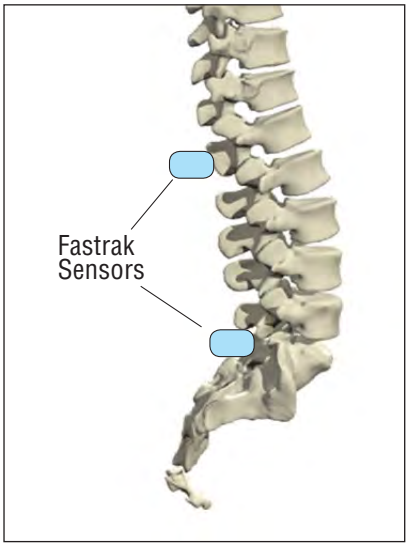


Figure 4.3 Fastrak sensor placement on base of sacrum and L1.

4.4.8. Range of movement measurements

Participants were asked to stand upright with their feet hip width apart whilst a neutral position of the electromagnetic sensors was set (this allowed the starting position of the sensors to be recorded). The following instructions were given for the movements indicated (also see Figures 4.4 and 4.5).

- Flexion: 'bend forwards, as far as possible, running your hands down the front of your thighs.'
- Extension: 'lean backwards as far as possible.'
- Lateral flexion: (indicating the participants left side) 'running your hand down the side of your leg bend as far sideways as possible.' ...'and to the other side.'
- Rotation: 'crossing your arms across your chest turn to your left as far as possible.' ...'and to the other side.'

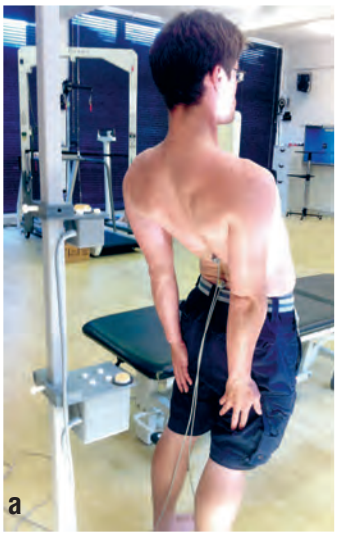


Figure 4.4. Lumbar extension (a) and flexion (b) range of movement.

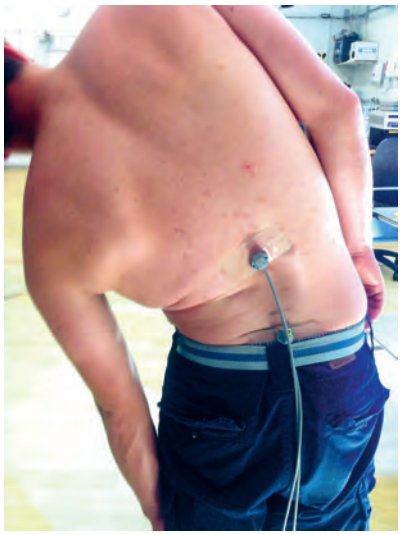


Figure 4.5. Lumbar lateral flexion range of movement.

4.4.9. Stiffness measurements

For the stiffness measurements, the participant was asked to take a deep breath in, breathe out and refrain from breathing in (Shirley et al., 1999) whilst 5 cycles of PA mobilisations were applied to L4 spinous process by the researcher using the indenter at a rate of 0.5Hz (equivalent to one PA cycle every 1.5 seconds) standardised by the use of a metronome.

4.4.10. Pressure pain threshold measurements

In order to test the sensitivity of points within each signature zone (identified by Nitta et al., 1993), PPT were tested at different locations within each zone. The algometer was applied to the skin and depressed at a rate of 1kg/cm^2/sec; participants were asked to depress the patient control switch 'at the point where the sensation of pressure turned to the sensation of pain', at which point the algometer was removed and a PPT reading was recorded. Participants were asked for feedback on the sensitivity of the area. A testing point was deemed to be suitable if it was not too sensitive (some sites were sore with the application of the algometer head, even before pressure has been applied), or too insensitive (some sites required a lot of pressure which was difficult for the operator to apply and may have caused bruising which would have affected the reliability of subsequent readings). The same procedure was followed for sites on and close to the spinous process of the vertebra and the deltoid muscle.

In order to identify the same site on different individuals and reliably return to the same site on one individual (when testing on different occasions), the relationship between anatomical landmarks and these sites was established.

It was important to standardise the algometer application at 90 degrees. In order to identify the best position for this to be achieved, the participants firstly lay prone, then supine, then side lying and finally in supported long sitting on a modified plinth whilst the researcher identified the optimum position to achieve a 90-degree angle at each PPT site. The plinth was a fixed height plinth (modified so that it could be mounted on the force plates); therefore in order to achieve the optimum testing position the researcher stood on different sized wooden blocks.

4.4.11. Results and discussion

Examination of range of movement data demonstrated clear traces for flexion, extension and lateral flexion demonstrating good face validity. Figure 4.6 depicts a graphical representation of the data for one participant for movement over time. The first movement performed was flexion, followed by extension (in red). Participants were then asked to move into left and right lateral flexion movements (demonstrated by changes in the green trace). The last movements that were

performed were left and right rotation (blue trace). As seen in Figure 4.6, left rotation (positive values) which preceded right rotation (negative values) was not clear and it was not possible to be certain when left rotation was starting or when it had reached maximum range. This cast doubt over the face validity of rotation movement measurements (that it appeared to measure what it is supposed to measure (Streiner and Norman, 2008)). Because range of rotation in the lumbar spine is small, amounting to approximately 5 degrees in total (Kapandji, 1974), and due to the difficulties in measurement, it was decided not to include measurements of rotation in the main procedure.

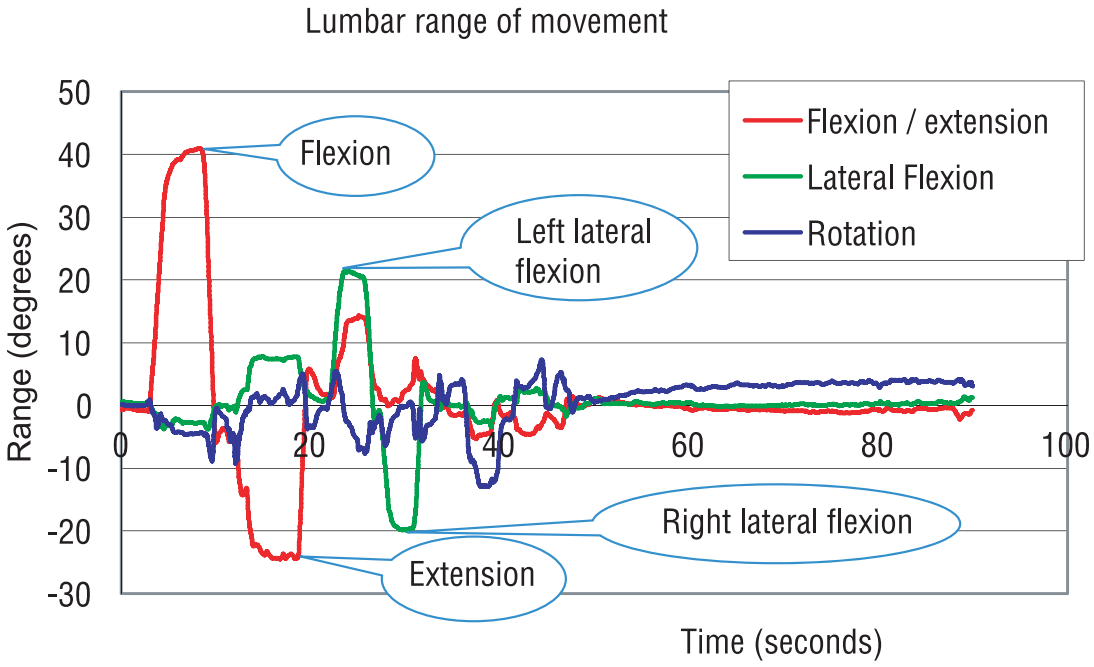


Figure 4.6. A plot of Fastrak data for range of movement. Discernable peaks for flexion and extension and lateral flexion are indicated. Left lateral flexion was followed by right lateral flexion (positive range figures). Peaks for left rotation are unclear.

On stiffness testing, visual inspection of sensor movement during the application of PA force to the spine suggested that skin movement as opposed to angular rotation dominated movement of the sensors. This suggested that movement did not follow the three-point bending theory of movement during PA loading and raised concerns over the choice of stiffness measurement methods. These observations caused the researcher to revisit the alternative, displacement method, of stiffness measurement. Most studies using the alternative force /displacement method of stiffness testing had employed a motor driven indenter (see section 3.2.1) which was not available. However other researchers had developed a hand held indenter and reported good reliability (Owens et al., 2007a,b). Because this pilot work raised concerns regarding the validity of three-point bending measurements and a lack of comparison between the methods was evident in the literature, a hand held indenter (similar to that developed by Owens et al (2007a,b)) was developed to enable measurements of the displacement method of stiffness measurement to be obtained, alongside the three-point bending measurements. The reliability study and single-arm trial (chapters 5 and 6), compared stiffness measures simultaneously collected using both displacement and three-point bending methods.

It was immediately apparent that some potential PPT sites were very sore, causing the participants to indicate that the pain threshold had been reached with little more than the weight of the algometer itself. Small differences in positioning of the algometer tip appeared to make large differences to the PPT.

The following points are of particular note:

- The insertion area of deltoid was very sensitive compared to the middle of the muscle.

- The area immediately over the spinous processes was found to be particularly sensitive; moving 2 fingers breadth laterally, over the paravertebral muscles resulted in less immediate soreness. Possible S1 sites on the little toe sites were sensitive with minimal pressure (often less than 1kg) and thus a site on the lateral heel was used for the S1 signature zone.

- L1 signature zone (below the anterior superior iliac spine in the groin area) proved to be very sensitive. It was also difficult to preserve participants' modesty whilst testing this area which created an ethical dilemma. It was decided that it was not possible to find an L1 site that was within a signature zone and appropriate for testing.

Finding the same anatomical location on two, different sized participants proved difficult; for example when trying to reproduce a position in the mid-thigh, measuring 15 cm above the patella produced a reproducible point on a single individual but located a different anatomical location on the leg in the two different sized participants included in this study. Therefore when measuring PPT in the mid-thigh (for the L2 dermatome), the length of the participant's leg was measured from the participants' anterior superior iliac spine to the base of the patella. This measurement was halved to identify the PPT testing site. The same issue arose with the L3 measurements; a site a set distance above the patella produced a different location in the different individuals (in one it was at a point in the quadriceps muscle belly whilst on the other it was at a point where the muscle was becoming tendinous). This study found that using three of the participant's finger widths to measure above the patella produced a similar anatomical position in different sized participants. Identifying a site three of the participant's fingers breadth below the tip of the acromion was also found to locate a consistent site in the deltoid muscle. The locations for all algometry testing sites determined by this study were used in the main studies included in this thesis.

Repeated testing of PPT was problematic due to increasing sensitisation of the area. This was particularly evident where one test was completed soon after the previous test at that site. Participants commented on the 'memory' of the previous test inhibiting their concentration on the subsequent test. Sensitivity resulting from repeated testing has been acknowledged by other authors (Pentelka et al., 2012; Ohrbach et al., 1998). Indeed, the number of repeated measures needed to ensure reliable PPT measurements has been a matter for debate (see section 3.4.2, page 38). Ohrbach and Gale (1989) found that the mean of the first two measurements was better than the first or second measurement on their own, but more than 2 measurements was not justified. The studies in chapters 5 and 6 of this thesis included 3 sets of measurements within a 1-hour period; if the mean of three measurements was taken this would result in 9 pressures at each site. Considering the evidence from studies examining the reliability of combined data from different trials and the problems with sensitisation at the testing sites it was decided that future studies would use the mean of 2 PPT measurements, reducing the amount of repeated tests to 6.

Participants commented on the difficulty in assessing the exact point of pain onset, sometimes participants commented that there was lingering soreness after testing and it appeared to the researcher that they had depressed the switch later than the first onset of pain. Additionally, one of the two participants seemed very stoic and appeared to try and tolerate pain, this participant had initial high PPT followed by a much lower second set of readings, possibly caused by peripheral sensitisation.

Most of the published work seems to use the term ‘pressure to pain’. However other work has noted that participants found this point difficult to determine and have altered the standard instructions for example to ‘the moment the applied force becomes unpleasant’ (Dhondt et al., 1999) and ‘barely perceptible pain’ (Buchanan and Midgley, 1987). For this reason it was decided to emphasise to participants that the desired measure was not how much pain they can tolerate, but ‘the point at which the sensation changes from one of just pressure, to either discomfort or pain’. Indeed a recent unpublished study (McCardle, 2013), found that the instructions given to participants influenced the measurement error. Instruction of ‘pressure to pain’ had greater measurement error than ‘pressure to discomfort’.

Another issue that arose during this pilot study was the importance of the participant’s full engagement in the testing procedure. It was important that participants concentrated on the exact point of change. On some occasions this didn’t occur due to distractions, e.g. where the participant lost attention, and the sensation sometimes became painful. For this reason the following was added to future instructions ’it is important that you attend to the point of change from just pressure to something else; you might call it ‘discomfort’ or ‘pain’.

Rotating through the measurements in each position resulted in a longer time interval between repeated measures. So whilst participants were lying prone, 1 measurement was performed at the symptomatic spinal level, paravertebral muscle site, followed by 1 measurement at the T10 paravertebral muscle site followed by a 2nd measure at the symptomatic level paravertebral muscle site and a 2nd measure at T10 paravertebral muscle site. This was thought to be beneficial, as participants had concentrated on at least one different reading before they returned to the same site; it also allowed a ‘recovery period’ from the previous reading.

This pilot study resulted in the protocol detailed in Table 4.2. This was determined to be the optimum protocol in terms of participant and researcher positions and identification of PPT sites. In each position participants were required to lie on the edge of the plinth closest to the researcher. The PPT instructions provided to participants were standardised and carefully worded to try and maximise participant concentration and avoid participants tolerating any pain.

Table 4.2. Algometry testing procedure established from pilot work.
The researcher stood on a block to perform testing.

Site Number	PPT site	Participant position	Landmark	Blocks
1	Paravertebral muscles at L4 level (chapter 5) or at symptomatic level (chapter 6 and 7)	Prone	Paravertebral muscles two fingers breadth from spinous process.	20cm high block
2	Paravertebral muscles at T10 level	Prone	Paravertebral muscles two fingers breadth from spinous process.	20cm high block
3	Deltoid	Side lying. Participant with elbow positioned in waist	Two participant fingers breadth below the middle of the acromion.	20cm high block
4	S1 dermatome	Side lying Bottom leg bent forward to allow testing leg to lie flat against plinth	Posterolateral heel. Two fingers breadth below and one fingers breadth posterior to the tip of the lateral malleolus.	10cm high block
5	L2 dermatome	Supine	Mid-thigh. Mid way between the anterior superior iliac spine and the base of the patella (measured using a tape measure).	20cm high block
6	L3 dermatome	Supine	Two participant fingers breadth above base of patella	20cm high block
7	L4 dermatome	Supine Leg turned out (hip in flexion lateral rotation)	Two fingers above medial malleolus.	10cm high block
8	L5 dermatome	Supine Knee flexed so sole of foot flat on plinth.	Proximal to head of metatarsal.	10cm high block

4.5. Development of a hand held indenter for the displacement method of spinal stiffness measurement

The researcher manufactured a 15cm long cylindrical indenter (see Figure 4.7). It consisted of a 3.2cm diameter dowel (to avoid electromagnetic interference it was made from wood) with 0.5cm of thick, firm foam padding. A Fastrak electromagnetic sensor was mounted on the top of the indenter to measure vertical displacement and measurements of this system were validated against a ruler. This was similar to the hand held indenter used by Owens et al., (2007a,b). It is recognised that the compression of the foam padding will have contributed towards the measured displacement; however this will have produced a small and systematic error. This is not considered to be a serious limitation as the intention was to use the indenter to compare serial measurement.

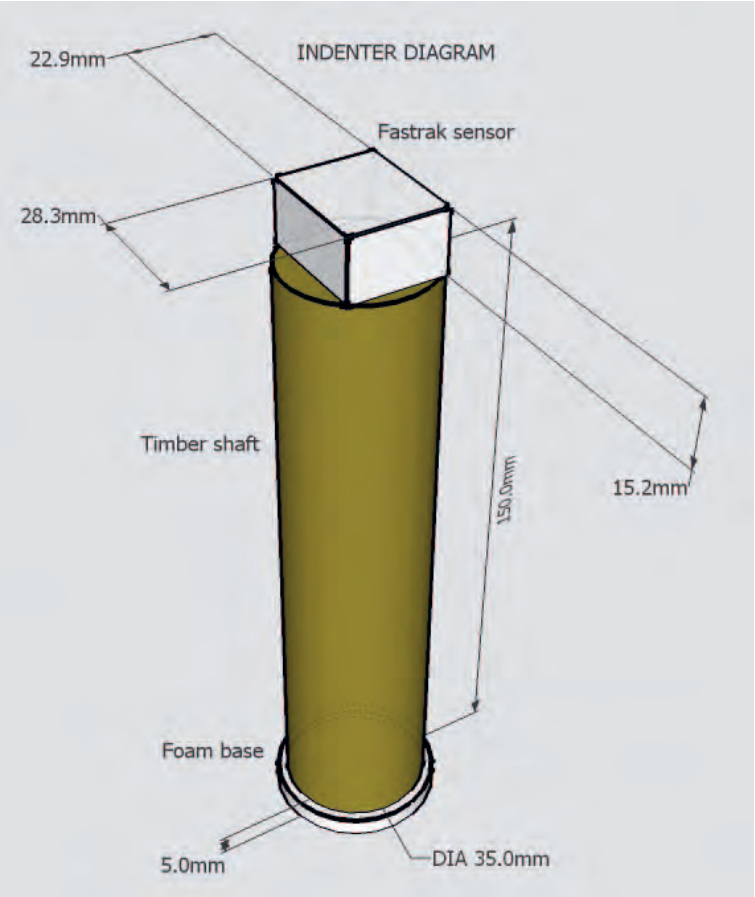


Table 4.7. Handheld indenter

4.6. Key learning points from the preliminary studies.

The preliminary work in this thesis identified a number of key learning points which were carried forward to the main studies. These were as follows:

- Measurement of rotation range of movement was not easily distinguishable on the movement graphs and thus the face validity of rotation movements was questioned. Therefore rotation range of movement measurements was not included in the main studies.
- During PPT measurements the positioning of the participant and researcher was important during PPT measurements in order to ensure consistent application of pressure.
- The instruction given during PPT measurements appeared to be important in reducing soreness resulting from repeated testing.
- Observation of three-point bending data cast doubt over the validity of these measurements.

4.7. Pilot work conclusion

Examination of ROM data highlighted the difficulties in measuring rotation. Therefore range of rotation was not measured in the later studies. Examination of three-point bending data raised concerns about the validity of measurements. This resulted in a hand held indenter being developed in order to enable synchronised measurement of stiffness using both methods evident in the literature (three-point bending and displacement). A standardised protocol for identification of PPT sites and positioning for algometry testing was established. During the course of this study it became apparent that instructions given during testing might influence sensitisation of the testing site. Modification of the instruction appeared to reduce sensitisation and discourage the participants from tolerating pain. These instructions were used in the later studies in this thesis.

The following chapter reports on a study which assesses the reliability of the stiffness, pain and ROM measurements used in later studies in this thesis.

Chapter 5.

The within- and between-day test-retest reliability of pressure pain thresholds, range of movement and stiffness measurements of the lumbar spine.

5.1. Introduction

This study was conducted to establish the within- and between-day reliability of pain, ROM and stiffness measures in order to underpin later studies in this thesis (chapter 6 and 7), when the effects of a mobilisation treatment dose on these variables were investigated.

Reliability is a measure of the amount of error in a measurement (Streiner and Norman, 2008). Good test-retest reliability of lumbar ROM measurements using electromagnetic tracking devices has been reported (see section 3.1.1, page 25); as have stiffness measurements using both deformation (see section 3.2.1, page 28) and three-point bending methods (see section 3.2.2, page 32). However reliability can vary according to the instruments used and methodological differences such as sensor fixation and thus it was deemed necessary to investigate reliability of ROM and stiffness measurements using the protocols that would be employed in the later studies in this thesis.

Excellent PPT test-retest reliability has also been reported (see section 3.4.2, page 38) but it varies according to the PPT site tested. Later studies in this thesis (chapter 6 and 7) investigated the extent of the hypoalgesic effect of mobilisations applied to the symptomatic vertebral level and thus measured PPT in 8 different locations, not all of these locations have been previously tested for reliability. Thus an investigation of the reliability of measurements at all 8 PPT sites was necessary prior to the later studies in this thesis.

In a later study (chapter 7) the immediate and short-term effects of a mobilisation treatment were investigated. For this reason the current study was designed to establish both within- and between-day reliability of ROM, stiffness and PPT measurements. Pilot work (section 4.4) highlighted potential problems with the validity of three point bending stiffness measurements. For this reason an indenter was developed to enable comparison of three-point bending and displacement methods of stiffness measurement.

5.1.1. Research questions

What is the within- and between-day reliability and measurement error of the following measurements: ROM measures using an electromagnetic tracking device, stiffness (using three-point bending and displacement methods) and pressure pain thresholds (at each of 8 sites)?

5.1.2. Study aims

1. To determine the within- and between-day reliability of measurements of ROM, stiffness and pressure pain thresholds.
2. To explore the validity of stiffness measurements

5.2. Method

5.2.1. Study design

This was a within- and between-day reliability study

5.2.2. Ethics approval

This study was approved by the Faculty of Health and Social Science Research Ethics and Governance Committee (FREGC) (Appendix 2).

5.2.3. Participants

Twenty asymptomatic participants were recruited via posters placed on the university email. Potential participants were sent a participant information sheet and list of inclusion and exclusion criteria and asked to contact the principal researcher again if they wished to take part, at which point an appointment was made for them to attend the human movement laboratory, Robert Dodd Annex, Eastbourne.

5.2.4. Inclusion criteria and exclusion criteria

Potential participants were required to be between 18-70 years of age.

Potential participants for this study were excluded if they had a history of back pain as it may have affected the reliability of readings. To prevent potential soreness or damage to their spine participants with conditions that may have affected their spine and associated structures were excluded from the study. This resulted in the following exclusion criteria:

- Spinal congenital abnormality
- History of spinal fracture
- History of malignancy
- Bone disease (osteoporosis, osteomyelitis, tuberculosis, Paget's)

- Inflammatory arthritis (rheumatoid arthritis, ankylosing spondylitis, gout)
- Congenital generalised hypermobility (Ehlers-Danlos syndrome)
- Advanced degenerative changes

Participants with the following precautions to mobilisations were also excluded:

- History of steroid therapy
- Pregnancy
- Current anticoagulant medication

5.2.5. Confidentiality

All participant information was kept confidential and only made available to the study investigator and supervisors. All participants were allocated with a code; to ensure anonymity and all data was stored under that code, the key to which was kept on a password protected computer. To fulfil the requirements of the Data Protection Act 1998 all personal data was destroyed at the end of the study. Anonymised data will be kept for 10 years following completion of the study.

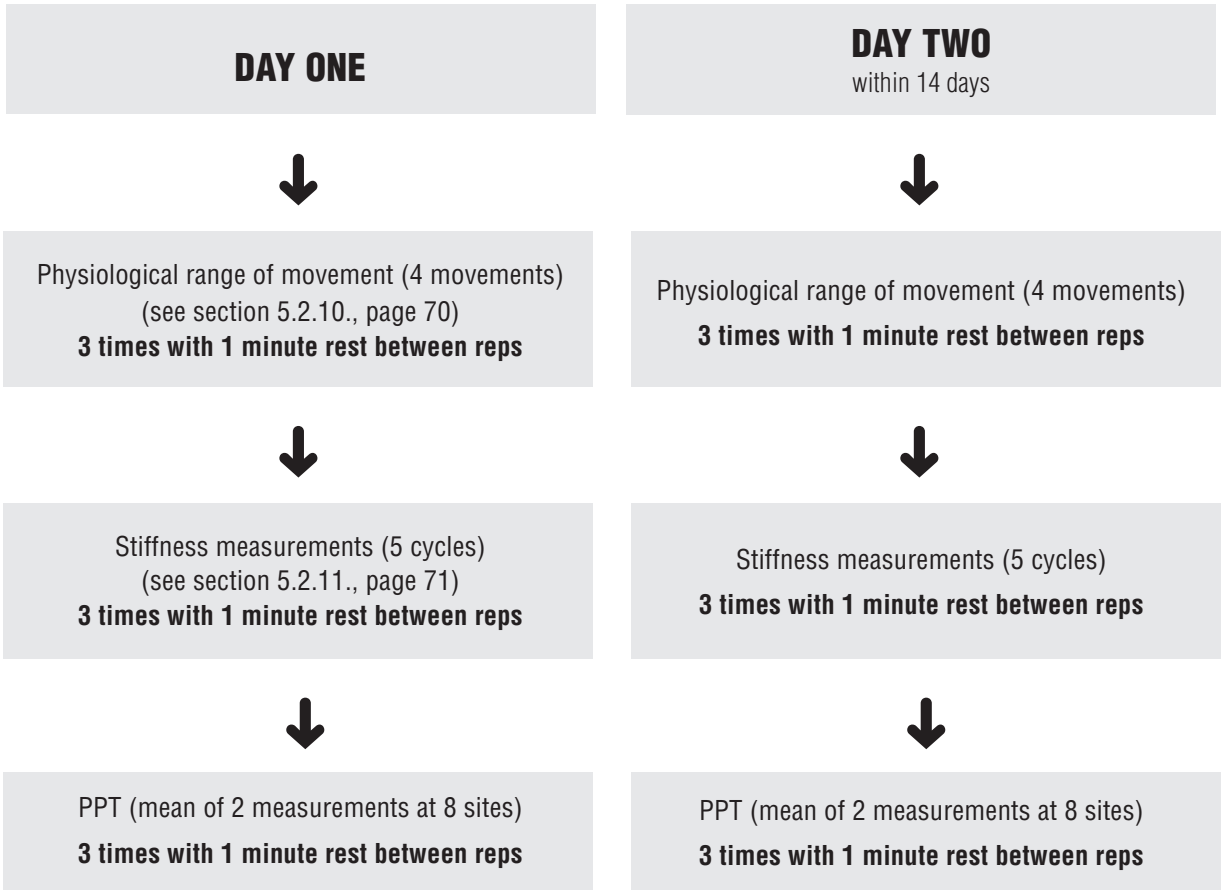


Figure 5.1. Flowchart depicting the reliability study procedure.

5.2.6. Research approach and methods

This study was a same subject repeated measures design. Measurements were taken 3 times on participants' first visit to establish within-day (intra-day) reliability. Three measurements were also taken on a second visit to enable calculation of between-day (inter-day) reliability. See Figure 5.1 for participants' journey through the study.

5.2.7. Instrumentation and measurements

ROM was measured using Fastrak electromagnetic tracking system (3SPACE Fastrak, Polemus Inc. Colchester, VT, USA). Lumbar stiffness was measured simultaneously using three-point bending (force/angle) and displacement (force/displacement) methods. This required force and Fastrak motion sensor data measurements to be taken simultaneously during the application of PA force. Motion was measured using Fastrak and force was measured using non-conductive ground reaction force plates (AMTI OR6-7 – Advanced Mechanical Technology Inc., Watertown, MA, USA). The force and motion data was synchronised using a TG200 function generator, (Thurlby Thandar Instruments Ltd., Cambridgeshire, England). For three-point bending measurement two electromagnetic sensors measured the change in the curvature of the spine (angular rotation) and to measure displacement measurements, the electromagnetic sensor mounted on the indenter (as described in section 4.5, page 61) measured vertical displacement.

The force plates indirectly measured the force applied by the therapist (Lee, 2005a). The researcher stood on a wooden platform with a lean bar (see Figure 4.1, page 53) during the stiffness testing procedure to ensure that only the therapist's mobilising force was measured by the force plates. The force and motion data was synchronised using a TG200 function generator, (Thurlby Thandar Instruments Ltd., Cambridgeshire, England).

PPT were measured using an electronic pressure algometer (Tracker computerised algometry system, JTECH medical industries, Salt Lake City, Utah) fitted with a $1cm^2$ tip. The algometer had two features designed to aid reliability. Firstly an on-screen dial to facilitate the researcher in standardising the rate of application at $1kg/cm^2$/sec (see Figure 4.2, page 54); standardisation of the rate of application has been shown to vary results (List, 1991; Jensen et al., 1986). Secondly, a patient control switch, which enabled the participants to freeze the recording at the point 'that the sensation of pressure changes to pain or discomfort'. The patient control switch prevented a time delay between the participant communicating the point of change and the researcher recording a measurement. PPT readings were automatically saved when the patient control switch was pressed.

5.2.8. Procedure

Participants attended the human movement laboratory at the University of Brighton on two days. On each day the principal researcher greeted them and led them to a screened area. On the first day participants received a verbal explanation of the study and were asked to sign a consent form. The time period between days was not standardised but was kept to a maximum of 14 days. ROM, stiffness and PPT measurements were taken 3 times on each day as depicted in Figure 5.1.
This study was designed to underpin later studies in this thesis which investigated the effects of a lumbar mobilisation treatment applied to the most symptomatic vertebral level. Because participants in this study were asymptomatic the L4 vertebral level was chosen to represent the 'symptomatic level'. The L4 spinous process was located through palpation of bony landmarks (see following section) and marked with a pen, as were the points for PPT testing. The sites for PPT testing (Figure 5.3, page 72) were located using the landmarks detailed in Table 4.2 (page 61). The algometer tip was placed on the skin and drawn around, to allow for accurate repositioning with repeated testing.

5.2.9. Fastrak sensor placement

To allow measurement of lumbar range of movement the Fastrak sensors were mounted on thin plastic plates (103 x 48 x 1mm) in a fixation method previous found to be reliable (Ha, 2010), and positioned on the sacrum and L1 spinous process using the following procedure: The skin on the participants back was cleaned using an alcohol wipe. The plastic plates were attached to the skin overlying the 1st lumbar vertebra and sacral base with double-sided tape (see section 4.4.7, page 54 for details on palpation of these anatomical landmarks). The bottom edge of the superior plastic plate was aligned with the spinous process of L1 and the top of the inferior plate was aligned with the base of the sacrum (Figure 5.2).

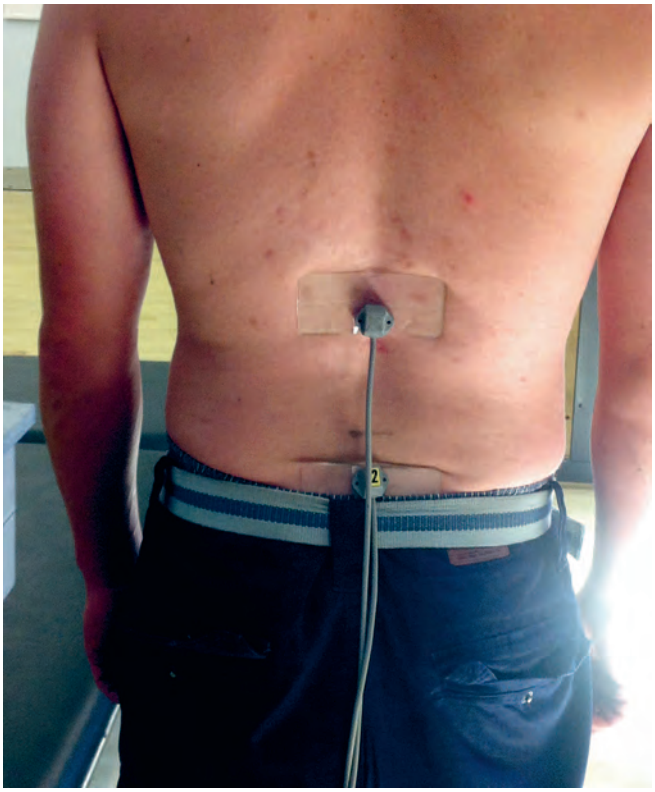


Figure 5.2 Fastrak sensor placement on base of sacrum and L1.

5.2.10. Range of movement measurements

On both days, prior to taking ROM readings, participants were asked to bend as far as possible; forwards, backwards and to each side from a standing position. This was repeated 3 times. This enabled the fixing of the sensors to be checked and served to precondition the spine. Participants were then asked to stand upright with their feet hip width apart whilst a neutral position of the electromagnetic sensors was set (this allowed the starting position of the sensors to be recorded). The following instructions were given for the movements indicated.

- Flexion: 'bend forwards, as far as possible, running your hands down the front of your thighs.'
- Extension: 'lean backwards as far as possible.'
- Lateral flexion: (indicating the participants left side) 'running your hand down the side of your leg bend as far sideways as possible.' ...'and to the other side.'

(Figures 4.4 and 4.5, page 55).

The first cycle of movements was followed by a one minute rest period where participants were allowed to move around on the spot; a further two repetitions of ROM measurements with an intervening one minute rest period followed. This resulted in 3 ROM measurements on the 1st Day. This procedure was repeated on a 2nd day which occurred at least 24 hours (maximum 14 days) later.

In this study the reliability of measurements of single movements were explored (as opposed to taking the mean of 3 (Petty, 1995) or mean of 6 (Stamos-Paspastamos et al., 2011). This was to reflect clinical practice, where physiotherapists perform a treatment and in order to assess the effectiveness of this treatment, immediately reassess the effect the treatment has had on physical tests such as ROM. Most of the previous studies investigating the effects of mobilisation on ROM have also used 1 repetition (Powers et al., 2008; Chiradenjnant et al., 2002 and 2003; Goodsell et al., 2000) (Table 2.2, page 10).

5.2.11. Measurement of stiffness

Lumbar spinal stiffness (with the force applied at L4) was measured simultaneously using three-point bending (force/angle) and displacement (force/displacement) methods. For three-point bending measurement two electromagnetic sensors (positioned as detailed in section 5.2.9 and Figure 5.2) were used to measure the change in the curvature of the spine (angular rotation) and to measure displacement, the electromagnetic sensor mounted on the indenter (section 4.5, page 61) measured vertical displacement.

Prior to stiffness measurement, 30 seconds of grade IV+ (small amplitude in the last third of resistance) PA mobilisations were applied to the L4 spinous process to precondition the spine (Lee and Evans, 1994). The indenter was positioned over the L4 spinous process and to allow accurate repositioning, drawn around with a temporary marker pen.

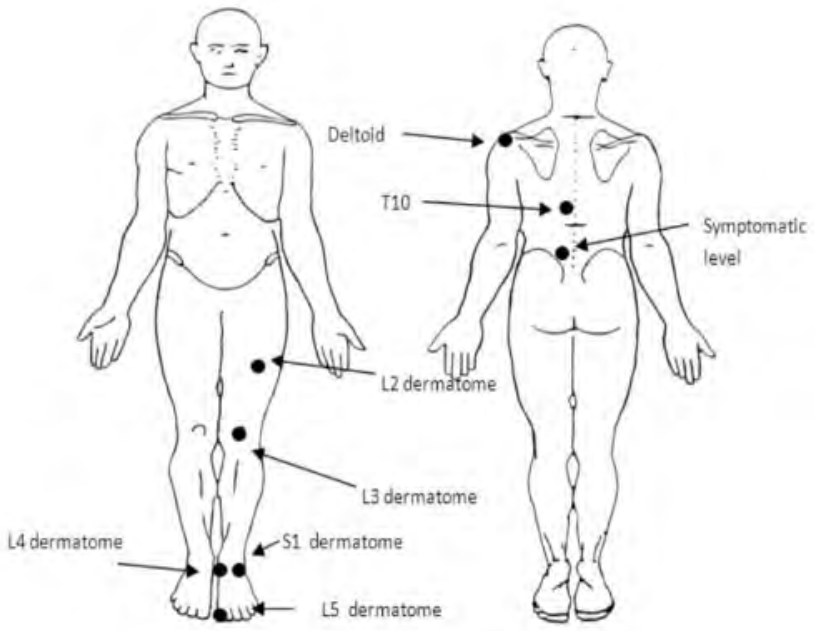
For the stiffness measurements, the participant was asked to take a deep breath in, breathe out and refrain from breathing in (Shirley et al., 1999) whilst 5 cycles of PA mobilisations were applied to L4 spinous process by the researcher using the indenter at a rate of 0.5Hz (equivalent to one PA cycle every 1.5 seconds), standardised by the use of a metronome.

5.2.12. Procedure and order of PPT testing.

At the start of PPT testing, a familiarisation PPT was carried out on the dorsal aspect of the hand at the web-space between the thumb and index finger (enabling participant's to experience PPT at one site, prior to measurements being recorded).

The algometer was applied perpendicular to the marked area of skin at all testing sites. It was explained to participants that the desired measurement point was when the sensation exceeded that of just pressure. Participants were asked to press the button 'as soon as' the sensation changed from just pressure to something else — 'you might call it discomfort or pain'. Once participants depressed the button the pressure was removed and the PPT data was saved.

The order of testing was designed to allow sufficient rest between repetitions with the least changes in participant's position. All tests (see Table 4.1, page 48 and Figure 5.3) were completed sequentially in one position before changing the participant's position. Therefore 2 repetitions were completed at each site tested in prone (sites 1,2,1,2,) before moving into side lying and performing the testing sequentially in this position (sites 3,4,3,4). Participants were then asked to turn supine where the remaining sites were tested sequentially (sites 5,6,7,8,5,6,7,8). This procedure was carried out twice more to gain repeated measurements for the overall testing procedure. The testing positions for T10, deltoid, L3 and S1 can be seen in Figure 5.4 – 5.7. The same procedure was carried out on a second day to enable calculation of between-day reliability.



PPT sites

Paravertebral Muscles

1. **Symptomatic level**	1.5cm left of symptomatic spinous process
2. **T10**	1.5cm left of T10 spinous process
3. **Deltoid**	3 fingers breadth from acromion
4. **S1 Dermatome**	Lateral heel, 2 fingers posteroinferior to malleolus
5. **L2 Dermatome**	Measured mid-thigh
6. **L3 Dermatome**	3 fingers above patella
7. **L4 Dermatome**	1 finger below medial malleolus
8. **L5 Dermatome**	Great toe, proximal to metatarsal head

Figure 5.3. PPT testing sites.

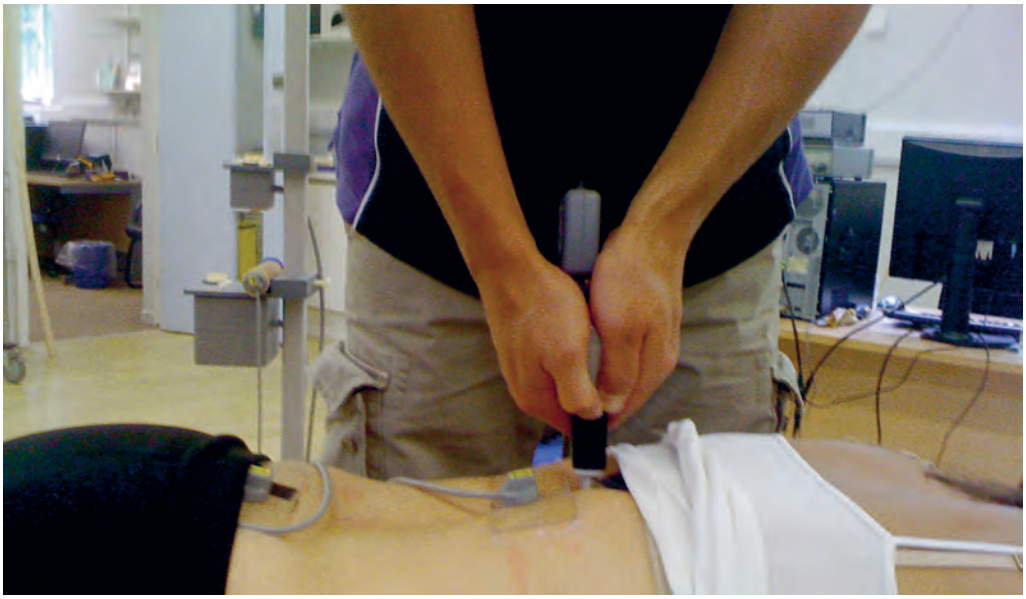


Figure 5.4. PPT testing at T10 paravertebral muscles.

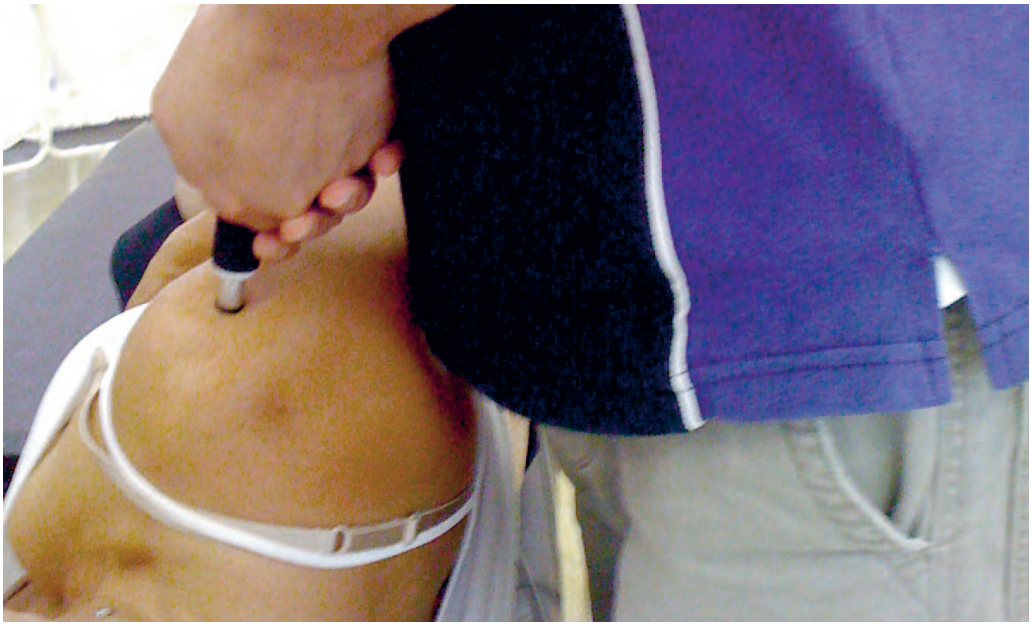


Figure 5.5. PPT testing at the Deltoid site

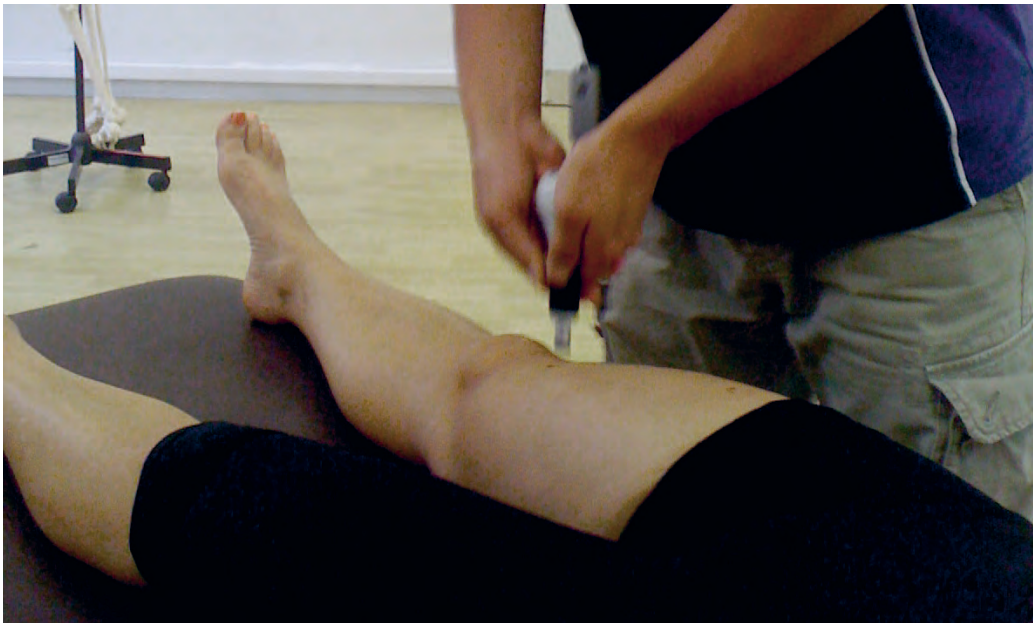


Figure 5.6. PPT testing at L3 dermatome site.

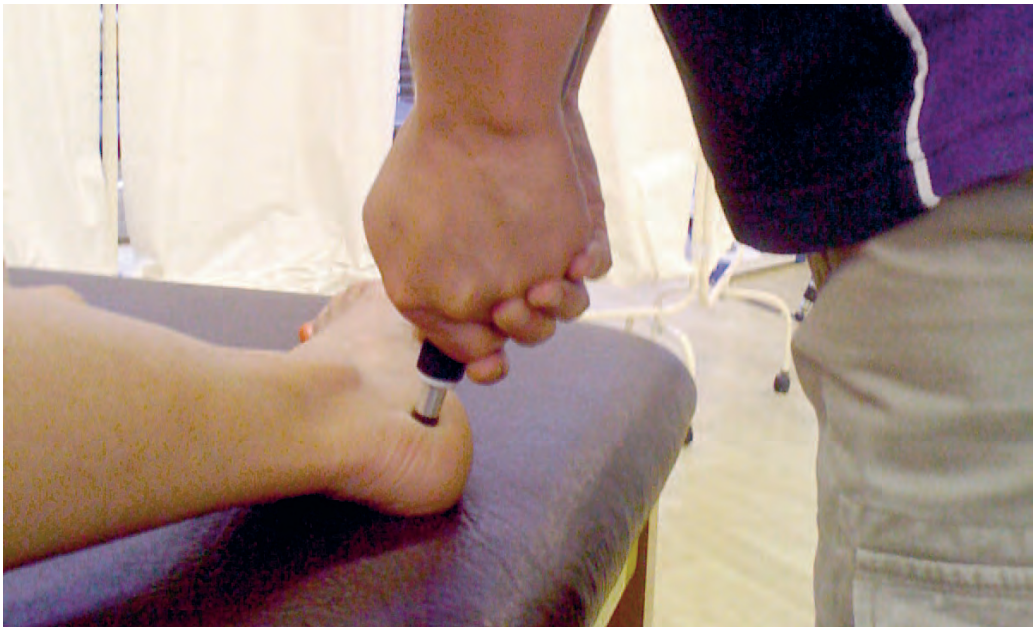


Figure 5.7. PPT testing at S1 site.

5.3. Data analysis

5.3.1. Analysis of range of movement data (ROM).

The raw data for ROM was processed using a macro written in Visual BASIC for Applications (Microsoft Inc., Redmond, Washington) in Microsoft Office Excel 2007 (Version 12.0, Microsoft UK, Reading, England) see Appendix 3. The processed data was checked for errors by hand. Descriptive statistics were performed on all data using Statistical Package for the Social Sciences (PASW version 18.0 for Windows). For ROM the maximum values of each movement, (flexion, extension, left lateral flexion and right lateral flexion) was used for further analysis. Due to large amounts of skin movement during ROM testing, slippage of the electromagnetic sensors can occur. Therefore data that greatly exceeded the ranges reported in previous literature utilising electromagnetic tracking systems was removed (see Table 3.1, page 27). The maximum ranges beyond which data sets were removed were as follows:

- Flexion 100 degrees
- Extension 70 degrees
- Lateral flexion 80 degrees

5.3.2. Analysis of stiffness data

The raw data for ROM and stiffness was processed using a macro written in Visual BASIC for Applications (Microsoft Inc., Redmond, Washington) in Microsoft Office Excel 2007 (Version 12.0, Microsoft UK, Reading, England). The processed data was checked for errors by hand. The macro calculated the stiffness coefficient using force/angle (three-point bending) and force/vertical displacement (displacement) data by linear regression of the loading phase between 30-100N on the force-displacement curve (see Appendix 3). For stiffness the mean of cycles 2-5 was calculated and used in further analysis (cycle one was discarded due to transient behaviour on start-up). Descriptive statistics were performed on all data using Statistical Package for the Social Sciences (PASW version 18.0 for Windows).

5.3.3. Analysis of pressure pain threshold data

For PPT the mean of the two measurements at each site was used for further analysis. Descriptive statistics were performed on all data using Statistical Package for the Social Sciences (PASW version 18.0 for Windows).

5.3.4. Normality testing of data

Processed data was analysed for normality in Statistical Package for the Social Sciences (PASW version 18.0 for Windows) using the Shapiro-Wilk test.

5.3.5. Reliability analysis

For reliability testing of ROM, stiffness and PPT measurements, a two-way random effects model ANOVA was used to break down the total variance score into variance due to patients, day and error (Streiner and Norman, 2008). The variation in intra-day and inter-day measures were calculated separately from the variance breakdown of the ANOVA using the random factor Intraclass Correlation Coefficients (ICC's) described by Eliasziw et al., (1994). In order to improve precision this method uses all observations in the analysis (Eliasziw et al., 1994). One-sided 95% confidence intervals (CI) for the ICC, standard error of measurement (SEM) and minimal detectable change (MDC) were calculated as recommended by Eliasziw et al., (1996). The SEM and MDC were calculated as it was recommended that this degree of change was necessary when evaluating pre and post treatment measures in order to be able to attribute the change to treatment (Eliasziw et al., 1994).

5.3.6. Analysis of the correlation between three-point bending and deformation

The relationship between three-point bending and deformation data sets was analysed using Spearman's correlation.

5.4. Results of the reliability study.

Three males and 17 females participated in the study. Participants had an age range of 18-40 years, and a mean age of 23.2 years (SD 6.48); their mean height was 168cm (SD 8.9) and weight 65.9kg (SD 7.9). All participants completed the study without reporting any adverse effects. The time between participant's first and second attendance ranged from 1-13 days (mean 5.45, SD 3.91). Due to some corrupted data not all participant's data was used for each measure; for this reason demographic data for the participants included is presented individually in each measurement section.

5.4.1. Results of reliability of range of movement measurements

One ROM file for one participant (participant 4) was corrupted. Four participants (6, 8,16 and 17) exhibited extreme ranges for right lateral flexion (see Figure 5.8) so these data sets were removed as outlined in section 5.3.1 (page 75).

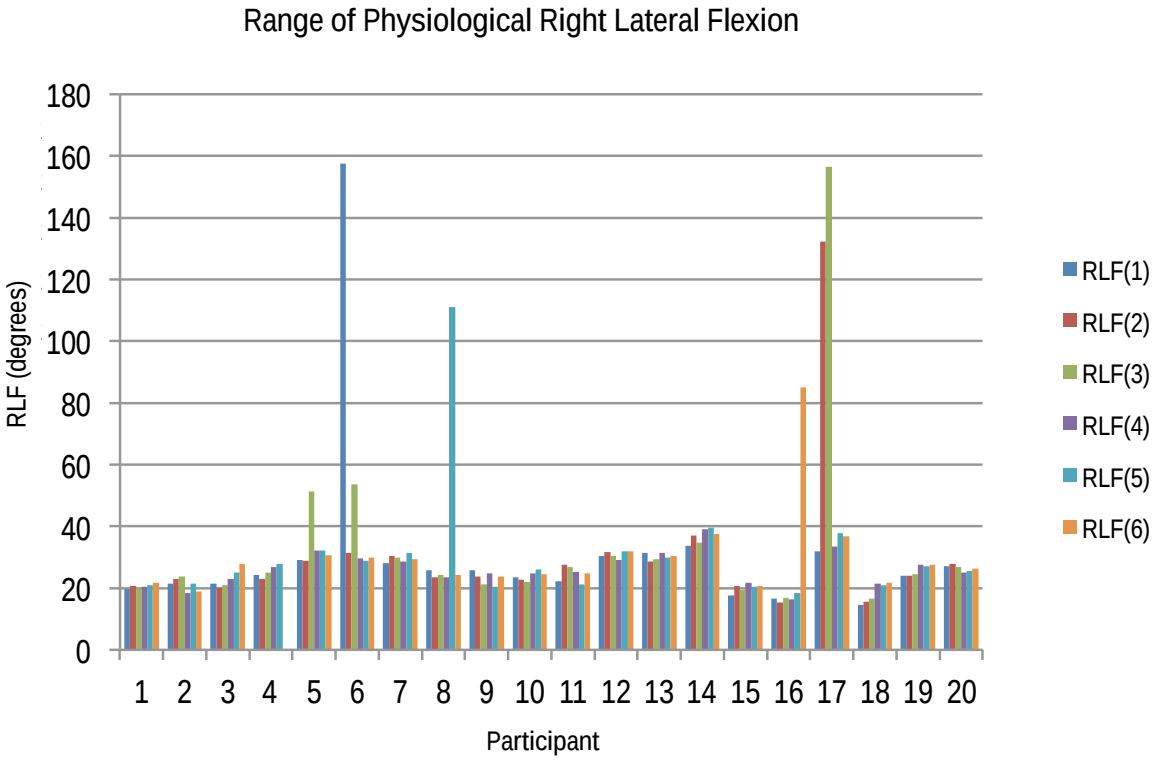


Figure 5.8. Right lateral flexion (RLF) range of movement for all participants on all occasions (RLF 1-6). Data for participants 6, 8, 16 and 17 was excluded, as it was greater than anatomically possible and greater than ranges reported in previous studies.

Data for 2 male and 13 female participants (age range 18-31 years, mean 20, SD 4.5) were included in the analysis. Normality testing revealed that 22 of the 24 data sets (for 4 movements on 6 occasions) were normally distributed. There were minor deviations on two data sets (p=0.009 and p=0.024) Appendix 4.

The differences between mean measures of range of movement were less than 3.5 degrees within one day and less than 5 degrees between days (Figures 5.9 and 5.10). This demonstrated small variation in mean measurements.

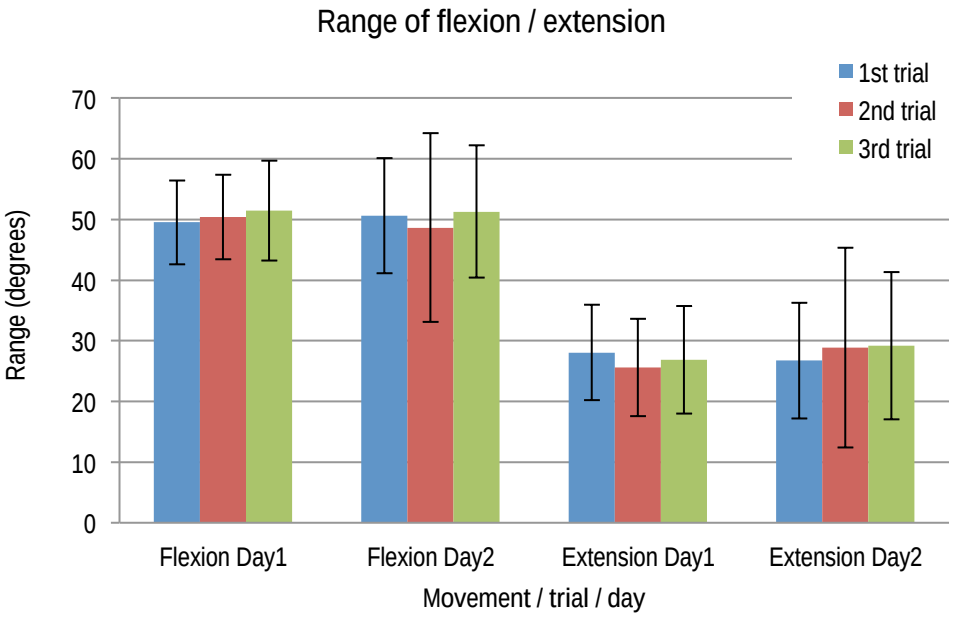


Figure 5.9. Range of flexion and extension for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=15).

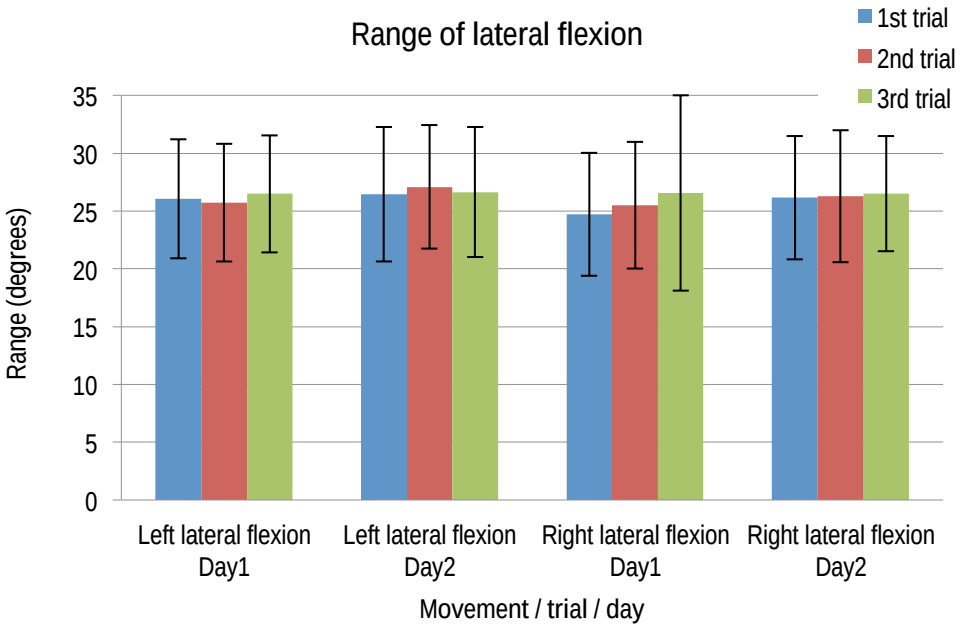


Figure 5.10. Range of lateral flexion for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=15).

Reliability statistics for ROM are displayed in Table 5.1. The within-day reliability for lateral flexion and extension (ICC 0.80-0.94; one sided CI 0.62-0.86), fall within the range of ICC's described by Fleiss (1986) as excellent. The ICC (ICC 0.69; one sided CI 0.39) for flexion suggested that reliability of flexion ROM fall within the range representing fair to good (Fleiss,1986). The ICC only provides a point estimate and the lower CI for flexion (0.39) indicates that on different occasions reliability may be poor.

Between-day reliability was lower than within-day in all cases; ICC's for lateral flexion demonstrated that between-day reliability remained excellent (ICC 0.75-0.79; one sided CI 0.59-0.61). However, between-day reliability for extension (ICC 0.48; CI 0.03) and flexion (ICC 0.43; CI 0.14) were fair (Table 5.1) and they fell just above the level representing poor reliability. Again, the lower CI (0.03-0.14) suggested that on other occasions reliability may be poor.

Movement	Within-day ICC	Within-day lower CI	Within-day SEM (°)	Within-day MDC (°)	Between-day ICC	Between-day lower CI	Between-day SEM (°)	Between-day MDC (°)
Flexion	0.69	0.39	5.6	15.4	0.43	0.14	7.7	21.4
Extension	0.95	0.88	2.2	6.0	0.48	0.03	7.0	19.6
Left Lateral flexion	0.94	0.86	1.4	3.8	0.79	0.61	2.5	6.8
Right lateral flexion	0.80	0.62	2.7	7.5	0.75	0.59	3.0	8.3

Table 5.1. Within-day and between-day reliability of ROM measurements (n=15). Figures are Intraclass Correlation Coefficient (ICC), 95% one sided confidence Intervals (ICC), standard error of measurement (SEM) and minimal detectable change (MDC). SEM and MDC are in degrees.

5.4.2. Results of reliability of stiffness measurements.

There was an error in the Fastrak and force plate files for 5 participants where they failed to synchronise. Therefore 15 data sets were suitable for analysis. Data for 1 male and 14 female participants (age range 18-40 years, mean 23, SD 6) were included in the analysis. Three-point bending data displayed much greater range and standard deviation than the displacement data (Figures 5.11 and 5.12), suggesting that there was greater variability in three-point bending than displacement measurements. Normality testing revealed that 7 of the 12 data sets (for 2 methods on 6 occasions) were normally distributed.

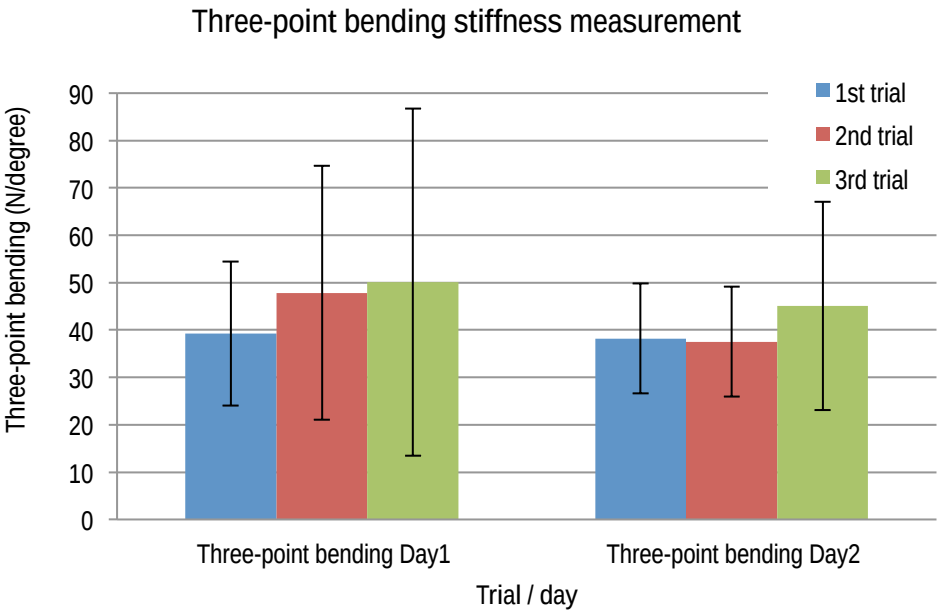


Figure 5.11. Three-point bending measurements for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=15).

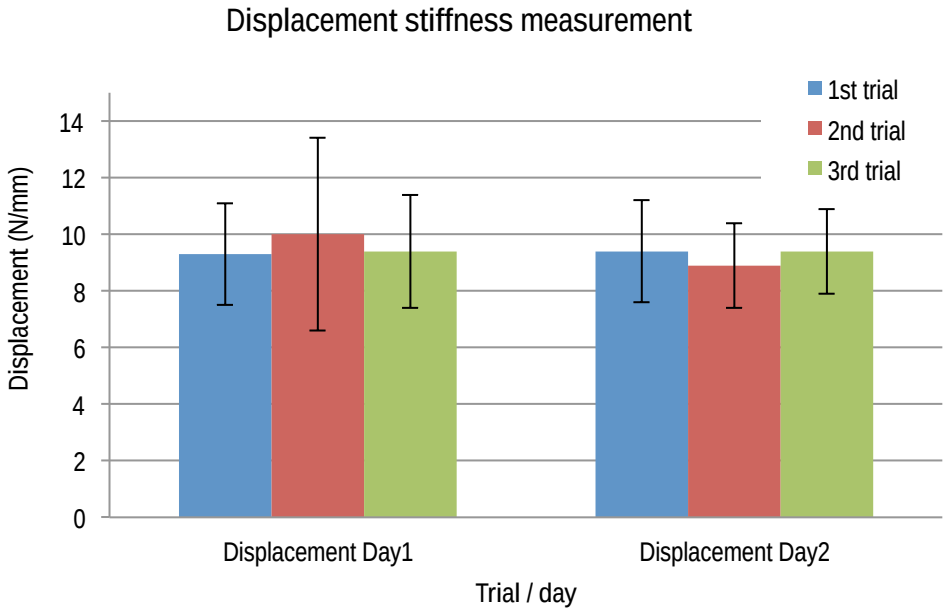


Figure 5.12. Displacement measurements for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=15).

Reliability of stiffness measurements are displayed in Table 5.2. The ICC value for within-day three-point bending measurements was excellent (ICC 0.77). Between-day stiffness (0.47) was just sufficient to achieve the fair to good range described by Fleiss, (1986). The ICC values (0.56-0.61) within- and between-days for displacement measurements of stiffness fell within the range representing fair to good reliability.

Stiffness method	Within-day ICC	Within-day lower CI	Within-day SEM	Within-day MDC	Between-day ICC	Between-day lower CI	Between-day SEM	Between-day MDC
Three-point bending	0.77	0.52	0.20 N/°	0.57 N/°	0.47	0.18	0.31 N/°	0.87 N/°
Displacement	0.56	0.30	0.14 N/mm	0.39 N/mm	0.61	0.44	0.13 N/mm	0.37 N/mm

Table 5.2. Within-day and between-day reliability of three-point bending and displacement stiffness measurements (n=15). Figures are Intraclass Correlation Coefficient (ICC), 95% one sided confidence Intervals (ICC), standard error of measurement (SEM) and minimal detectable change (MDC). SEM and MDC are expressed in Newton /degrees (N/0) for three-point bending and N/mm for displacement.

5.4.3. Correlation between three-point bending and displacement measurements.

Visual inspection of the force displacement curves revealed quite different force displacement profiles for the displacement and three-point bending data. The displacement curves during the loading cycles appeared sinusoidal with smooth peaks. In contrast the three-point bending (angle) data showed a more saw, or sharks' tooth pattern, with an irregular peak (see Figure 5.13).

A correlation between baseline data from the first day for three-point bending and displacement demonstrated that there was a significant (p=.01) but moderate (r=0.64) positive correlation, 95% confidence interval (CI) 0.20-0.87 (Figure 5.14). This correlation was repeated on baseline data from the second day (Figure 5.15), this resulted in a positive correlation with an increased significance level (p=.003, r=0.70) 95% CI 0.30-0.89 (Appendix 5). These correlations demonstrated that higher three-point bending measurements were associated with higher displacement measurements.

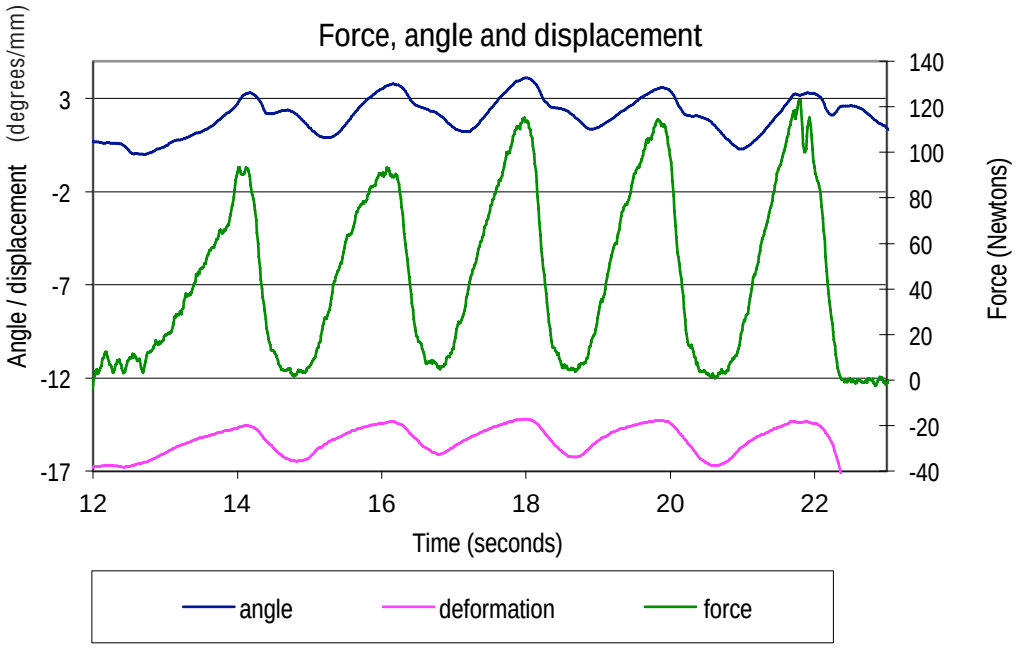


Figure 5.13. Example of a force / displacement and angle graph. Angle data has a saw tooth pattern as opposed to the sinusoidal pattern of deformation data.

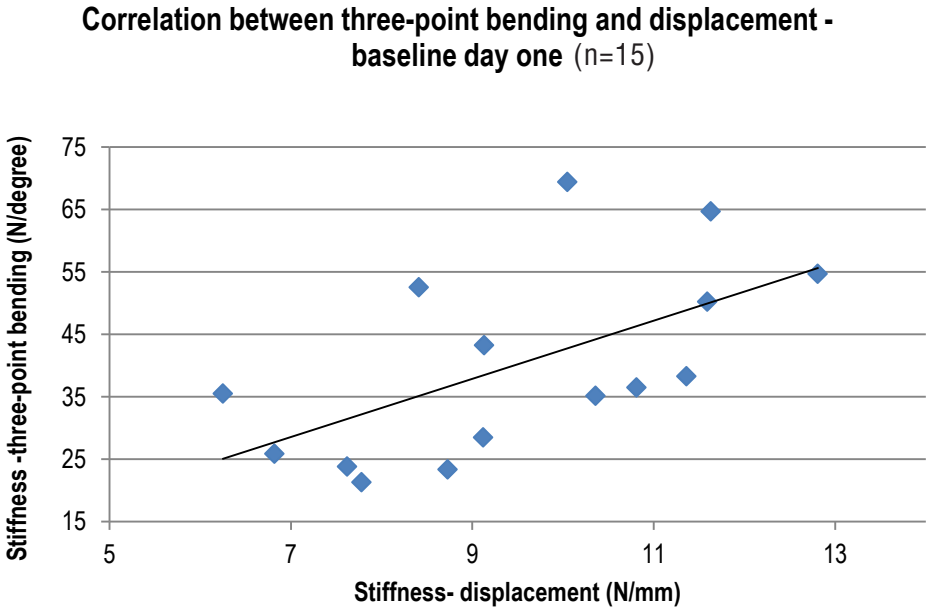


Figure 5.14. Correlation between three-point bending and displacement measurements at baseline on day 1 demonstrated that there was a significant (p=.01) but moderate (r=0.64) positive correlation, 95% confidence interval (CI) 0.20-0.87.

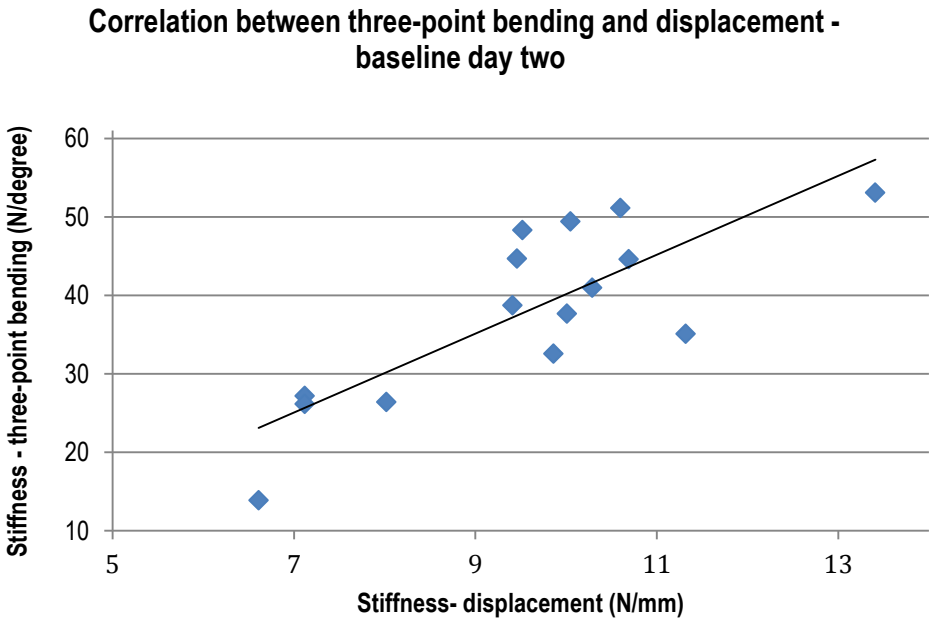


Figure 5.15. Correlation between three-point bending and displacement measurements at baseline on day 2 demonstrated a positive correlation with an increased significance level (p=.003, r=0.70) 95% CI 0.30-0.89

5.4.4. Results of reliability of Pressure Pain Thresholds

All PPT data sets were suitable for analysis. Descriptive statistics for all 6 repetitions (3 repetitions on each of 2 days) are displayed in Figures 5.16 and 5.17. The largest within-day difference between mean measurements (0.5 kg/cm^2) was at the S1 dermatome site. The largest within-day difference between mean measurements was (0.6 kg/cm^2) at the L4 paravertebral site. This demonstrated that there were small variations in mean PPT measurements.

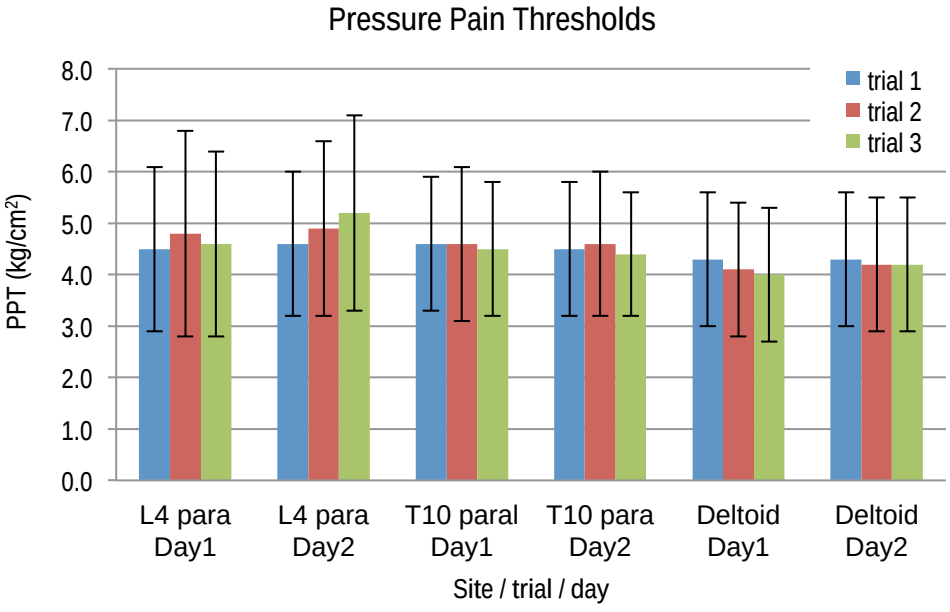


Figure 5.16. PPT measurements for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=20).

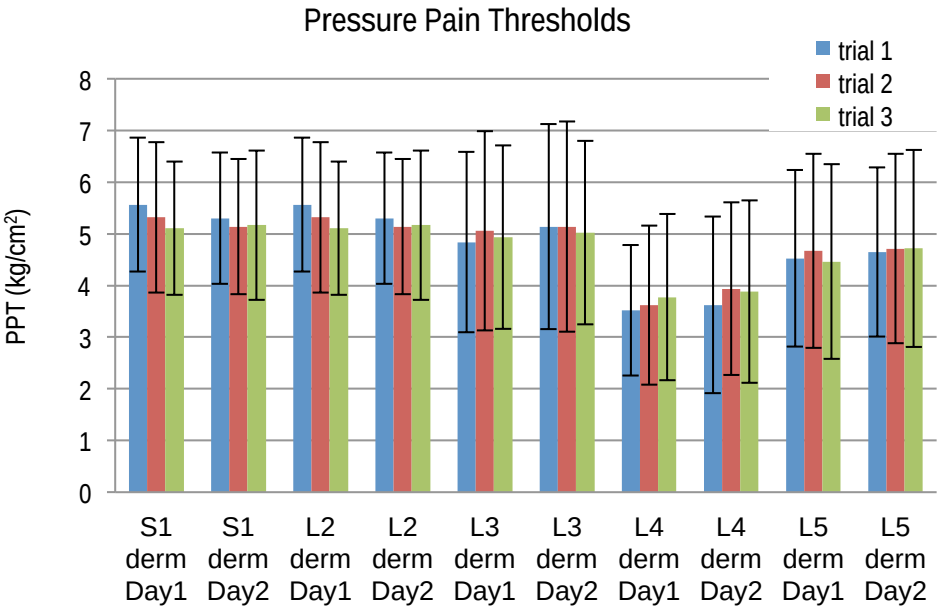


Figure 5.17. PPT measurements for all 6 trials (3 trials on 2 different days). The data are means. Error bars represent +/- standard deviation (n=20).

Normality testing revealed that 46 of the 48 data sets (for 8 sites on 6 occasions) were normally distributed. There were minor deviations on two data sets (p=.012 and p=.015). The reliability results for PPT are shown in Table 5.3.

Within-day reliability was excellent at all PPT sites (Table 5.3). Between-day reliability for the PPT at L4 and T10 paravertebral muscles, L2, L3 and L5 dermatome signature zones was excellent (ICC 0.72-0.84). Between-day reliability at Deltoid muscle and L4 and S1 dermatomes (ICC 0.56-0.68) fell within the range representing fair to good reliability (Fleiss, 1986).

PPT site	Within -day ICC	Within-day lower CI	Within-day SEM kg/cm²	Within-day MDC kg/cm²	Between-day ICC	Between-day lower CI	Between-day SEM kg/cm²	Between-day MDC kg/cm²
L4 sp	0.88	0.78	0.62	1.71	0.84	0.75	0.69	1.91
T10	0.84	0.72	0.54	1.49	0.79	0.67	0.62	1.71
Deltoid	0.84	0.70	0.51	1.41	0.64	0.42	0.80	2.19
S1	0.76	0.56	0.65	1.81	0.56	0.35	0.90	2.49
L2	0.86	0.74	0.62	1.71	0.72	0.55	0.89	2.44
L3	0.89	0.80	0.62	1.71	0.78	0.63	0.89	2.47
L4	0.87	0.75	0.55	1.53	0.68	0.48	0.88	2.43
L5	0.92	0.85	0.51	1.42	0.82	0.69	0.78	2.16

Table 5.3. Within-day and between-day reliability of PPT measurements (n=20). Figures are Intraclass Correlation Coefficient (ICC), 95% one sided confidence Intervals (ICC), standard error of measurement (SEM) and minimal detectable change (MDC). SEM and MDC are in kg/cm².

5.5. Discussion

This study investigated the reliability of ROM, stiffness and PPT measures in order to underpin later studies in this thesis which investigated the effects of lumbar mobilisations on these variables. The Intraclass Correlation Coefficient (ICC) was used to give a measurement of reliability (1 being almost perfect and 0 being most unreliability (Landis and Koch, (1977)). The SEM and MDC were calculated for consideration alongside the results of a later study (chapter 7) in order to identify participants who responded to treatment. Measurements of lumbar stiffness were obtained using two different methods and the results from these methods have been compared.

5.5.1. Discussion of reliability of range of movement measurements

Previous studies have reported similar within-day ICC's to those reported in this study; for example Mannion and Troke, (1999) reported within-day ICC's of 0.82-0.99 and Lee and Wong, (2002) reported a co-efficient of multiple determination of 0.98. Lower between-day reliability was expected, as it required highly accurate identification of bony landmarks and repositioning of the electromagnetic sensors. However Mannion and Troke, (1999) reported higher between-day ICC's (0.72-0.81) than those in this study.

Unfortunately Mannion and Troke, (1999) only reported a point estimate (the ICC) and therefore their results do not provide a complete picture of reliability. The interpretation of ICC scores varies (Table 5.4) and is considered to be an arbitrary interpretation as reliability data should be considered in relation to the measure's intended use (Fleiss, 1986) and alongside the CI, SEM and MDC statistics (Eliasziw et al., 1994). The SEM and MDC provide a greater picture that can be contextualised in relation to the intended use. The MDC in this study indicated that a measurement change above 15.41° flexion within one day and 21.4° between days would be necessary to be 95% sure that an actual change had occurred (rather than a change due to natural variability and measurement error). This represents a change of nearly one-third of the total range – a difference that is unlikely to occur with treatment. MDC for other movements was less than that of flexion; for example for lateral flexion the within-day MDC was 3.78° and inter-day MDC was 6.81°. The reliability of these measurements may be suitable for the intended use but required further consideration alongside the change seen with treatment explored in the following study in this thesis.

Reliability classifications

Landis and Koch (1977)	
0.81 - 1	Almost perfect
0.61 - 0.80	Excellent
0.41- 0.60	Moderate
< 0.40	Fair to poor

Fleiss (1986)	
> 0.75	Excellent
0.40 - 0.75	Fair to good
< 0.40	Poor

Table 5.4. Different interpretation of intraclass correlation coefficients.

The ranges of movement reported in the current study were similar to those identified in the literature review; the mean range of flexion in this study was 50°-52°, comparable to previously reported flexion ranges of 58° (Lee and Wong, 2002) and 49° (Lee et al., 2003). The mean range of extension in the current study was 25-27°, similar to the extension range (mean 23°) reported by Stamos-Papastamos et al., (2011). Range of lateral flexion in the current study was 26° for left lateral flexion and 25-26° for right lateral flexion, similar to the 22° reported by Lee and Wong, (2002).

Although the ROM in the current study was similar to those previously reported, some measurements for right lateral flexion were very large (as high as 157.56° for a single reading). These aberrant data sets were removed in accordance with the criteria set out in section 5.3.1 (page 75). These measurements were considerably greater than anatomically possible and although measurements of physiological range taken at the skin's surface overestimate the range of joint movement due to movement of the skin, the aberrant movements in this study far exceeded those reported in previous studies measuring ranges using electromagnetic tracking systems (Hindle et al., 1990; Peach et al., 1998; Mannion and Troke, 1999).

Some participants in this study were perspiring heavily as they had cycled to the laboratory; every attempt was made to clean and dry the skin but on some individuals good adhesion was not possible and on a few occasions the tape fixing the electromagnetic sensor became unstuck and required reapplication.
On some individuals the sensors required re-sticking after each cycle of movements. Right lateral flexion was the last in the cycle of movements (the movement order in one cycle was flexion, extension, left lateral flexion, right lateral flexion) and therefore would have been more likely to be subject to error due to the sensors becoming unstuck. This may have occurred without the researcher becoming aware and may have affected readings on an individual basis. Fixation of the sensors on the skin whilst participants moved over large ranges proved difficult and has been recognised and received considerable attention previously (Ha, 2010). Moreover on participants with high level of perspiration this remains an on-going challenge.

In summary although on initial appraisal the ICC's could be regarded as acceptable, the CI's suggest that on other occasions reliability may be insufficient. The MDC indicated that in some cases a large difference would need to have occurred before it could be attributed to a treatment effect. These reliability statistics required further consideration alongside studies investigating the effect of treatment. The ranges of movement were comparable with the published literature. Where anomalies were evident it is likely that these were due to poor fixation of the sensors. In future work it will be important that considerable care is paid to preparation of the skin, ensuring it is dry and cleansed with alcohol wipes to remove any oils on the skin's surface. It is also important to emphasise to participants that they should not exercise immediately prior to data collection.

5.5.2. Discussion of reliability of stiffness measurements

Only one study has previously reported on within-day reliability of three-point bending, quoting ICC's of 0.97-0.99 (Lee et al., 2005a). Within-day reliability of three-point bending measurements in this study was lower (ICC 0.77). Lee et al., (2005a) calculated reliability of stiffness measurements of three consecutive oscillatory cycles whereas those for this study were calculated using the mean of cycles 2-5 repeated at 5-minute intervals. There are a number of factors that could explain the lower within-day reliability figures reported in the current study. These include inaccuracy in repositioning of the indenter over the spinous process (following the 5-minute interval), and measuring at a different point in the respiratory cycle. The lower between-day reliability (ICC 0.47) can be explained by additional between-day variables such as inaccurate identification of the vertebral level at which testing took place, inaccurate re-positioning of the electromagnetic sensors and within-subject variation.

In the current study reliability of the displacement method of stiffness measurement was lower than that in previous research reporting within-day ICC's ranging from 0.88-0.96 (Latimer et al. 1996a; Lee and Svensson 1990) and a between-day ICC of 0.88 (Shirley et al., 2002). These studies all used a mechanically driven indenter which was able to standardise the rate and amount of force applied. An important difference in the current study was the use of a hand held indenter, which introduced human error into the application of force. For this reason it was anticipated that the reliability of measures in this study would be lower than those in published studies. Although every attempt was made during the current study to standardise the application of force, operator variation (of maximum force, frequency and angulation) could not be removed altogether. One group of researchers have used a hand held manually operated indenter similar to the one used in the current study and reported an ICC of 0.79 (CI 0.74-0.83, SEM 1.62 N/mm) in measurements taken 5 minutes apart (Owens et al., 2007a). This is higher

than the reliability seen in this study. However Owens et al., (2007a) removed 10% of the cycles, as they did not show a linear force displacement graph, which may have resulted in improved reliability. It is questionable whether it was appropriate to remove these cycles as it is common for force displacement graphs from PA's to be non-linear (Nicholson et al., 2001). The only cycles removed from testing in the current study were those where there was an error with synchronisation of the force and motion data.

When considering the reliability of both three-point bending and displacement methods of measuring stiffness it is important to take into account the size of the between-subject variation as this can lead to unrepresentatively high ICC's (Portney and Watkins, 1990). The large range and standard deviation of three-point bending measurements indicated that either a large amount of random error occurred during testing or that there was a high variability of stiffness between participants (Figure 5.11). The standard deviation was smaller on the second day of testing suggesting that a learning effect had occured. This could be explained by participants becoming accustomed to force being applied to their spine through the indenter. High between-subject variability has been widely observed in previous studies using both the three-point bending method (Stamos-Papastamos et al., 2011) and displacement method (Lee et al., 1996). It has been suggested that normal subjects will display stiffness values ranging from 50-200% of the mean value (Lee and Liversidge, 1994). However the greater spread of data with three-point bending than with displacement measurements may have resulted in inflated ICC's for three-point bending.

Mean three-point bending measurements in this study (37.5 – 50.1 N/degree (SD 11.6 - 36.7)) were considerably higher than those reported by Stamos-Papastamos et al., (2011) who reported mean stiffness of 23.14 N/degree (SD 19.66). No other studies have calculated three-point bending measurements in N/degree. Although the three-point bending method used in this study was similar to that used by Lee et al., (2005a) there are important differences between the methods and data analysis that make comparisons between the data inappropriate. Firstly the sensor placement was different from that used by Lee at al., (2005a). In order to measure both lumbar ROM and stiffness, in this study, the cephalic electromagnetic sensor was positioned on L1, whereas Lee et al., (2005a) placed the cephalic sensor on T8/9. Furthermore Lee et al., (2005a) developed an equation, which reportedly took into account the geometry of the spine when calculating stiffness measurements. In this study three-point bending was calculated simply by dividing the force applied by the resulting change in angle of the spine, thereby producing a measure of stiffness. This calculation method was also used by Stamos-Papastamos et al., (2011).

The stiffness figures for the displacement method (9.0-10.0 N/mm) are lower than those reported in previous literature; Shirley et al., (1999) reported stiffness values at L4 of 14.8 N/mm (SD 5.2). Other authors have reported mean values of 15.5N/mm (Viner et al., 1997) and 13.3 N/mm (Lee et al., 1998). The lower figures in this study may be due to participant or methodological difference; spinal stiffness has been shown to be greater in males (Snodgrass et al., 2008; Owens et al., 2007b) and all but one of the participants in this study were female. Previous studies applied force at angles varying from 4.5 degrees caudad (Shirley et al., 1999) to 13.3 degrees caudad (Lee et al., 1998), whereas the current study applied force at zero degrees (as it was not possible to standardise other angles using the hand held indenter). However the difference in angulation does not necessarily explain the lower figures reported in this study as applying inclined pressure means that the force is more in line with the facet joint and therefore might be more likely to result in lower stiffness values than pressure applied at zero degrees.

In summary, although within-day reliability of three-point bending was excellent, between-day reliability was fair. Furthermore the high between-subject variation may have resulted in inflated ICC's. These results suggest that further investigation of this method is necessary before it is used in future work. The displacement measurements of stiffness showed good reliability. For either method of stiffness measurement the magnitude of the changes must be large enough to be statistically and clinically significant (Portney and Watkins, 2000), so it is necessary to consider the reliability figures reported in this study alongside the results of work investigating the effects of mobilisation treatment on stiffness. The reliability of stiffness in this study is lower than in previous studies. This is largely explained by the use of a manually applied indenter.

Preliminary work (section 4.4) had cast doubt over the validity of the three-point bending method. One aim of this study was to explore the validity of stiffness measurements in order to establish which method would be most suitable for monitoring change resulting from mobilisation treatment. The following section considers the validity of stiffness measurements.

5.5.3. Validity of three-point bending and displacement methods of stiffness measurements.

One aim of this study was to explore the validity of three-point bending and displacement methods of stiffness measurements. Visual inspection of movement during the application of force to the spine demonstrated that skin movement resulting from the application of force dominated movement of the sensors. Furthermore, when watching the electromagnetic sensor motion during the application of a PA pressure they did not appear to produce the angular

displacement that would be evident if three-point bending were occurring. This raised concerns about the face validity of three-point bending measurements. Establishing the validity of the stiffness measurements is difficult as it requires one to determine that three-point bending measures what they intended to measure (Portney and Watkins, 2000) – in this case spinal stiffness.

This study investigated criterion validity, which is the ability of one test to predict the results of another (Streiner and Norman, 2008). In this case of spinal stiffness tests using three-point bending and displacement methods a component of criterion related validity called concurrent validity (when measures are taken at the same time so they reflect the same event) was explored. The correlation performed calculated the extent to which the relationship between three-point bending and displacement could be described by a regression line, and therefore reflected the association between the two sets of data (Portney and Watkins, 2000). The correlations found in this study were significant and moderate to very strong positive correlations, demonstrating that higher three-point bending measurements were associated with higher displacement measurements.

Criterion validity, ideally compares one test considered to be the gold standard measurement for that variable to predict the results of another (Streiner and Norman, 2008). Although the displacement method has been used widely in the measurement of spinal stiffness (see section 3.2.1), it is not necessarily considered to be a gold standard. Portney and Watkins, (2000) emphasised the need of establishing the validity of the gold standard measure using three criteria; it is reliable, it is independent and free from bias and most importantly that it is relevant to the behaviour being measured. It is essential to consider the validity of the displacement method using these three criteria: Firstly the displacement method of stiffness testing has been shown to be reliable in previous work (Lee and Svensson, 1990 and Latimer et al., 1996b), however only moderate reliability was achieved in this study. Secondly testing is standardised by the indenter. In this study the indenter was applied by a human operator (as opposed to the mechanical indenters used in some previous work) and for this reason in this study it may be considered not to be entirely free from bias. The final criterion of a gold standard is that it is relevant to the behaviour being measured and if the aim is to test the stiffness that physiotherapists perceive during assessment, then the displacement method of stiffness measurement would meet this criterion. Accepting the displacement method of stiffness measurement as a gold standard is not without its limitations, however there is no other method of stiffness testing against which to judge three-point bending. Portney and Watkins, (2000) advocated that where testing against a gold standard is not possible, construct validity should be considered.

Construct validity is an on-going process, which involves continually testing its predictions. An example of this for stiffness testing would be the ability of the measure to detect change over time. This relies on scores remaining stable when the patient is unchanged, and scores changing with changes in the patient. In the current study three-point bending was measured on 6 occasions (3 measures on each of two days, 1-13 days apart); although the ANOVA showed that there were no significant differences in stiffness values over these occasions (p=.27), the between-day reliability was fair (ICC 0.46). It is unknown how actual changes in participant's spinal stiffness contributed to the poor reliability, however these were asymptomatic participants and it has been demonstrated that stiffness remained consistent in asymptomatic individuals over a similar period of time (Shirley et al., 2002).

Validity of displacement method of measuring stiffness has previously been established when tested against a beam of known stiffness value (Lee and Svensson, 1990 and Latimer et al., 1996b). However this may not transfer to valid measurement of spinal stiffness due to the spine's complex structure. The displacement method measures stiffness in a similar way to stiffness testing performed by a therapist and therefore is likely to represent what therapists perceive. For this reason it could be considered to have face validity and be suitable for the purpose it is intended.

Another component of construct validity is assessing the responsiveness to treatment. In this case, assessing the responsiveness of stiffness to treatments designed to reduce stiffness. When comparing the responsiveness of both methods, one may show a change with treatment whilst the other does not. This is further explored for stiffness measurements in a single-arm trial in chapter 6 of this thesis.

In summary, observation of the sensor movement occurring during testing cast doubt over the validity of three-point bending measurements. There was a significant and strong positive correlation between three-point bending and displacement methods of stiffness testing demonstrating that these measurements were associated with one another. However displacement has not been accepted as gold standard for stiffness measurement and therefore this association does not confirm the validity of three-point bending measurements. Further consideration of the validity of stiffness measurements by assessing the responsiveness to mobilisation treatment is reported on in the following single-arm trial in this thesis (chapter 6).

5.5.4. Discussion of reliability of pressure pain thresholds

As expected the PPT reliability within one day was higher than reliability over two occasions some days apart. Within-day reliability at all sites was excellent (ICC 0.76-0.92). The MDC (depending on the testing site) indicated that a 1.4-1.8 kg/cm^2 change in PPT would need to occur before change within one day to be 95%

sure that the change could be attributed to treatment as opposed to measurement error. Between-day reliability was fair to excellent, depending on the testing site (Table 5.3 page 85). Between-day reliability at Deltoid muscle and L4 and L2 were moderate. MDC statistics indicated that changes above 1.7- 2.5 kg/cm^2 (depending on site) would be necessary to be certain that change was due to treatment. These reliability figures are similar to those reported previously (see Table 3.4, page 40). The reliability of PPT in this study suggests that they are suitable for measuring the effects of mobilisation treatment.

The PPT measured in the current study at the paraspinal sites (at the level of T10 (4.6 kg/cm^2, SD 1.4) and L4 (4 .7 kg/cm^2, SD 1.8) were slightly lower than those reported in previous studies; mean PPT values reported in the literature vary, but range from 7.4kg/cm^2 (Farasyn and Meeusen, 2005) to 5.0kg/cm^2 (Dhondt et al., 1999) at the T10 paravertebral level. The higher values quoted in previous studies may be explained by differences in participants' gender; over 50% of the participants in the study by Farasyn and Meeusen, (2005) and a quarter of the participants in the study by Dhondt et al., (1999) were men, who have been shown to have higher PPT values (Riley et al., 1998). In the current study there were only 2 male participants (10%). Additionally, slightly lower values could be anticipated from this study as unlike previous studies the algometer had a patient control switch which may have reduced any delay between the participant indicating that the threshold has been reached and recording of the PPT value.

PPT at the L4 paraspinal site were also lower than those reported in previous work. Fischer, (1987) reported paraspinal mean PPT at the L4 level in females of 6.1kg/cm and in males of 8.8 kg/cm^2, however these measurements were taken at a point more lateral that the site used in this study. A mean PPT of 5.0kg/cm^2 was reported at a more medial site at the paravertebral level of L5 (Dhondt et al., 1999), which was similar to the figure found at the L4 paravertebral site in the current study.

Previous work has reported mean PPT in Deltoid of 5.1 Kg/cm^2 (Fischer, 1987) and 5.0 kg/cm^2 (Antonaci et al., 1998), similar to the mean value of 4.2 kg/cm^2 in the current study. The other sites used in this study have not been used in previous work hence comparisons are difficult. A site described as 'ventral to the lateral malleolus' was used by Dhondt et al., (1989); a mean PPT of 5.0 kg/cm^2 (SD1.83) was reported. This site is in a similar position to S1 where a mean reading recorded in this study was 5.3kg/cm^2.

In summary the reliability of PPT measures was good to excellent. The magnitude of readings found in the current study are slightly lower than those reported in previous studies but can be explained by the low proportion of male participants (who have higher PPT (Riley et al., 1998)) and the use of a patient control switch

(which reduces a delay between participants indicating the point of change and the measurement recording).

5.5.5. Key learning points form the test-rest reliability study.

Conducting the reliability study identified a number of key learning points which were carried forward to the later studies in this thesis. These were as follows:

- Rebooting the computer between each set of measurements reduced the number of synchronisation errors and corrupted data sets (potentially due to reducing errors resulting from buffer overflow).
- Considerable attention needed to be made to cleaning and drying the skin prior to application of the Fastrak sensors. Time in the data collection schedule is required to enable participants to 'cool down' if they cycle to the laboratory.

5.5.6. Overall summary of discussion

The first aim of this study was to establish the within- and between-day reliability and measurement error of ROM, stiffness and PPT measurements. Reliability reflects the extent to which a measurement is consistent and free from error or variation; it is a measure of the extent to which observed scores vary from true scores (Portney and Watkins, 2000). Measures both within a day and between days will always be subject to some variation, particularly when measuring factors on people; a number of factors including the time of day, their mood, hormonal cycle or diet and what they did the night before (be it exercise or a late night) may influence the repeatability of measurements. The aim of this study was to establish the variation in measures that could be attributed to day-to-day variations and within-day variations, and to establish the magnitude of change required to be sure a treatment effect had occurred.

The SEM and MDC were calculated for consideration alongside the following studies in this thesis. An important reason for calculating SEM and MDC is that high between-subject variation can lead to inappropriately high ICC's; using the SEM alongside the ICC allows greater interpretation of the usefulness of a measure. For this reason, when using pre and post intervention measures to determine the effects of treatment, Eliasziw et al., (1994) recommended calculation of the MDC in addition to the SEM. Changes found in the data should be greater than the MDC to consider that a clinical effect has occurred. These will be used in later studies (chapter 6 and 7) to identify the number of individuals experiencing a clinical meaningful difference in these measures.

The following chapter reports on a study that investigates the effect of different durations of mobilisation of pain, ROM and stiffness.

Chapter 6

A single-arm trial investigating the immediate effects of duration of lumbar mobilisation treatment on pain, stiffness and ROM in patients with LBP.

6.1 Introduction

Although mobilisations applied to the lumbar spine have been shown to produce a hypoalgesic effect in asymptomatic participants (Krouwel et al., 2010 and Willett et al., 2010), no studies have established whether an analgesic effect occurs in patients with LBP (see section 2.9, page 14 for further details).

Physiotherapists commonly use 30 or 60 seconds of mobilisations, repeated up to 3 times (up to 3 minutes in total). This treatment dose was advocated in a seminal text by Maitland first published in 1964 and has not been subjected to experimental evaluation since. Despite there being some evidence to suggest that longer treatment duration may create a greater effect on ROM (as discussed in sections 2.5 and 2.6 pages 8-11) and pain (as discussed in section 2.9, page 14), studies have not investigated the effects of duration of mobilisation treatment (on pain, ROM or stiffness).

Although the previous literature has demonstrated that mobilisation treatment results in an immediate pain relieving effect, as measured by PPT (Sterling et al., 2001; Vicenzino et al., 1996). There is limited evidence on the effect of mobilisation treatment on patient reported measures of pain (as discussed in section 2.9.2). Furthermore the relationship between changes in PPT and clinical outcome remains speculative, with Sterling et al., (2001) reporting dissociation between change in PPT and VRS after mobilisation to the cervical spine. The relationship between PPT and patient reported outcomes therefore require further investigation.

Studies examining the extent of the hypoalgesic effect of lumbar mobilisations in asymptomatic populations have reported widespread changes in PPT (Krouwel et al., 2010; Willett et al., 2010) and have suggested that this is indicative pain modulation via a systematic analgesic mechanism (as discussed in section 2.10.4, page 21). This has not been investigated in a symptomatic population.

The previous study in this thesis (chapter 5) established the within- and between-day reliability of ROM, stiffness and PPT measurements. ICC results varied from good to poor, when using interpretation of ICC suggested by Fleiss, (1986) and Landis and

Koch, (1977). However (Fleiss, 1986) deemed this an arbitrary classification and advocated consideration of reliability figures against their intended use. One aim of the current study was to investigate the magnitude of change in ROM, stiffness and PPT resulting from a mobilisation treatment dose for consideration alongside these reliability statistics in order to focus the forthcoming study in this thesis.

Anecdotal evidence suggests that some patients are likely to experience immediate relief of their symptoms following mobilisations, whereas others may experience an exacerbation of their symptoms. Furthermore, previous work has attempted to identify clinical features in patients that may predict their response to treatment, but the results of these studies are inconclusive (Kamper et al., 2010). This study sought to explore responders to mobilisations and investigate factors that may influence patients' response to mobilisations.

6.1.1. Research question

What are the immediate effects of 3 and 6 minutes of lumbar mobilisation treatment on pain, stiffness and ROM in patients with non-specific low back pain?

6.1.2. Study aims

To establish whether 6 minutes of lumbar mobilisation treatment has a greater immediate effect on pain, stiffness and ROM than 3 minutes of lumbar mobilisation treatment in patients with chronic non-specific LBP.

- To establish whether there is a correlation between changes in patients' reported measures of pain relief and changes in PPT following lumbar mobilisations.

- To determine the extent (local, segmental, systemic) of the analgesic effect resulting from a lumbar mobilisation treatment dose.

- To consider factors (from the questionnaires and examination findings) which may predict patients' response to lumbar mobilisations.

- To compare the responsiveness to treatment of three-point bending and displacement methods of stiffness measurement.

6.2. Methods

6.2.1. Study design

This was a single arm trial investigating the effects of applying a longer duration of treatment. The single-arm design was employed as a precursor to an RCT.

6.2.2. Ethics approval

This study was approved by the Faculty of Health and Social Science Research Ethics and Governance Committee (FREGC) (Appendix 2).

6.2.3. Participants

PS power and sample size calculations (version 2.1.31) were used to determine the required sample size for a power of 0.8 with a *p* value of .05. Calculations were made using means and standard deviation from published data, examining the immediate effects of mobilisation. Maximum difference 25.81 Kpa and standard deviation of 20.4Kpa were used for PPT measurements (Vicenzino et al., 1998). Maximum difference of 0.41 Nm/degree and standard deviation of 0.4 Nm/degree were used for stiffness measurements (Lee et al., 2005b). A minimum sample size of 16 was suggested. Eighteen potential participants met the inclusion criteria and were recruited to the study. Recruitment posters were placed on the university email and in local shops and community centres. Advertisement of the study also occurred through word of mouth, for example, those participating in the study informed friends or colleagues about the study and provided them with the contact details of the principal researcher. Potential participants were sent a participant information sheet and list of inclusion and exclusion criteria and asked to contact the principal researcher if they wished to take part, at which point an appointment was made for them to attend the human movement laboratory, Robert Dodd Annex, Eastbourne.

6.2.4. Inclusion and exclusion criteria

Potential participants were required to be between 18 and 70 years of age, have suffered from LBP for a minimum of 3 months and experience their symptoms on active movement and PA pressure to the spine.

Participants with precautions and contraindications to mobilisations were excluded from the study. This resulted in the following exclusion criteria:

- Spinal congenital abnormality
- History of spinal fracture
- History of malignancy
- Bone disease (osteoporosis, osteomyelitis, tuberculosis, Paget's)
- Inflammatory arthritis (rheumatoid arthritis, ankylosing spondylitis, gout)
- Congenital generalised hypermobility (Ehlers-Danlos syndrome)
- Advanced degenerative changes
- History of steroid therapy
- Pregnancy
- Current anticoagulant medication
- Pins and needles, tingling or numbness in the lower limbs

- Severe and / or irritable symptoms (symptoms which are so intense that they prevent the participant from moving, or which result in one movement producing lasting pain).

Potential participants were also excluded if they were undergoing current treatment for low back or leg pain (or had done so in the last 3 months).

6.2.5. Confidentiality

All participant information was kept confidential and only made available to the study investigator and supervisors. All participants were allocated with a code; to ensure anonymity all data was stored under that code, the key to which was kept on a password protected computer. To fulfil the requirements of the Data Protection Act 1998 all personal data was destroyed at the end of the study. Anonymised data will be kept for 10 years following completion of the study.

6.2.6. Instrumentation and measurements

ROM was measured using Fastrak (section 5.2.7., page 68). The electromagnetic sensors were placed on L1 and the sacrum as detailed in section 5.2.9. (page 69).

Lumbar stiffness was measured simultaneously using three-point bending (force/angle) and displacement (force/displacement) methods. This required force and Fastrak motion sensor data measurements to be taken simultaneously during the application of PA force (section 5.2.7., page 68). For three-point bending measurement two electromagnetic sensors measured the change in the curvature of the spine (angular rotation) and to measure displacement measurements, the electromagnetic sensor mounted on the indenter (as described in section 4.5., page 61) measured vertical displacement. For Force Plate descriptions see section 5.2.7., page 68. PPT were measured using an algometer (as described in section 5.2.7, page 68).

A verbal rating scale (VRS) was utilised to gain a score of pain intensity at the end of each physiological movement and on the application of PA force to the most symptomatic vertebral level. The VRS is a scale that is used extensively in clinical practice and requires patients to score their pain on a scale of 0-10; 0 no pain and 10 being the most pain imaginable.

6.2.7. Pilot work

This study aimed to standardise all components of treatment dose (for components of treatment dose see section 2.3, page 6). However, during pilot work, it became apparent that standardisation of the grade of treatment was not possible. In some participants a grade III or III+ mobilisation was too painful and it was deemed

unethical to apply mobilisations without regard for symptom reproduction. The element of standardising grade of treatment was re-evaluated and a decision was made to apply the grade pragmatically.

6.2.8. Procedure

Potential participants attended the Human Movement Laboratory at the University of Brighton; School of Health Professions on two occasions each lasting for approximately 45 minutes. On each occasion the researcher greeted them and led them to a screened area. The researcher performed all examinations and treatments in the study. To avoid potential bias, a co-researcher took all of the experimental measurements.

6.2.9. Occasion one procedure

On the first occasion participants received a verbal explanation of the study and were given an opportunity to ask questions. They were then asked if they wished to take part in the study before being asked to sign a consent form. This was followed by a physiotherapy assessment. The assessment was conducted to ensure that participants met the inclusion criteria (of pain on active movement and PA pressure) and determine the vertebral level from which their symptoms were arising. A past medical and drug history were also taken to ensure that participants had no exclusion criteria. This assessment was typical of the assessment performed by physiotherapists in clinical practice (see Appendix 6 for details).

Once the physiotherapy assessment was completed and inclusion and exclusion criteria were confirmed, participants were asked to complete the questionnaires detailed in section 3.5, page 41, and given an opportunity to clarify questions that they were unsure of. The following questionnaires were included to assesses the participants' pain experience and risk factors for LBP (see Appendix 7 for full questionnaires):

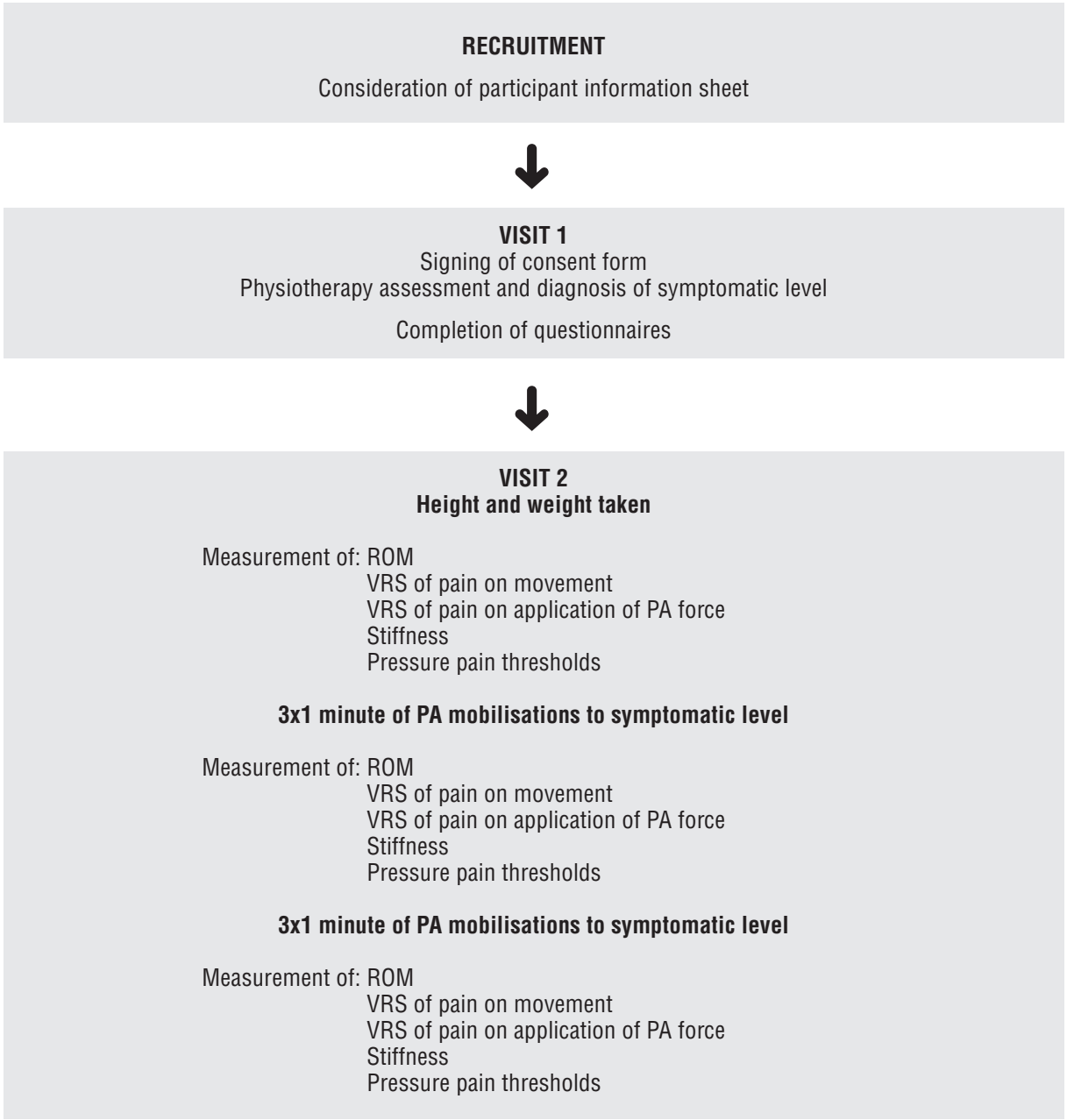
- Alcohol consumption (Townshend and Duka, 2002) and nicotine dependence questionnaire (Heatherton et al., 1991), as these substances may affect pain relieving mechanisms.
- The McGill pain questionnaire (Melzack, 1975) describes the pain.
- The Oswestry disability questionnaire (Fairbank et al., 1980) measures the impact of the pain.
- The survey of pain attitude (Tait and Chibnall, 1997) measures attitudes associated with the pain.
- A demographic questionnaire, which includes questions regarding, education, employment, income and activity levels.
- The General Health Questionnaire (GHQ28, Goldberg et al.,1979) provides an assessment of psychiatric distress.

6.2.10. Occasion two procedure

Participants attended on a second occasion for the experimental testing (see Figure 6.1). They were greeted by the researcher and led to a screened area and asked to undress to shorts (and for female participants shorts and bra), before their height and weight were measured and recorded.

Participants were asked to lie prone on a plinth whilst the symptomatic spinous process, sites for Fastrak sensor placement (detailed in section 5.2.9., page 69) and PPT testing were identified by manual palpation (see Table 6.2). Baseline ROM, stiffness and pain measures were taken (Figure 6.1).

Figure 6.1: a flowchart to depict participants' journey through the study.



6.2.11. Range of movement measurements

Participants were asked to stand upright with their feet hip width apart whilst a neutral position of the electromagnetic sensors was set (this allowed the starting position of the sensors to be recorded). Before participants started to move they received the following instructions: *'I would like you to perform some movements of your low back. At the end of each movement I would like you to tell me how bad your symptoms are out of 10; 0 being no pain and 10 being the worst pain you could imagine'*. At the end of range of each movement participants were prompted for the VRS. The instructions provided for each movement are shown in Table 6.1.

Table 6.1. Instructions given to participants during ROM testing.

Movement	Instructions
Flexion	'Bend forwards, as far as possible, running your hands down the front of your thighs… How many on a scale of 0-10 is that?'
Extension	'Lean backwards as far as possible… How many out of 10 is that?'
Lateral flexion	Indicating participants' right / left side: 'run your hand down the side of your leg, bending as far sideways as possible… How many out of 10 is that?'
Rotation	Indicating participants' right / left side: 'keeping your feet where they are, twist as far to this side as possible… How many out of 10 is that?'

6.2.12. Verbal rating of pain on PA pressure to the symptomatic vertebral level

Following rating pain on active movement, participants were asked to lie prone and rate their pain on an 11-point VRS, whilst the researcher applied a PA force to the symptomatic vertebral level (identified on their first visit).

6.2.13. Three-point bending and displacement stiffness measurement procedures.

The indenter was positioned over the symptomatic spinous process and to allow accurate repositioning, drawn around with a temporary marker pen. After the neutral position of the Fastrak sensors was set, participants were asked to take a deep breathe in, breathe out and refrain from breathing in (Shirley et al., 1999) whilst 5 cycles of PA mobilisations were applied by the researcher using the indenter at a rate of 0.5Hz (standardised by the use of a metronome). During stiffness measurement the researcher stood on a wooden lean bar to ensure that all the therapists force was transferred to the force plates.

6.2.14. Pressure pain threshold measurement procedure

Pressure Pain Threshold testing was performed using the sites and positions indicated in Table 6.2. Two pressure pain thresholds (PPT) readings were taken at each of the eight sites. Prior to testing, a familiarisation PPT was taken on the

dorsal aspect of the hand at the web-space between the thumb and index finger (enabling participants to experience PPT at one site). It was clearly explained that this was not intended to be a test of pain tolerance and that the intended point of measurement was when the sensation became anything more than just pressure, whether that was discomfort or pain. During the testing participants were asked to 'push the button as soon as the sensation of pressure turned to a sensation of discomfort or pain', at which point the pressure was removed and the PPT data was saved.

Table 6.2. PPT testing procedure.

Site Number	PPT site	Participant position	Landmark	Blocks
1	Paravertebral muscles at symptomatic level	Prone	Paravertebral muscles two fingers breadth from spinous process.	20cm High block
2	Paravertebral muscles at T10 level	Prone	Paravertebral muscles two fingers breadth from spinous process.	20cm High block
3	Deltoid	Side lying. Participant with elbow positioned in waist	Two participant fingers breadth below the middle of the acro-mion.	20cm High block
4	S1 dermatome	Side lying Bottom leg bent forward to allow testing leg to lie flat against plinth	Posterolateral heel. Two fingers breadth below and one fingers breadth posterior to the tip of the lateral malleolus.	10cm High block
5	L2 dermatome	Supine	Mid-thigh. Mid way between the anterior superior iliac spine and the base of the patella (meas-ured using a tape measure).	20cm High block
6	L3 dermatome	Supine	Two participant fingers breadth above base of patella	20cm High block
7	L4 dermatome	Supine Leg turned out (hip in flexion lateral rotation)	Two fingers above medial malleolus.	10cm High block
8	L5 dermatome	Supine Knee flexed so sole of foot flat on plinth.	Proximal to head of metatarsal.	10cm High block

Wooden blocks were utilised to ensure the researcher was at an optimum height for PPT testing

The algometer was applied perpendicular to the marked area of skin at all testing sites. The order of testing was designed to allow sufficient rest between repetitions with the least changes in a participant's position. All tests were completed sequentially in one position before changing the participant's position. Therefore 2 repetitions were completed at each site tested in prone (sites 1,2,1,2,) before moving into side lying and performing the testing sequentially in this position (sites 3,4,3,4). Participants were then asked to turn supine where the remaining sites were tested sequentially, (sites 5,6,7,8,5,6,7,8). The testing positions for T10, deltoid, L3 and S1 can be seen in Figure 5.4-5.7 (pages 73-74).

6.2.15. Mobilisation treatment

A central PA mobilisation technique consisting of repeated oscillatory movements was applied to the most symptomatic vertebral level for 3 x 60 seconds with a 60-second rest between sets. Mobilisations were performed using the pisiform grip (Figure 2.2 page 6) at a rate of 1.5Hz standardised by a metronome. The amount of treatment force applied was determined according to the severity of symptoms and in negotiation with the participant as pilot work (section 6.2.7., page 98) had established that standardisation of the treatment force might have resulted in undue reproduction of participants' symptoms.

Following 3 minutes of mobilisations measurements of ROM, stiffness and pain were retaken, this was followed by a further 3 x 60 second sets of mobilisations and a further set of measurements (as depicted in Figure 6.1).

6.3. Data Analysis

The raw data for ROM and stiffness was processed using a macro written in Visual BASIC for Applications (Microsoft Inc., Redmond, Washington) in Microsoft Office Excel 2007 (Version 12.0, Microsoft UK, Reading, England) see Appendix 3 for details on how the macro processed the data. The processed data was checked for errors by hand.

For ROM the maximum values of each movement (flexion, extension, left lateral flexion and right lateral flexion) was used for further analysis. Due to large amounts of skin movement during ROM testing, slippage of the electromagnetic sensors can occur. Therefore data that greatly exceeded the ranges reported in previous literature was removed. The maximum ranges beyond which data sets were removed were as follows:

- Flexion 100 degrees
- Extension 50 degrees
- Lateral flexion 85 degrees

The macro calculated the stiffness coefficient using force/angle (three-point bending) and force/vertical displacement (displacement) data by linear regression of the loading phase between 30-100N on the force-displacement curve (see Appendix 3). For stiffness the mean of cycles 2-5 was calculated and used in further analysis (cycle one was discarded due to transient behaviour on start-up (Latimer et al., 1996a)).

Descriptive statistics were first calculated for all data (questionnaire, ROM, stiffness, PPT and VRS of pain) using Statistical Package for the Social Sciences (PASW version 18.0 for Windows). Percentage differences in stiffness measurement were calculated (using the equation 100 x (post treatment stiffness-pre treatment stiffness) / (pre treatment stiffness)) to allow comparison of the change in stiffness using three-point bending and displacement methods. For PPT the mean of the two measurements at each site was used for subsequent analysis. Percentage changes in PPT after 3 and 6 minutes of treatment were calculated (using the equation 100 x (post treatment PPT-pre treatment PPT) / pre treatment PPT)) to allow comparison with previous research. Verbal rating of pain on individual movements were summed and used in further analysis.

6.3.1. Analysis of response to treatment

Cumulative proportion of responders' analysis was used to describe the likelihood of response over a range of response levels (Farrar et al., 2006).

Responders' analysis was performed to explore the number of participants experiencing a minimal clinical important change. For PPT clinical important changes were determined from the SEM and MDC statistics from the reliability study (chapter 4) and improvements of greater than 15%. As previous studies have reported greater local changes in PPT following mobilisations (Pentelka et al., 2012; Willett et al., 2010) PPT responders' analysis was determined for sites local to the treatment. The site most distant to treatment was also used in order to compare local and systemic difference between treatment durations.

For VRS of pain scores, change of 1-point was used to represent a clinically important difference as it has been suggested that changes of these magnitudes represent clinically meaningful change for participants with low starting pain score (Salaffi et al., 2004). There is no agreed level of change for VRS that is recognised to represent clinically meaningful change, Farrar et al., (2001) suggested 2-point change in VRS a clinically important difference. However it has been recognised that studies determining clinical significance often exclude participants with an initial pain score of less than 4/10 (Rowbotham, 2001). Participants in the current

study had low initial pain scores and it is recognised that when pain scores start at less than 4/10 a reduction smaller than 0.5 may represent 'much improved' (Rowbotham, 2001).

6.3.2. Normality testing of data

Iterative statistical analyses were performed using Statistical Package for the Social Sciences (PASW version 18.0 for Windows). All the data were tested for normality using the Shapiro-Wilk test. ANOVA was used when minor departures from normality were evident as ANOVA is robust to minor departures of normality (Agresti and Finlay, 2009). Where major deviations from normality were observed, they were transformed. Data were transformed using Logarithms to the power of 10 (Lg10). All transformed data were retested for normality.

6.3.3. Analysis of Variance

The effect of duration of treatment was analysed separately for ROM and PPT data using two-way repeated measures analysis of variance (ANOVA). For ROM the two independent variables were duration, which had three levels (before, after 3 minutes and after 6 minutes of treatment) and movement, which had four levels (flexion, extension, right lateral flexion and left lateral flexion). For PPT the two independent variables were duration, which had three levels (before, after 3 minutes and after 6 minutes of treatment) and site, which had 8 levels (symptomatic paravertebral, T10, deltoid, S1, L2, L3, L4, L5) of deviations.

Stiffness was analysed separately for displacement and angle data using one-way repeated measures ANOVA the independent variable was duration, which had three levels (baseline, after 3 minutes and after 6 minutes of treatment).

Verbal rating of pain on movement and verbal rating of pain on the application of PA force to the symptomatic level were analysed using one way repeated measures (ANOVA). For both measures, the independent variable was duration of treatment, which had 3 levels (baseline, after 3 minutes and after 6 minutes of treatment).

In order to test for prognostic or confounding variables, covariate adjustments between pain measures and questionnaire data (SOPA, Oswestry disability and GHQ28) were preformed using analysis of covariance (ANCOVA). Because PPT were performed at 8 different sites covariate analysis was performed using the changes local to the treatment site (the symptomatic paravertebral site), as previous studies have reported greater local changes in PPT following mobilisations (Pentelka et al., 2012; Willett et al., 2010).

6.3.4. Correlation between measures

Pearson's correlations were performed to investigate the relationship between three-point bending and displacement methods of stiffness measurement. Pearson's correlations were also performed to investigate the relationship between changes in verbal rating of pain and change in PPT.

6.4. Results

Thirty potential participants were recruited via University email; 18 met the physical testing inclusion criteria and became participants in the study. One subject's pain increased considerably after the first set of treatment; clinically no further treatment would have been applied to this participant so the researcher advised them to withdraw from the study. Seventeen participants completed the study.

The demographic data and details of duration of symptoms and symptomatic level are displayed in Table 6.3. One participant failed to complete the questionnaires so the questionnaire results (displayed in Table 6.4 and 6.5) are for 16 participants. The McGill pain questionnaire was not completed by a further 3 participants so McGill pain scores are for 13 participants. The Oswestry disability questionnaire scores demonstrated that most participants were in the lowest scoring band (0-20%) and are described as having minimal disability. The range indicated that some participants fell in the moderate disability-scoring band (20-40%). The mean GHQ28 score indicated that all participants had low levels of psychiatric distress (Richard et al., 2004).

Table 6.3. Demographic and symptom information for participants, n=17.

Sex	Age (years)	Height (cm)	Weight (kg)	Symptomatic level (number of particpants)	Symptom Duration (years)
7 female 11 male	Mean 44 SD10.7 Range 25-58	Mean 178 SD10	Mean 83 SD12	L5 (11) L4 (4) L1 (2)	Mean 12.25 SD 9.55 Range 0.25-30

Table 6.4. Questionnaire results, n=17.

Alcohol		Smoking	GHQ28	McGill	Oswestry % score
Units	Binge score				
Mean 10 SD 7 Range 2-33	Mean 8 SD 6 Range 1-22	1 smoker score 2	Median 0 Mean 0.8 SD 2 Range 0-5	Mean 18 SD 11 Range 6-36	Mean 16 SD 8 Range 6-36

Table 6.5. Survey of pain attitudes scores. The data are means, standard deviation (SD) 95% confidence interval (CI) and range (n=17).

	Control	Disability	Harm	Emotion	Medication	Solicitude	Medical cure
Mean	11.4	4.4	4.6	5.3	3.3	4.2	10.3
SD	3.2	3.0	3.5	5	2.3	3.3	3.4
95% CI	9.6-13.1	2.8-6.0	2.8-6.5	2.6-7.9	2.2-4.5	2.4-5.9	8.5-12.1
Range	6-18	0-10	0-12	0-15	0-8	0-10	3-16

6.4.1. Results of mobilisation treatment on lumbar range of movement

Out of the 12 sets of data (4 movements on three occasions) 11 were normally distributed (Appendix 8). The two-way ANOVA (sphericity assumed) indicated that neither 3, or 6 minutes of treatment had a significant effect on ROM ($F_{2,32}$ =0.89, p=.42) – see Figure 6.2 (and Appendix 9 for statistical output).

Mean ROM varied between measurements. For example mean flexion range decreased after 3 minutes of treatment (by 2.8°) and decreased further after a further 3 minutes of treatment (a total decrease of 4.7°). There was a negligible mean increase in extension (1.2°) and left lateral flexion (1.8°). Mean range of right lateral flexion increased after the first 3 minutes (by 5.8°) but there was a reduction in the increase after a further 3 minutes of treatment resulting in a variation of 1° from baseline following 6 minutes of treatment (Figure 6.2).

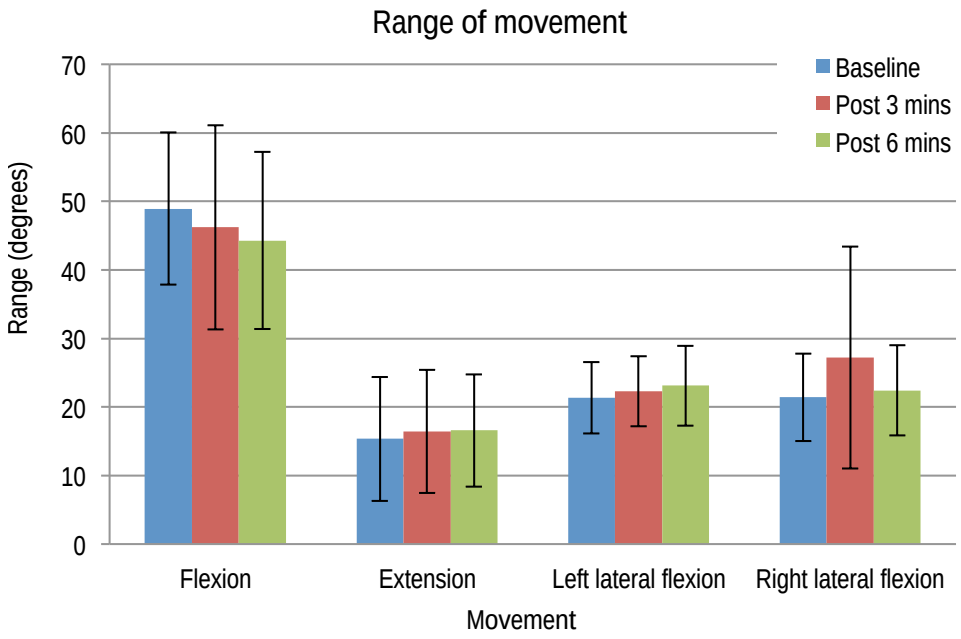


Figure 6.2. Range of movement at baseline and after 3 and 6 minutes of mobilisation treatment. The data are means. Error bars represent +/- standard deviation, n=17.

6.4.2. Results of mobilisation treatment on lumbar stiffness

Three stiffness data sets were excluded from the main analysis as there was an error with the synchronisation of the force plates and Fastrak.

The stiffness data sets were tested for normality using the Shapiro-Wilk test and found to be normally distributed (see Appendix 8). The one-way ANOVA (Appendix 9) revealed that neither 3 nor 6 minutes of mobilisation treatment had a significant effect on stiffness, for three-point bending ($F_{2,26}$=0.14, p=.99) or displacement ($F_{2,26}$=2.39, p=.11). See figure 6.3.

The mean variation in three-point bending measurements was -1.86N/degree following 3 minutes of treatment and 0.60 N/degree following 6 minutes of treatment. The mean variation in displacement measurements was 1.25N/mm following 3 minutes of treatment and -0.16N/mm following 6 minutes of treatment (Figure 6.3).

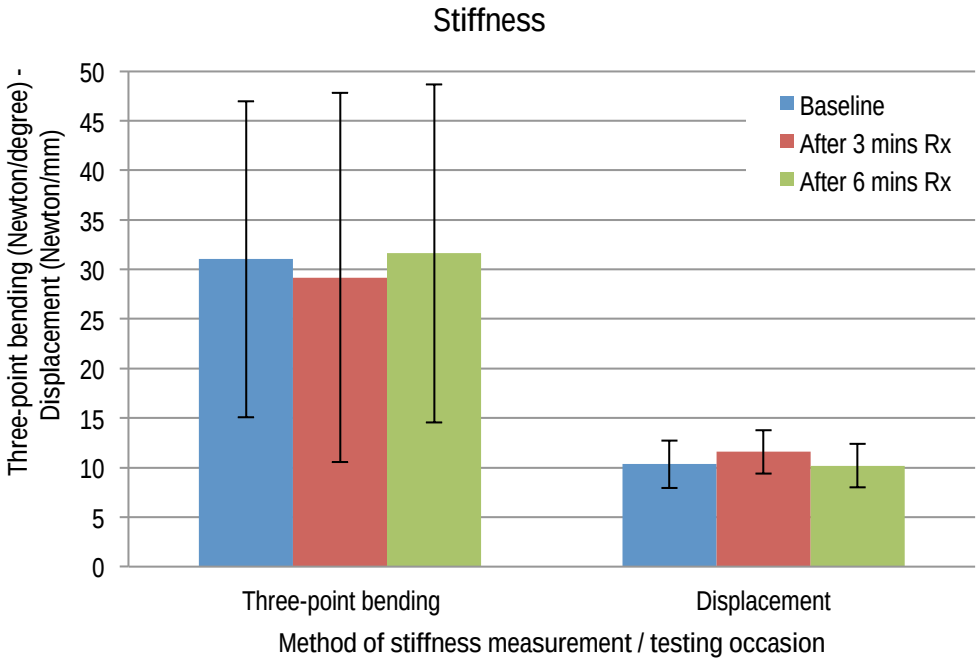


Figure 6.3. Stiffness at baseline and after 3 and 6 minutes of mobilisation treatment. The data are means. Error bars represent +/- standard deviation, n=14.

To enable comparison between changes using displacement and three-point bending methods of stiffness measurement (which are in different units of measurement) percentage changes in stiffness after 3 and 6 minutes of treatment are presented in Table 6.6. For change after 6 minutes of treatment 1 additional data set was included as this was not affected by the error in synchronisation.

	Three-point bending. % change after 3 minutes Rx n=14	Three-point bending. % change after 6 minutes Rx n=15	Displacement % change after 3 minutes Rx n=14	Displacement. % change after 6 minutes Rx n=15
Mean	-0.3	6.3	15.9	-1.1
SD	41.2	33.8	27.2	22.8
Range	161.8	129.1	94.8	96.0

Table 6.6. Percentage change in three-point bending and displacement stiffness values after 3 and 6 minutes of treatment. The data are means, standard deviation (SD) and range.

The Pearson's correlation using baseline data revealed that there was no correlation between three-point bending and displacement measurements (p=.17, r=0.38). See Appendix 10. To assess responsiveness to treatment correlations were also performed on the percentage change following 3 and 6 minutes of treatment. There was no correlation between percentage change in three-point bending and displacement methods of measuring stiffness after 3 minutes of treatment (p=.75, r=0.09), (Appendix 10), however there was a significant positive correlation between the percentage changes in three-point bending and displacement measurements after 6 minutes of treatment (p<.01, r=0.69), (Figure 6.4 and Appendix 10), demonstrating that following 6 minutes of mobilisation treatment, percentage change in three-point bending increased as percentage change in displacement also increased.

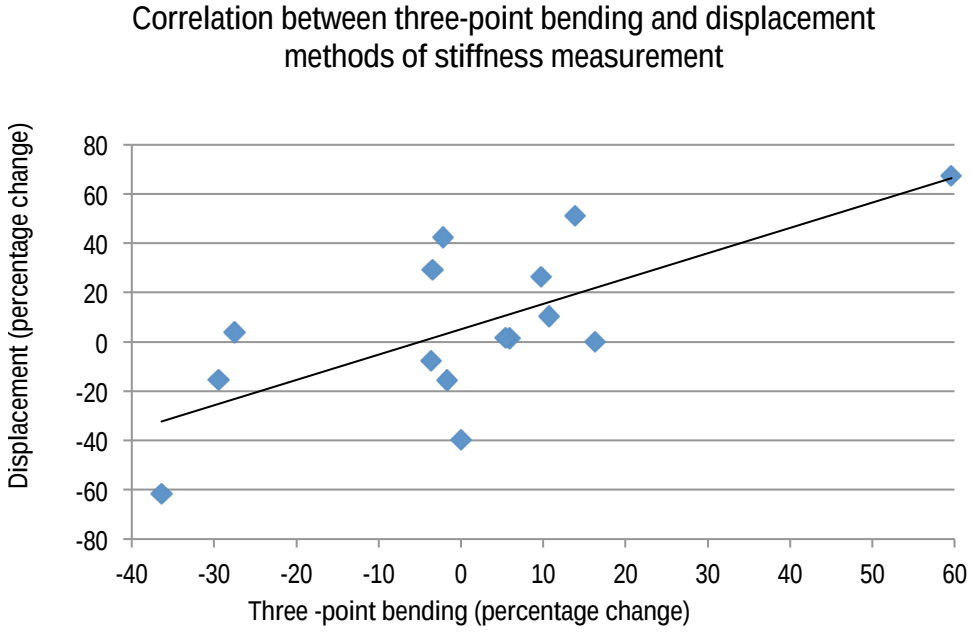


Figure 6.4. Scatter plot demonstrating positive correlation between the percentage changes in three point bending and displacement measurements after 6 minutes of treatment (p<.01, r=0.69), n=15.

6.4.3. Results for pressure pain thresholds

One set of data was excluded as an operational fault had resulted in the loss of three readings (for one participant). PPT data sets were not normally distributed and therefore the data was transformed using Logarithms (Lg10). Re-testing for normality revealed that minor deviations from normality were found (Appendix 8).

The two-way ANOVA revealed that duration of treatment had a significant effect on PPT ($F_{2, 30}$=19.02, p<.01). See Appendix 11. Bonferroni pairwise comparisons demonstrated significant difference between baseline and 3 minutes of treatment (p<.01) and baseline and 6 minutes of treatment (p<.01) see Appendix 11. There was no significant difference between 3 and 6 minutes of treatment (p=.72). See Figures 6.5 and 6.6.

There was a significant site*duration interaction effect ($F_{14, 210}$=1.79, p=.04). Post hoc testing was performed to establish the effect of both durations at each site. Compared to baseline a significant effect was observed following both 3 and 6 minutes of mobilisation at the symptomatic and T10 paravertebral, and the L2, L4 and L5 dermatome sites. At the L3 dermatome site there was a significant change in PPT following 6 minutes of mobilisations. No significant changes were observed at the deltoid or S1 dermatome sites (Figures 6.5 and 6.6).

Planned covariate adjustment for Oswestry disability, GHQ28 and SOPA questionnaire results demonstrated that the variance in PPT did not alter with covariate adjustment.

At all sites PPT measurements after treatment exceeded baseline values (Figures 6.5 and 6.6). The largest mean difference in PPT between measurements was observed at the paravertebral muscle site adjacent to the level of treatment. At all sites except S1 and L4 dermatomes mean PPT measurements were greater after 6 minutes of treatment than after 3 minutes of treatment. Previous studies often report percentage changes and to enable comparison these are presented in Table 6.7.

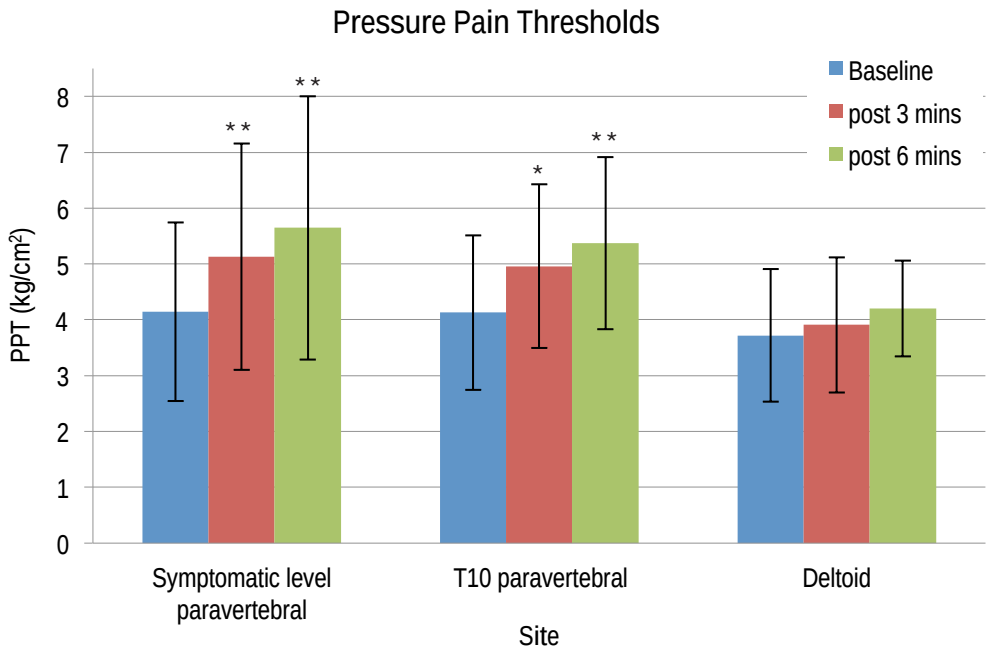


Figure 6.5. PPT at baseline and after 3 and 6 minutes of mobilisation treatment. The data are means. Error bars represent +/- standard deviation.
* p< .05 versus baseline, ** p< .01 versus baseline n=16

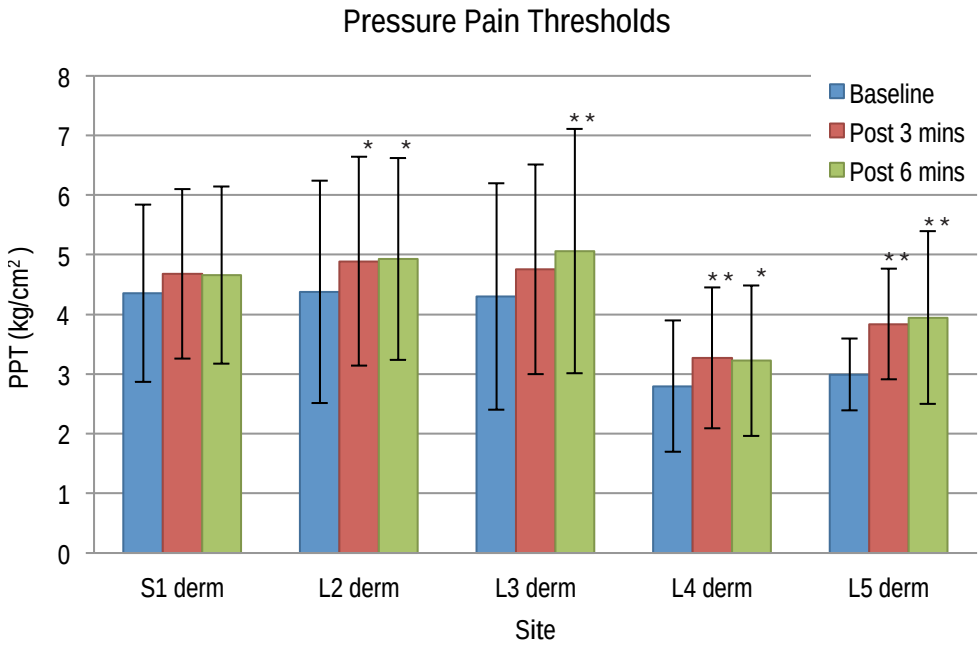


Figure 6.6. PPT at baseline and after 3 and 6 minutes of mobilisation treatment. The data are means. Error bars represent +/- standard deviation.
* p< .05 versus baseline, ** p< .01 versus baseline. Derm=dermatome n=16

	% change mean (SD) 3 mins Rx (n=16)	% change mean (SD) 6 mins Rx (n=16)
Sympt paravertebral muscle	31 (36.1)**	46.5 (54.7)**
T10	25.2 (36.4)*	34.8 (36.6)**
Deltoid	8.0 (22.1)	21.7 (39.1)
S1	14.7 (36.2)	13.4 (31.6)
L2	15.8 (33.3)*	16.7 (23.0)*
L3	14.9 (24.1)	21.2 (24.0)**
L4	19.8 (18.6)**	17.7 (26.8)*
L5	29.7 (24.0)**	30.9 (33.9)**

Table 6.7. Percentage change in PPT at each site after 3 and 6 minutes of treatment.
* $p < .05$ versus baseline, ** $p < .01$ versus baseline.

Cumulative proportion of responders' analysis (Figure 6.7) demonstrated that at the symptomatic paravertebral PPT site, approximately 80% of participants had increased PPT immediately following treatment. 40% had an increase in PPT of approximately 50%; this was similar for both 3 and 6 minutes of mobilisations. Following 3 minutes of treatment 14, and following 6 minutes of treatment 15 of the 16 participants and were classified as responders (Table 6.8).

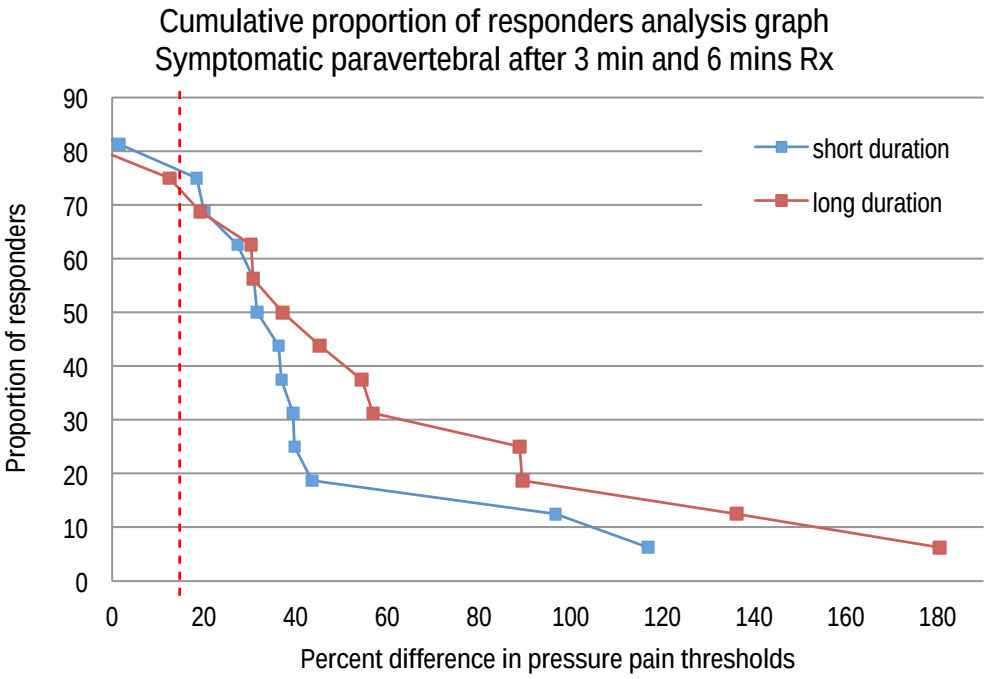


Figure 6.7. Cumulative proportion of responder analysis for PPT at the symptomatic paravertebral level following 3 and 6 minutes of treatment. n=16. Vertical line represents clinically relevant change (>15%).

Number of participants =16	3 minutes treatment	6 minutes treatment
Increase exceeding SEM	11	9
Increase exceeding MDC	3	6
SEM and MDC combined	14	15
Greater than 15% increase	12	11

Table 6.8. Number of responders to treatment based on changes in symptomatic paravertebral PPT.
SEM= number of participants with change greater than standard error of measurement;
MDC= number of participants with change greater than minimal detectable change;
%= number of participants with change greater than 15%.

In summary these results demonstrate that a mobilisation treatment may have a hypoalgesic effect as measured by PPT, however there was no difference between 3 and 6 minutes of treatment. The change in PPT was not observed at all sites.

6.4.4. Results for verbal ratings of pain

Participants' verbal rating of pain for each physiological movement are presented in Figure 6.8. After 3 minutes of treatment 10 of the 17 participants experienced an overall reduction in verbal rating of pain on movement. After 6 minutes treatment 14 participants experienced an overall reduction in verbal rating of pain on movement. Three participants reported an increase in VRS after 3 minutes and 2 experienced an increase after 6 minutes of treatment.

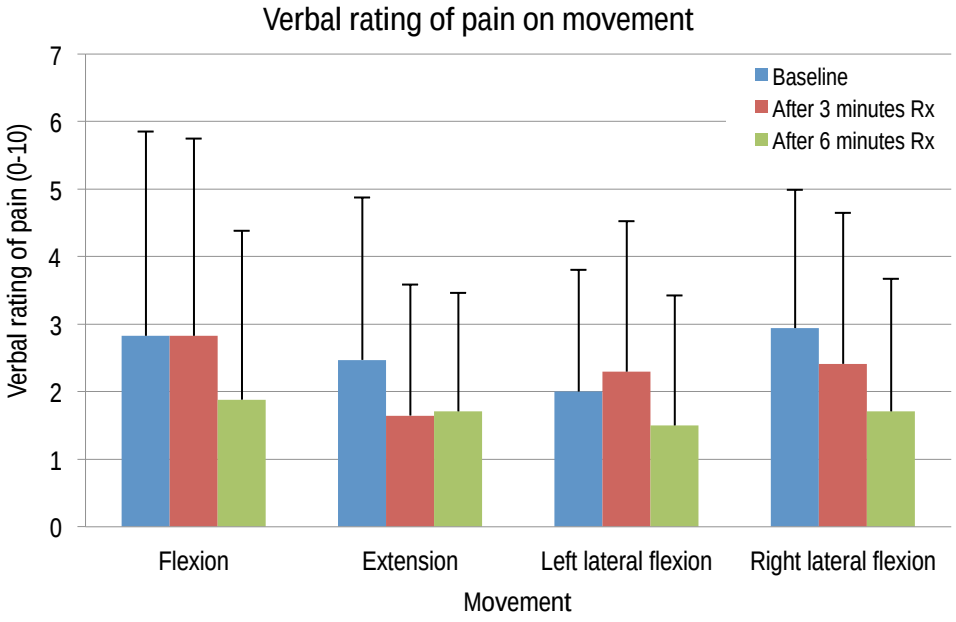


Figure 6.8. Verbal rating of pain on movement.
The data are means. Error bars represent + standard deviation (n=17).

Normality testing of VRS revealed that minor deviations from normality were present. Observation of the data suggested that this was due to an outlier (see scatterplot in Appendix 8). For these reasons the data was not transformed. The total score of pain on movement (for all movements combined) was used in the ANOVA for VRS of pain on movement.

There was a significant main effect of duration of treatment on VRS of pain on movement ($F_{2, 30}$=7.09, p<.01). Pairwise comparisons revealed that a significant decrease in verbal rating of pain occurred between baseline and 6 minutes of treatment (p<.01) and between 3 and 6 minutes of treatment (p=.03). Relative to baseline there was no significant change in VRS following 3 minutes of treatment (p=1.00). This demonstrated that 6 minutes produced a significantly greater reduction in pain on movement than 3 minutes of treatment. Furthermore 6 minutes of treatment was required to produce a significant reduction in verbal rating of pain on movement.

Planned covariate adjustment for Oswestry disability, GHQ28 and SOPA questionnaires demonstrated that the variance in VRS of pain on movement did not alter with covariate adjustment (Appendix 12)

Cumulative proportion of responders' analysis (Figure 6.9) demonstrated that over 60% of participants receiving 3 minutes of treatment and over 85% of those receiving 6 minutes of treatment experienced a decrease in pain on movement. The number of responders to 3 and 6 minutes of treatment for individual and summed VRS scores is shown in table 6.9.

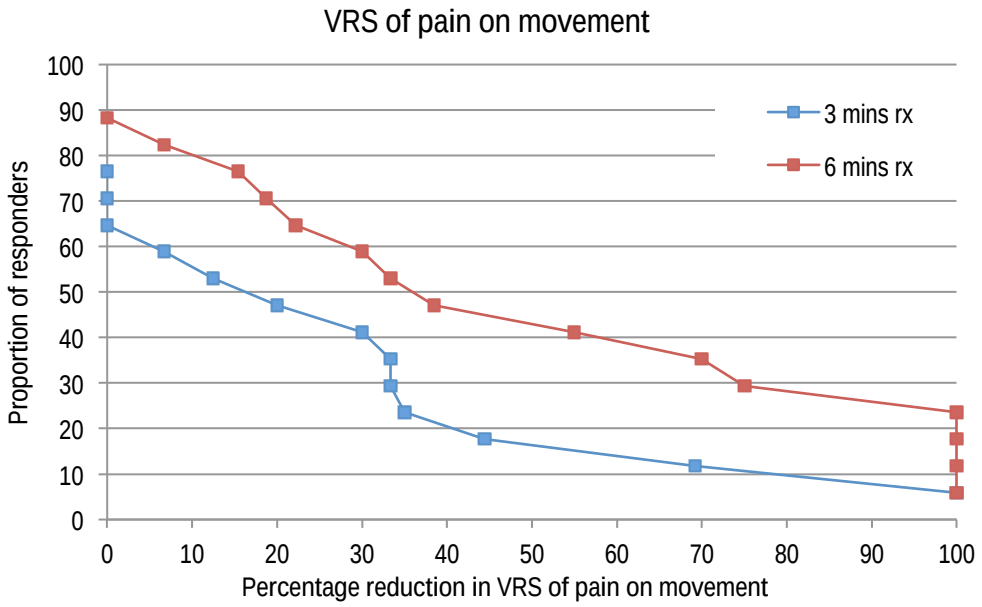


Figure 6.9. Cumulative proportion of responder analysis for verbal rating of pain on movement following 3 and 6 minutes of treatment (n=17).

Number of participants = 17	3 minutes treatment	6 minutes treatment
Flexion	5	7
Extension	7	6
Right lateral flexion	4	9
Left lateral flexion	4	8
Total VRS (sum of VRS on all movements)	10	14

Table 6.9. Number of participants who had a positive response to treatment, based on changes in VRS of pain on movement of 1 or more. Numbers are shown for individual movements and for combined VRS of pain.

Verbal rating of pain of the application of PA force to the symptomatic spinal level are presented in Figure 6.10. Importantly 6 out of the 17 participants did not experience any pain on application of PA force at baseline, so in these participants no improvement was possible. Mean VRS scores were less on the application of PA force after 3 and 6 minutes of treatment than at baseline (Figure 6.10). After both 3 and 6 minutes of mobilisation treatment 8 out of 17 participants experienced less pain on the application of a PA force and 1 experienced an increase. Relative to baseline mean VRS reduced by 0.9 (SD 2.7) after 3 minutes and 1.0 (SD 2.1) after 6 minutes of treatment.

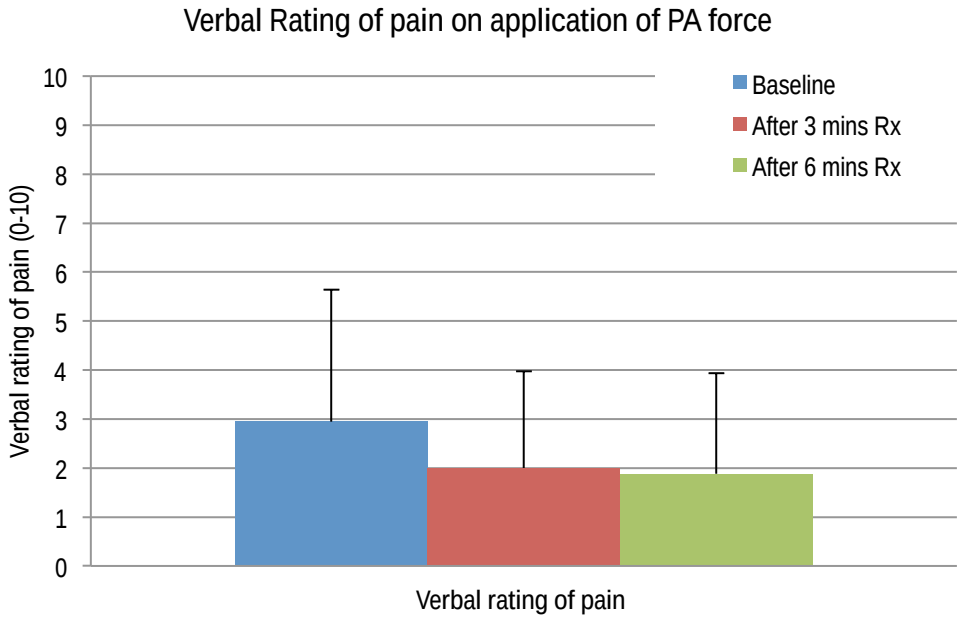


Figure 6.10. Verbal rating of pain on application of PA force.
The data are means. Error bars represent + standard deviation

Mauchly's test demonstrated that sphericity could not be assumed so the Greenhouse-Geisser was used to correct for violations of sphericity. ANOVA suggested that there was a significant difference in VRS of pain on the application

of a PA force to the most symptomatic level ($F_{1.2, 18.02}$=5.65, p=.02). However posthoc correction for multiple comparisons revealed that no significant differences occurred between baseline and 3 minutes of treatment (p=.07) or between baseline and 6 minutes of treatment (p=.06).

Planned covariate adjustment for Oswestry disability, GHQ28 and SOPA questionnaires demonstrated that the variance in VRS of pain the application of PA force did not alter with covariate adjustment (Appendix 13).

6.4.5. The relationship between change in PPT and change in VRS.

Correlations established that there was dissociation between change in PPT and change in verbal rating of pain on movement (change from baseline to 3 minutes treatment p=.83, r=.75, change from 3 minutes to 6 minutes of treatment p=.60, r=.14, change from baseline to 6 minutes of treatment p=.22, r=-.33) (see Appendix 14). Due to the large number of participants with no pain on the application of PA force at baseline, correlations were not performed with VRS of pain on PA force and PPT.

6.4.6. Summary of findings

- 6 minutes of mobilisation treatment was required to produce a significant reduction of pain on movement, producing significantly greater reduction in pain relative to baseline than 3 minutes of treatment.
- 3 and 6 minutes of mobilisation treatment both resulted in significant increases in PPT relative to baseline indicating a hypoalgesic effect. There was no overall difference between durations. However there was a significantly greater reduction in PPT at the L3 dermatome site after 6 minutes of mobilisation compared to 3 minutes of mobilisation treatment.
- The increase in PPT was not evident at all sites. Changes at the S1 dermatome and deltoid muscle site failed to reach significance.
- The greatest percentage changes in PPT were at the paravertebral muscles sites local to the site of treatment.
- There was dissociation between PPT and VRS of pain on movement.
- The effects of 3 and 6 minutes of mobilisation treatment on verbal rating of pain of the application of PA force to the symptomatic level failed to reach significance.
- The effects of 3 and 6 minutes of mobilisation treatment on ROM and stiffness failed to reach significance.

6.5. Discussion

6.5.1. Discussion of the effects of mobilisation on lumbar range of movement

There was no significant change in ROM relative to baseline with either 3 or 6 minutes of treatment. This is in agreement with most of the published literature, which has found that mobilisations do not have an effect on range of physiological movement (Petty 1995; Goodsell et al., 2000; Chiradejnant et al., 2002). Although two studies have found an increase in extension these applied mobilisations to all lumbar levels resulting in longer treatment durations of 7 and 9 minutes (Powers et al., 2008; McCollam and Benson, 1993). Although the duration used in this study was not as long, the results suggest that duration of treatment may not be the factor. It could be that the reported change in range occured when treating multiple spinal levels. This is the first study to report the effects of different durations of treatment on ROM.

The variation in mean ROM ranged from 1° - 5.8°. The largest difference in mean range relative to baseline was in right lateral flexion which demonstrated the poorest reliability and greatest measurement error in the reliability study (chapter 5); the minimum detectable change (MDC) reported in the reliability study was 7.5°. The variation in ROM measurements is similar to that reported in other studies investigating the response to mobilisation treatment (Power et al., (2003) reported a 3.6° increase and McCollam and Benson, (1993) a 2-3° increase in ROM after treatment). These variations in measurement following treatment are small and are likely to be due to measurement error. This is confirmed by comparing the effect size to the MDC reported in the reliability study (chapter 5, page 65).

6.5.2. Discussion of the effects of mobilisation on stiffness

Relative to baseline there were no significant differences in stiffness after 3 or 6 minutes of treatment using either three-point bending or displacement methods of measurement. This is in agreement with most previous studies investigating the effect of mobilisation treatment on lumbar spine stiffness (Latimer et al., 1996b; Stamos-Papastamos et al., 2011). Conversely studies led by one author, using the three-point bending method, found a reduction in stiffness following mobilisations in both symptomatic and asymptomatic populations (Shum et al., 2013; Lee et al., 2005b). One study is only available in poster format allowing limited evaluation (Lee 2005b). The later study (Shum et al., 2013), compared the immediate effects of mobilisation treatment on pain and stiffness in asymptomatic participants and participants with LBP (and thus did not include a placebo-control group). A greater reduction in stiffness following treatment in participants with LBP was reported. However participants with LBP had higher

pre-treatment stiffness values and there is no mention of correction for baseline differences. Furthermore the LBP patients received a higher force of treatment (121N as opposed to 105N in the asymptomatic participants). Another difference in the study by Shum et al., (2013) is the high values over which stiffness was calculated (50-250N). Previous studies have calculated force over various ranges but mostly with a peak force of 100N or less (see Table 3.3, page 35 for further information). The application of 250N of force is likely to have elicited a pain response in participants with LBP – this may have resulted in increased muscle activity or the participants tensing, explaining the higher baseline stiffness levels.

The mean difference in three-point bending measurements between testing occasions was -1.86N/degree following 3 minutes of treatment and 0.60 N/degree following 6 minutes of treatment. Using the same method Stamos-Papastamos et al., (2011) reported a larger but also insignificant mean change of 4.27 N/degree. The corresponding range of variation in measurements was very large, 48.46 N/degree (after 3 minutes) and 58.62 N/degree (after 6 minutes). This was equivalent to a range of 161.77% difference following 3 minutes of treatment and a range of 129.11% difference following 6 minutes of treatment. It is possible that the low mean difference in stiffness was caused by a wash-out effect created by some participants experiencing an increase in stiffness following treatment whilst others experienced a decrease in stiffness following treatment. Alternatively the differences could be caused by measurement error.

The mean difference in displacement measurements between testing occasions was 1.25N/mm following 3 minutes of treatment and -0.16N/mm following 6 minutes of treatment. This is similar to that reported by Goodsell et al., (2000) who reported a -0.31N/mm change after 3 minutes of mobilisations. The corresponding range of change was smaller than that for three-point bending (9.60N/mm and 10.05 N/mm) – equivalent to a 94.78% range after 3 minutes and 96% range after 6 minutes. The difference in range and standard deviation of measurements and the discrepancy between the percentage changes suggests that the two measurement methods may not be measuring the same behaviour.

6.5.3. Comparison of three-point bending and displacement stiffness measurements.

Previous work in this thesis (section 4.4.11. and section 5.5.2.) cast doubt over the validity of three-point bending stiffness measurement. The reliability study (chapter 5) reported an association between three-point bending and displacement stiffness measurements. In order to further consider the validity

of stiffness measurements this study evaluated responsiveness to mobilisation treatment by comparing synchronised measurements of three-point bending and displacement measurements of spinal stiffness at baseline and after treatment. There was no significant correlation between baseline measurements of three-point bending and displacement. This is contradictory to the association between measures reported in an asymptomatic population (chapter 5).

To explore responsiveness to treatment percentage change figures from this study were correlated. There was dissociation between percentage change in three-point bending and displacement following 3 minutes of treatment, but percentage change was associated following 6 minutes of treatment. The variability in the association between three-point bending and displacement measurements reported in this study could be due to random variation of measurements. Additionally the varying association between measurements taken using the two methods suggests that three-point bending and displacement are not necessarily measuring the same behaviour. This is further supported by the large differences in between-subject variability observed with three-point bending (evident from the large range and standard deviation of measurements), compared to much smaller (although still relatively large) between-subjects variability with displacement. Comparison of the range of percentage change with the two methods also shows a marked difference, again suggesting that they are not measuring the same behaviour.

None of these results clarify whether three-point bending or displacement is the best method for measuring stiffness, however the displacement method is similar to the procedure performed by physiotherapists assessing spinal stiffness so may have more face validity than three-point bending. Furthermore the displacement method of measuring stiffness could be considered to be more experimentally robust as there is only one sensor that is securely mounted on the indenter. With the three-point bending method 2 sensors are placed on the spine and may be accidently moved or loosened during the application of mobilisation without the researcher becoming aware. Reliability of the displacement method (chapter 5) may be improved with the use of a mechanically driven indenter to ensure standardisation of rate and maximum mobilisation force. This method has been reported to be reliable in previous research (Latimer et al., 1996b).

Observation of the electromagnetic sensors movement during testing casts doubt over the assumptions underpinning the three-point bending method of stiffness measurement. As explained in section 3.2.2 (page 32) three-point bending theory uses engineering equations for beam bending. A stiffness value is calculated linking the PA force, the rotation of the sensors and the measurements of the ‘beam length’, in this case the distance between the sensors and the point of force

application. This engineering theory hinges on a number of assumptions. These assumptions are as follows; that the spine is supported only at either end by the rib cage and pelvis; there are no significant horizontal compressive forces (Lee and Evans, 1994), and that the slope and deflection of the beam are very small. In order to accept this mathematical model the appropriateness of these assumptions warrants scrutiny.

Kulig et al., (2004) used MRI to investigate intervertebral movement during PA loading and found that the application of force produced movement in consecutive segment. This motion was found to propagate caudad and cephalad – Kulig et al., (2004) claimed that this was not the way predicted by the three-point bending model, which would predict that the amount of movement was greater at the target vertebra with less motion at adjacent segments.

The engineering model describes the lumbar spine as a beam supported at either end by the pelvis and thoracic cage; this assumes that the abdomen provides little or no support or resistance to PA loading (Lee and Evans, 1997). However, the BMI of a typical population would mean that in many individuals, the 'beam' described by Lee et al., (2005a) would be supported centrally by the abdomen in addition to the support at either end. Therefore the three-point bending theory may only be applicable on slight individuals.

Furthermore, the thoracic end of the beam was assumed to be a pin joint. This assumption of the three-point bending theory was based on pilot work which reported that no significant movement occurred at the thoracic cage during the application of a mobilisation force (Lee et al.,2005a). However the contribution of movement of the thoracic cage has been demonstrated experimentally by Chansirinukor et al., (2003) who investigated the difference in stiffness (using the displacement method) on PA loading to T12 to L4 when the thoracic spine was unconstrained and when it was constrained in a clamping device. Stiffness significantly increased with a constrained thoracic spine irrespective of the level tested. Moreover Caling and Lee, (2001) reported 1.1 – 1.4 degrees of thoracic rotation during the application of a PA force; although clinically this is a small amount of rotation it may not be considered small in mathematical terms. The predictability of pelvic movement is also questionable as demonstrated by Caling and Lee, (2001) who investigated the influence of direction of PA force applied to L5 and found a significant linear trend for sacral rotation to decrease as the direction of application changed from cephalad to caudad. Importantly pelvic rotation changed from anterior rotation when forces were directed more cephalad to posterior rotation when forces were applied caudad. This would mean that the three-point bending method is not an appropriate model for forces applied

in a caudad direction. A number of the current studies measuring stiffness at L5 have used a caudad force (Goodsell et al., 2000; Shirley et al., 1999; Lee et al., 1998), which may not have produced three-point bending. Therefore, if all other assumptions are accepted it may be that three-point bending will only occur in response to forces angulated in a cephalad direction.

Another assumption of the three-point bending method is that there are no significant horizontal compressive forces. However in order for the individual vertebra and intervening discs to form a beam some horizontal compressive force would be necessary. The acceleration of the vertebrae during mobilisation was also assumed to be negligible (Lee and Evans, 1994). This is an assumption that remains untested. It is also assumed that slope and deflection of the beam were very small. Yet due to the structure of the lumbar spine vertebrae and intervening discs, and measurable intervertebral movement on PA loading, deflection is likely.

The concerns regarding the movement of the sensors and the safety of the assumption underpinning three-point bending theory suggest that the displacement method of stiffness measurement is preferable for future research. Furthermore this method does not represent how physiotherapists assess stiffness and in terms of measuring the stiffness that therapist perceive it lacks face validity.

6.5.4. Discussion of pain related measures

The main analysis found that there was a significant increase in PPT with both 3 and 6 minutes of treatment relative to baseline. The difference between durations failed to reach significance. The cumulative proportion of responder analysis (Figure 6.7) suggested that a slightly greater proportion of participants responded to a slightly greater increase in PPT with the longer duration of treatment. However as seen in Table 6.8 a similar number of participants experienced clinically meaningful changes with both 3 and 6 minutes of treatment, with most participants experiencing a clinically meaningful increase in PPT after both 3 and 6 minutes of treatment. This suggests that there is no additional change in PPT when applying mobilisations for longer than 3 minutes.

There was a 33% change in PPT at the symptomatic level, paravertebral muscle site, after 3 minutes of treatment. This is similar to that reported in previous studies (Sterling et al., 2001 and Vicenzino et al., 2000). The percentage change after 6 minutes was greater than that reported previously. However these values should be interpreted with caution, as although previous studies examining the effects of mobilisation have reported percentage change, often in the absence of reporting actual change values. This may be slightly misleading as demonstrated by the results of the current study, where despite their being a small actual change in PPT

in the paravertebral muscles (1kg/cm^2 after 3 minutes of treatment and 1.5Kg/cm^2 after 6 minutes), it was equivalent to a 31% change (SD 36.1) after 3 minutes and a 46.5% change (SD 54.7) after 6 minutes.

Post-hoc analysis revealed that significant analgesic effects were not evident at all PPT sites (Figures 6.5 and 6.6). Three minutes of mobilisations resulted in a significant difference at the paravertebral muscle PPT sites (both at the level of symptoms and at T10) and the L2, L4 and L5 dermatome sites. A further 3 minutes of treatment (6 minutes) resulted in significant changes also occurring at the L3 dermatome site. The differences at the S1 dermatome and deltoid site failed to reach significance. The greatest percentage changes were at the paravertebral muscle PPT sites, local to the site of treatment. These results suggest that analgesia is at least in part mediated by local rather than systemic analgesic mechanisms. The participants in this study were treated at the L1, L4 and L5 levels. Although signature zones were affected at dermatomal levels where treatment was not applied, this can be explained by the variability in and overlap between dermatomes (Nitta et al., 1993). Furthermore PA mobilisations have been shown to create movement throughout the lumbar spine (Lee and Evans, 1992), so a local, segmental analgesic effect, stimulated by the movement created through the lumbar spine may be evident at more than one level. The mechanism likely to be responsible for the analgesic effect observed in this study is the pain gate mechanism. Previous studies would support this hypothesis; Malisza et al., (2003) found that mobilisation of the knee in rats produced increased activity in areas of the spinal cord associated with pain (measured by MRI). Mobilisations have also been found to have a localised effect on temporal summation, suggesting inhibition of C-fibre activity in the dorsal horn of the spinal cord (George et al., 2006). Although widespread changes in PPT following mobilisation to the lumbar spine have been reported (Krouwel et al., 2010; Willett et al., 2010), these were conducted in asymptomatic participants.

These findings provide inconclusive evidence regarding the extent of the analgesic effect resulting from mobilisations but suggest a local or segmental, as opposed to a systemic, treatment effect. This casts doubt over the extent to which the hypoalgesia associated with mobilisations is mediated by higher centres in the brain such as the Periaqueductal Gray (and associated areas) as suggested previously (Wright, 1995 and Sterling et al., 2001). As discussed in section 2.10.2., descending inhibition of pain was proposed based on increases in SNS activity following mobilisations, which was also observed when stimulating the Periaqueductal Gray area in rats.

6.5.5. Discussion of the effect of mobilisation duration on verbal rating scales of pain.

Relative to baseline there was no significant decrease in participants rating of pain on movement after 3 minutes of treatment, but there was a significant change relative to baseline after 6 minutes of treatment. The difference between 3 and 6 minutes of treatment was significant. These results demonstrate that 6 minutes of mobilisation treatment was required to produce a significant reduction of pain on movement – producing significantly greater reduction in pain relative to baseline than 3 minutes of treatment.

Pain on movement scores (combined for all movements) reduced by 1.1 (SD 5.1) points on an 11-point VRS after 3 minutes of treatment and reduced by 3.4 (SD 4.3) points after 6 minutes of treatment. These changes are similar to those reported previously; Sterling et al., (2001) reported a 0.34 (SD 0.02) decrease of pain on neck rotation following 3 minutes of mobilisation to the cervical spine and Goodsell et al., (2000) reported a 13.4mm (SD 13.3) on a 100mm scale after 3 minutes of mobilisation treatment to the lumbar spine. Previous studies have calculated clinically meaningful changes in VRS. These values range from 1.5-2 depending on the population (Rowbotham, 2001). The mean effect of 6 minutes of treatment in the current study exceeded these values which suggests that the change may be attributable to treatment.

Relative to baseline there was no significant decrease in pain during the application of PA force to the symptomatic level. The low baselines scores may have contributed to this finding, as 6 of the 17 participants had no pain on the application of PA force at baseline so no improvement in VRS was possible for these participants. Mobilisations may have a greater effect on pain on the application of PA force in a population suffering from more severe symptoms.

6.5.6. Discussion of the relationship between verbal rating scales of pain and PPT.

There was dissociation between participants' verbal rating of pain on movement and PPT values. Although a change in PPT suggests that an analgesic mechanism has been stimulated, clinically changes in patient reported pain measures are of upmost importance. Sterling et al., (2001) also found dissociation between VRS and PPT in patients with neck pain. Despite these findings PPT are widely used to demonstrate pain relief in both symptomatic and asymptomatic participants. Further investigation would help to establish the relationship between PPT and patient reported outcomes and is an important area for future research.

6.5.7. Discussion of prediction of responders to treatment

It is well recognised by researchers and clinicians alike that not all patients

respond to mobilisation treatment. This has resulted in a number of studies investigating clinical prediction rules (factors which may predict individual patient's response to mobilisation). The large between-subject variability in percentage change has been recognised in previous studies (Willett et al., 2010). It has been suggested that 15% change in pain represents a clinically significant change (Salaffi et al., 2004). For this reason those participants who experienced a greater than 15% change in PPT are highlighted in Table 6.8. Nearly all of the participants in this study experienced a clinically significant change in PPT local to the site of treatment following both 3 and 6 minutes of mobilisation treatment.

Previous work has attempted to predict which patients will respond to mobilisation treatment but is inconclusive (Haskins et al., 2012 and Kamper et al., 2010). During the current study the results of the questionnaires were added as covariates to take into account the variance in change in pain that was attributable to these factors and thus establish whether they could be prognostic factors. The questionnaire results did not have an influence on pain and these factors could not be considered to be prognostic of the effects of mobilisation treatment on PPT or verbal rating of pain.

6.5.8. Study limitations

A single arm design was chosen as the effect of duration has not been previously investigated and it was important to establish whether duration had an effect before progressing to a randomised controlled trial. The single arm design does not rule out bias, regression to the mean or natural resolution of symptoms (although this is unlikely in this study because this study was investigating the immediate treatment effects in participants with a long history of LBP (mean 12.25 years)). Furthermore due to the single arm design, the temporal effect of the 3-minute period of mobilisation may have influenced the measurements after 6 minutes. Due to these limitations, a subsequent study was conducted incorporating a control group and removing the temporal element of the different durations of treatment and is reported on in the following chapter.

Because this was the first study to investigate the effect of different durations of mobilisation treatment the sample size calculation was based on the difference between treatment and no treatment, as opposed to between two different treatments. This may have resulted in the study being underpowered; this would have been particularly likely for the covariate adjustment. Retrospective power analysis based on the results from the current study suggested that 36 participants would be required to achieve sufficient power to detect a main effect of duration. Sample size calculations based on the difference between treatment duration reported in this study were used in the design of a subsequent study reported on in the following chapter.

Only the immediate changes in pain measures were investigated in this study. The longer-term effects have not been studied. The clinical relevance of findings would be enhanced if measures were obtained over a longer period following treatment. Furthermore there is empirical evidence which suggests that some patients demonstrate initial soreness but report improvement in their symptoms 24-48 hours after treatment. Future work should aim to look at the mid- and longer-term effects of mobilisation treatment. The following study, reported on in chapter 7, has reported on the analgesic effects of mobilisation 24-hours after treatment.

During this study all mobilisations were applied centrally to the spinous process irrespective of the area of symptoms and whether a central or unilateral mobilisation maximally reproduced the participants' symptoms. This did not reflect clinical practice where the most symptomatic site and orientation of mobilisation would be applied (where the symptoms are non-severe and non-irritable). This standardised approach to choice of mobilisation may have influenced the effect of treatment. Future work should consider using a pragmatic choice of both technique and direction of mobilisation and is further considered in the study reported on in chapter 7.

Because this study recruited a population of participants who were not currently undergoing treatment for their LBP, many potential participants did not experience pain on simple movements of the lumbar spine and thus were excluded from the study. Those included often reported low ratings of pain on movement and the application of PA force to the symptomatic level. Indeed 6 of the participants who experienced pain on the application of PA force to the spine on the initial assessment did not report any symptoms when force was applied on their second attendance. Future work should consider using a population with more severe symptoms and including the incorporation of pain on the application of pressure (overpressures) at the end of physiological movement.

6.6. Key learning point from the single-arm trial

Conducting the single-arm trial identified that neither 3 nor 6 minutes of mobilisations resulted in changes in lumbar range of movement or stiffness. For this reason these measurements were excluded from the final study in this thesis.

6.7. Conclusions

This study demonstrated that relative to baseline VRS of pain on movement was significantly greater with 6 minutes of treatment than with 3 minutes of treatment. Both 3 and 6 minutes of mobilisations resulted in a significant increase in PPT local to the site of treatment and in the signature zones of most lower limb dermatomes but not at a site unrelated to treatment. These findings suggest that the change in PPT is mediated via a local, segmental (as opposed to systemic) analgesic

mechanism. This is the first study to compare the effect of different durations of mobilisations in a symptomatic population and suggests that there may be a beneficial effect of applying longer durations of treatment than those advocated in clinical texts or investigated in previous research.

The dissociation between PPT and verbal rating of pain suggests that analgesia measured by PPT and patient report pain measures may be mediated by different analgesic mechanisms and highlights the need for inclusion of a number of different pain measures in order to gain a wide appreciation in change in pain experienced by patients.

This study found that neither 3 nor 6 minutes of mobilisations had an effect on range of movement and stiffness. This suggests that the immediate effects of mobilisations are predominantly neurophysiological. The following chapter reports on a randomised controlled trial which further explored the effects of mobilisation treatment on pain.

Chapter 7

A randomised placebo-controlled study investigating the immediate and 24 hour effects of mobilisation treatment duration on pain in participants with chronic LBP.

7.1. Introduction

The previous chapter in this thesis reported on a single-arm trial investigating the effects of 3 and 6 minutes of lumbar mobilisations on ROM, stiffness and pain in participants with chronic LBP. It was the first study to investigate the effects of different durations of mobilisations in a symptomatic population.

The single-arm trial found that 6 minutes of mobilisations was required to produce an analgesic effect as measured by a decrease in pain on movement. A hypoalgesic effect of mobilisations was also demonstrated by an increase in PPT. This was evident following both 3 and 6 minutes of treatment. There was dissociation between mobilisation-induced changes in PPT and changes in VRS of pain on movement. Since changes in PPT are often used to demonstrate an analgesic effect it was important to further investigate the relationship between these and patient reported changes in pain. This current study included a larger population of participants with LBP and as in the previous study measured PPT and verbal rating of pain on movement and on the application of PA force (applied to the most symptomatic spinal level) as well as incorporating additional patient reported outcome measures (verbal rating of pain at rest and global rating of perceived change). This study was also developed from the single arm trial by incorporating a placebo-control intervention and removing the temporal effects of one treatment duration on another.

The single arm trial measured the immediate effects of mobilisation. Anecdotal evidence suggests that some patients exhibit soreness immediately after treatment which is followed by a subsequent improvement of their symptoms (Maitland et al., 2005). However only one study has investigated the longer-term effects of a single dose of mobilisation treatment; in a placebo controlled study, Vicenzino et al., (1996) reported a significant reduction in the patients VRS of worst pain over the 24-hour period following 3 minutes of mobilisations to the cervical spine. The current study was therefore extended to measure the analgesic effect of lumbar mobilisations both immediately and 24 hours after application.

It is recognised that people respond to mobilisation treatment in different ways. For this reason there has been a move towards identifying factors that may predict patients response to mobilisation treatment (Childs et al., 2004). The single arm trial found that 80% of participants displayed a hypoalgesic response to mobilisations, demonstrated by increased PPT. However 20% experienced a decrease in PPT. Covariate analysis did not identify any predictor of mobilisation treatment outcome, however this may have been the result of the study being underpowered. Therefore this study continued to investigate the interaction between changes in pain and factors that may influence the analgesic response (such as disability, type of pain and pain attitudes).

It has been recognised that patients' expectations and experiences of pain are important. For example, a positive association between positive expectations and good functional outcomes has been reported previously (Kalauokalani et al., 2001). Specific to manual physiotherapy treatment, a study investigating the effects of expectations on the analgesic effects of manipulation treatment found that participants who were given negative expectations demonstrated hyperalgesia (an increase in pain) following treatment (Bialosky et al., 2008). This may suggest that participants who had low expectation of mobilisation treatment would experience an increase in pain following treatment and could explain the 20% of patients who experienced a decrease in PPT following mobilisations in the single arm trial. In order to explore the influence of participants' expectations and experience of receiving a mobilisation treatment this study incorporated a questionnaire asking participants about these factors.

In summary, although there is evidence that participants with neck pain experienced an immediate hypoalgesic effect following mobilisations, this remains un-investigated in participants with LBP. Furthermore there is limited evidence of the influence of duration of treatment on pain. Most studies have investigated the immediate post treatment period and the mid- to longer-term effects of a single treatment dose remain unknown. The need to identify predictors of treatment response has been identified but at present there is inconclusive evidence and this remains an area of on-going research. This study therefore set out to investigate the immediate and short-term effects of lumbar mobilisation on pain and identify factors which may predict response to treatment.

7.1.1. Research questions

1. What are the immediate effects of 1 and 6 minutes of lumbar mobilisation treatment on pain in patients with non-specific low back pain?
2. What is the effect of 1 and 6 minutes of treatment on pain at 24-hour follow-up?

7.1.2. Study aims

1. To establish the effects (immediately and after 24 hours) of a lumbar mobilisation treatment on PPT and patient reported pain measures in patients with non-specific LBP.

2. To establish whether 1 minutes or 6 minutes of mobilisation treatment produces a greater analgesic response.

3. To determine the extent of mechanical analgesia (using pressure pain thresholds) occuring after mobilisation of the lumbar spine (local, segmental or systemic).

4. To establish the relationship between changes in PPT and changes in patient reported pain measures.

5. To consider factors (demographics, anxiety and aspects of participants pain experience (pain description, disability due to the pain, pain beliefs and attitudes toward the pain)) which may predict patients' response to lumbar mobilisations.

6. To explore whether participants' expectations and experiences of receiving mobilisations influence their response to treatment.

7.2 Methods

7.2.1. Study design

This study employed a randomised placebo-controlled research design. A flow chart depicting the study design and participants journey through the study is shown in Figure 7.1. Two parallel groups (a short treatment duration group and a long treatment duration group), each received two interventions. The short duration treatment group initially received a placebo intervention consisting of 2 minutes of sham mobilisation followed by 1 minute of mobilisation treatment. The long duration treatment group received 2 minutes, followed by 4 minutes of mobilisation treatment. Participants were randomly allocated to either the short or long treatment duration group, using an online randomisation tool (Research randomizer.org).

Participants attended the laboratory on 3 occasions. Occasion 1 was conducted to enable a thorough exploration of the history of participants LBP to be gained through a subjective examination and for the symptomatic level to be identified through physical examination. Occasion 1 also allowed time for the completion

of questionnaires which collected information on factors (demographics, smoking and alcohol use, anxiety, and pain beliefs) which may have influenced participants response to treatment. Occasion 2 occurred at least 48 hours after occasion 1 to allow a washout period for any potential effects of the physical examination.

On occasion 2 all measurements were taken by a research assistant who exited the room whilst all treatment interventions were applied to ensure blinding to participants' group allocations. Baseline measurements were followed by two treatment periods with an intervening measurement period (see Figure 7.1). The first treatment period enabled a comparison of 2 minutes of sham mobilisation and 2 minutes of mobilisation treatment. The second treatment period enabled short and long durations of treatment to be compared. In treatment period 2, longer rest periods (see Figure 7.1) were incorporated for the short duration treatment group to ensure equitable treatment periods between groups.

Occasion 3 was conducted to establish the effects of mobilisations 24 hours after treatment. Measurements were taken by the research assistant (see Figure 7.1). Participants then completed a questionnaire on their expectations and experiences of receiving a mobilisation treatment. On completion of the study participants were given exercise and advice for their LBP.

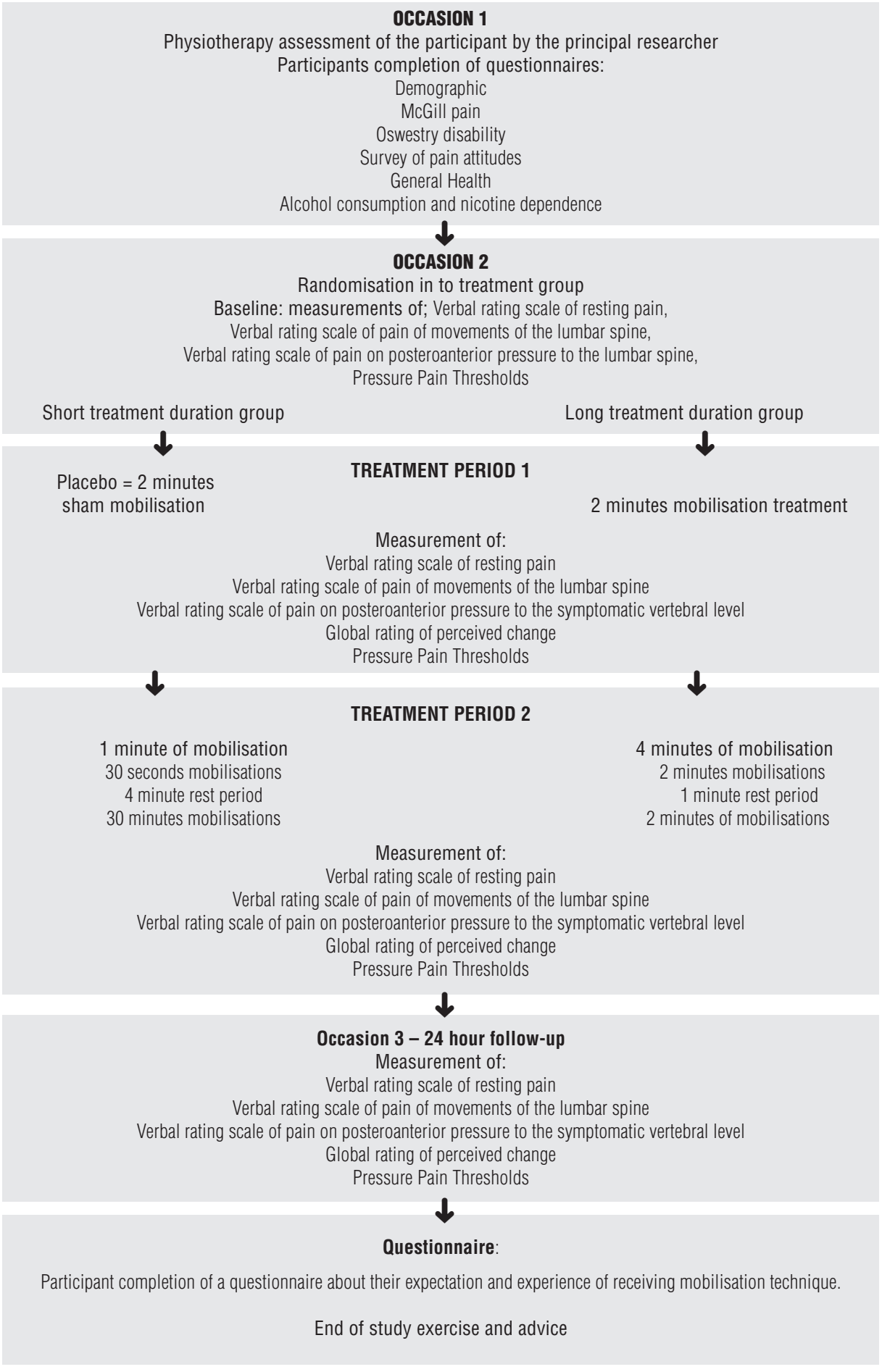


Figure 7.1. Participants journey through the study

7.2.2. Ethics approval

This study was approved by the Faculty of Health and Social Science Research Ethics and Governance Committee (FREGC) (for approval letter please see Appendix 2).

7.2.3. Participants

This study recruited a population with chronic low back pain. The power calculations performed using Minitab (version 16) were used to determine the required sample size for a power of 0.8 with a *p* value of .05. Calculations were made using the differences (mean difference 2.2kg and standard deviation (4.5kg)) between 3 and 6 minutes of mobilisation treatment reported in the previous study (chapter 6). Power calculation suggested a minimum sample size of 36 in each group. Recruitment posters were placed on university email and in local shops and community centres. Advertisements were also placed in local newspapers, on the website 'gum tree' (www.gumtree.com), in parent newsletters of local schools and through local church newsletters and intranet. Advertisement also occurred through word of mouth, for example, those participating in the study informed friends or colleagues about the study and provided them with the contact details of the principal researcher. Potential participants who contacted the researcher were sent a participant information sheet (Appendix 15) and a list of inclusion and exclusion criteria and to avoid coercion they were asked to contact the researcher again if they wished to take part. At this point an appointment was made for them to attend the Human Movement laboratory, Robert Dodd Annex, Eastbourne.

7.2.4. Inclusion criteria and exclusion criteria

Potential participants were required to be between 18-70 years of age, have experienced LBP for a minimum of 3 months and experience their symptoms on active movement.

Participants with precautions and contraindications to mobilisations were excluded from the study. This resulted in the following exclusion criteria:

- Spinal congenital abnormality
- History of spinal fracture
- History of malignancy
- Bone disease (osteoporosis, osteomyelitis, tuberculosis, Paget's)
- Inflammatory arthritis (rheumatoid arthritis, ankylosing spondylitis, gout)
- Congenital generalised hypermobility (Ehlers-Danlos syndrome)
- Advanced degenerative changes
- History of steroid therapy
- Pregnancy
- Current anticoagulant medication

- Pins and needles, tingling or numbness in the lower limbs
- Severe and / or irritable symptoms (symptoms which are so intense that they prevent the participant from moving, or which result in one movement producing lasting pain).

Potential participants were also excluded if they were undergoing current treatment for low back or leg pain (or had done so in the last 3 months).

7.2.5. Confidentiality

All participant information was kept confidential and only made available to the study investigator and supervisors. All participants were allocated with a code; to ensure anonymity all data was stored under that code, the key to which was kept on a password protected computer. To fulfil the requirements of the Data Protection Act 1998 all personal data was destroyed at the end of the study. Anonymised data will be kept for 10 years following completion of the study.

7.2.6. Instrumentation and measurements

PPT were measured using an electronic pressure algometer (Tracker computerised algometry system, JTECH medical industries, Salt Lake City, Utah) fitted with a $1cm^2$ tip. The algometer had an on-screen dial to facilitate the researcher in standardising the rate of application a patient control switch.

A verbal rating scale (VRS) was utilised to gain a score of pain intensity at the end of each physiological movement and on the application of PA force to the most symptomatic vertebral level. The VRS is a scale that is used extensively in clinical practice and requires patients to score their pain on a scale of 0-10; 0 no pain and 10 being the most pain imaginable. To assess participants' perceptions of the effect of their LBP a global rating of perceived change (GRPC) scale was utilised. The GRPC is an 11-point scale where 0 is on change, +5 is completely recovered and -5 is very much worse.

To measure the forces used in treatment, a lightly padded wooden plinth was mounted on non-conductive ground reaction force plates (AMTI OR6-7 – Advanced Mechanical Technology Inc., Watertown, MA, USA). The force plates indirectly measured the force applied by the therapist (Lee et al., 2005a). The researcher stood on a wooden platform with a lean bar (see Figure 4.1, page 53) to ensure that only the therapist's mobilising force was measured by the force plates.

7.2.7. Procedure

On each attendance participants attended the Human Movement Laboratory at the University of Brighton, Eastbourne site. They were greeted by the author and led to a screened area.

7.2.8. Occasion one procedure

On the first occasion participants received a verbal explanation of the study and were given an opportunity to ask questions. Participants were asked whether they would still like to participate before being asked to sign a consent form. This was followed by a physiotherapy assessment conducted by the researcher. The assessment was conducted to ensure that participants met the inclusion criteria (of pain on active movement, with or without overpressure) and determine the vertebral level(s) from which their symptoms were arising (see Appendix 6). This assessment was typical of the assessment performed by physiotherapists in clinical practice (Petty, 2011). Past medical and drug histories were also taken to ensure that participants had no exclusion criteria.

Participants were then asked to complete the following questionnaires which were included to measures factors that have previously been identified as risk factors for LBP, or potential indicator of treatment outcome (see Appendix 7 for full questionnaires):

- Alcohol consumption (Townshend and Duka, 2002) and nicotine dependence questionnaire (Heatherton et al., 1991), as these substances may affect pain relieving mechanisms.
- The McGill pain questionnaire (Melzack, 1975) describes the pain.
- The Oswestry disability questionnaire (Fairbank et al., 1980) measures the impact of the pain.
- The survey of pain attitude (Tait and Chibnall, 1997) measures attitudes associated with the pain.
- A demographic questionnaire, which includes questions regarding, education, employment, income and activity levels.
- The General Health Questionnaire (GHQ28, Goldberg et al.,1979) provides an assessment of psychiatric distress.

7.2.9. Occasion two procedure

The most symptomatic vertebral level (identified from the physiotherapy assessment on occasion 1) was located through palpation of bony landmarks and marked with a temporary pen, as were the points for PPT testing (Table 7.2).

7.2.10. Baseline measurements of verbal ratings of pain

Participants were asked to verbally rate their resting pain on an 11-point scale. Following rating of resting pain, participants were asked to stand with their feet hip width apart and active movements with overpressure (where the physiotherapist applied additional pressure at the end of range) were conducted. For participants with minimal or no symptoms on active movements with overpressure, combined

movements were also performed at the end of flexion and extension range, lateral flexion and ipsilateral rotation were added passively by the physiotherapist. The instructions provided to participants are provided in Table 7.1.

Table 7.1. Instructions given for verbal rating of pain during active movement.

Movement	Instructions
Starting instructions	'I would like you to perform some movements of your low back. At the end of each movement I would like you to tell me how bad your pain is out of 10; 0 being no pain and 10 being the worst pain you could imagine. At the end of each movement I will apply some pressure to your back and again, I will ask you to rate the pain out of 10'.
Flexion	'Bend forwards, as far as possible, running your hands down the front of your thighs. How many out of 10 is that? I am going to apply some pressure to your back, let me know what happens to your symptoms…How many out of 10 is that?'
Extension	'Lean backwards as far as possible. How many out of 10 is that? I am going to apply some pressure to your back, let me know what happens to your symptoms… How many out of 10 is that?'
Lateral flexion	Indicating participants' right / left side: 'run your hand down the side of your leg, bending as far sideways as possible. How many out of 10 is that? I am going to apply some pressure to your back, let me know what happens to your symptoms…How many out of 10 is that?'
Rotation	Indicating participants' right / left side: 'keeping your feet where they are, twist as far to this side as possible… How many out of 10 is that? I am going to apply some pressure to your back, let me know what happens to your symptoms…How many out of 10 is that?'
Flexion /lateral flexion/rotation	'Bend forwards, as far as possible, running your hands down the front of your thighs….Now cross your arm across your chest…. I am going to apply some extra movements to your back' right lateral flexion, followed by right rotation were added passively by the physiotherapist. …How many out of 10 is that?' This procedure was repeated adding left lateral flexion and left rotation.
Extension/lateral flexion/rotation	'Lean backwards as far as possible.?' …. I am going to apply some extra movements to your back' right lateral flexion, followed by right rotation were added passively by the physiotherapist. …How many out of 10 is that?' This procedure was repeated adding left lateral flexion and left rotation.

Following rating pain on active movement, participants were asked to lie prone on a plinth and rate on an 11-point scale their pain whilst the researcher applied a PA force to the symptomatic vertebral level.

7.2.11. Baseline measurements of PPT

PPT testing was performed using the sites and positions indicated in Table 7.2. Two pressure pain threshold (PPT) readings were taken at each of the eight sites. Prior to testing, a familiarisation PPT was taken on the dorsal aspect of the hand at the web-space between the thumb and index finger (enabling participant's to experience PPT at one site). It was clearly explained that this was not intended to be a test of pain tolerance and that the intended point of measurement was when the sensation became anything more than just pressure, whether that was discomfort or pain. During the testing participants were asked to 'push the button as soon as the sensation of pressure turned to a sensation of discomfort or pain', at which point the pressure was removed and the PPT data was saved.

The algometer was applied perpendicular to the marked area of skin at all testing sites. The order of testing was designed to allow sufficient rest between repetitions with the least changes in participant's position. All tests were completed sequentially in one position before changing the participant's position. Therefore 2 repetitions were completed at each site tested in prone (sites 1,2,1,2,) before moving into side lying and performing the testing sequentially in this position (sites 3,4,3,4). Participants were then asked to turn supine where the remaining sites were tested sequentially, (sites 5,6,7,8,5,6,7,8). The testing positions for T10, deltoid, L3 and S1 can be seen in Figure 5.4-5.7 (pages 73-74).

Order of test	Testing position	Site	Landmark identification
1	Prone	L4/ symptomatic level	two fingers breadth lateral to the spinous process.
2	Prone	T10	two fingers breadth lateral to the spinous process.
3	Side lying	Deltoid	the middle fibres, two fingers breadth below the tip of the acromion),
4	Side lying	S1 dermatome	posterolateral heel, two fingers breadth below and one fingers breath posterior to the tip of the lateral malleolus.
5	Supine	L2 dermatome	mid-thigh: using a tape measure, calculated by halving the distance measured from the anterior superior iliac spine to the base of the patella).
6	Supine	L3 dermatome	two fingers breadth above patella.
7	Supine	L4 dermatome	one finger breadth below the medial malleolus
8	Crook lying	L5 dermatome	proximal to the head of the 1st metatarsal

Table 7.2. The order of PPT testing: participant position and landmarks for each PPT testing site.

7.2.12. Treatment period 1: Placebo (2 minutes of sham mobilsation) intervention versus 2 minutes of mobilisation treatment

Following baseline measurements participants lay prone on the plinth whilst receiving the intervention – the short duration treatment group received 2 minutes of sham mobilisation which consisted of the principal researcher applying manual contact at the symptomatic vertebral level using the ulnar border of their hand or thumbs (whichever hand position was subsequently used to apply mobilisations for that participant in treatment period 2 – see below). All the studies in Table 2.3 (page 13) investigating the effects of mobilisation used a similar sham mobilisation for the placebo intervention.

Participants in the long duration of treatment group received 2 minutes of oscillatory PA mobilisation treatment applied to the most symptomatic level. Either a central or unilateral technique was selected, again based on which was the

most symptomatic. Unilateral mobilisations were applied using thumbs and central mobilisation applied using the ulna border of the hand. To replicate clinical practice the amount of treatment force applied was determined according to the severity of symptoms and in negotiation with the participant. The force was not standardised as pilot work had established that this might have resulted in undue reproduction of participant's symptoms (section 6.2.7, page 97).

7.2.13. Measurements after treatment period 1.

Immediately following 2 minutes of sham or PA mobilisation treatment, repeated measurements of participants' verbal rating of pain on movement and PA force to the symptomatic vertebral level were performed, followed by repeat testing of PPT. An additional measurement, global rating of perceived change (GRPC), measured on an 11-point scale, was also included (Appendix 16). Measurements after treatment period 1 measurements were followed by a second treatment period.

7.2.14. Treatment period 2: one minute of mobilisation treatment versus 6 minutes of mobilisation treatment

During the second period of mobilisation (Figure 7.1) participants lay prone on the plinth. The short treatment duration group received 30 seconds of mobilisations applied twice with a 4-minute rest period between repetitions. The longer treatment duration group mobilisations received 2 minutes of mobilisation treatment, applied twice, with 1-minute rest between repetitions. The rest period were included to replicate the use of mobilisations in clinical practice (see page 3 for typical treatment doses).

7.2.15. Measurements after treatment period 2

After the second period of mobilisation treatment, participants' verbal rating of pain on movement and PA force to the symptomatic vertebral level were performed, followed by repeat testing of PPT and GRPC.

7.2.16. Occasion 3 – 24 hour follow-up procedure

Participants attended on a third occasion a mean of 24 hours later (SD 1.8 hours, range 17.5-27). On this occasion participants' verbal rating of pain on movement and PA pressure to the symptomatic vertebral level were performed, followed by repeat testing of PPT and GRPC.

On completion of all the experimental measurement, participants completed a semi-structured questionnaire (Table 7.3 and Appendix 17) on their expectations and experience of receiving mobilisations. The questions were designed by the researcher and the questionnaire was piloted on two participants prior to the onset of the study. The questionnaire enabled participants' subjective expectations and experience to be compared to their response to treatment.

Questions
Have you had previous experience of receiving this mobilisation technique? Please describe any previous mobilisations that you have had.
What were you expecting from having this 'mobilisation technique' applied on this occasion?
Was there anything that you didn't expect about the mobilisation technique? If so, what happened that you didn't expect?
What were you thinking and feeling when the mobilisation technique was applied?
How comfortable was the technique?
What effect do you think the mobilisation technique had on your back?
Any other comments:

Table 7.3. The questions in the 'expectations and experience of receiving mobilisations' questionnaire.

7.3. Data Analysis

Descriptive statistics were first calculated for all data (participants' demographic, questionnaire, PPT and VRS of pain) using Statistical Package for the Social Sciences (PASW version 20.0 for Windows). For PPT the mean of the two measurements at each site was used for subsequent analysis. Percentage changes in PPT were calculated (using the equation 100×((post treatment PPT-pre treatment PPT) / pre treatment PPT)) to allow comparison with previous research reporting percentage change rather than actual measures. Verbal rating of pain on individual movements were summed and used in further analysis.

7.3.1. Normality testing of data

Iterative statistical analyses were performed using Statistical Package for the Social Sciences (PASW version 20.0 for Windows). All the data were tested for normality using the Shapiro-Wilk test. Where data were not normally distributed, they were transformed using Logarithms to the power of 10 (Lg10). All transformed data was retested for normality. Analysis of variance (ANOVA) was used even when minor departures from normality remained, as ANOVA is robust to minor departures of normality (Agresti and Finlay, 2009).

7.3.2. Mann-Whitney U test and independent samples T-test

Mann-Whitney tests (for skewed data) and independent samples T-tests (for normally distributed data) were used to examine for baseline differences between groups. Independent samples T-tests were also used to analyse differences in global rating of perceived effect between long and short duration treatment groups.

7.3.3. Analysis of Variance

The differences between groups for each measurement point were analysed individually (see Figure 7.1).

PPT data were analysed using a three-way mixed ANOVA with two within subjects' variables, time (before and after) and site, which had 8 levels (symptomatic paravertebral, T10, deltoid, and S1, L2, L3, L4, L5 dermatomes). The between subjects variable was duration (either placebo/treatment or short/long).

Planned covariate adjustments for demographic and questionnaire factors were performed using analysis of covariance (ANCOVA). Because PPT were performed at 8 different sites stratified and covariate analysis was performed using the changes local to the treatment site (the symptomatic paravertebral site), as previous studies have reported greater local changes in PPT following mobilisations (Pentelka et al., 2012; Willett et al., 2010).

VRS (for resting pain, pain on movement, pain on the application of PA force were analysed separately using two-way mixed ANOVA's, with one within subject variable (time) and one between subject variable duration (either placebo/ treatment or short/long).

7.3.4. Stratified analysis

Force of treatment was a potential confounding variable and therefore stratified analysis was performed using linear regression (Katz, 2003), to determine the proportion of the change in PPT that could be accounted for by the force of treatment. Analysis was performed for the change after treatment period 2, when all participants had received a mobilisation treatment dose and for changes at 24-hour follow-up.

7.3.5. Correlations

Spearman's correlations were used to investigate the relationship between verbal rating of pain on movement, pain on the application of PA force, resting pain and PPT.Bootstrapping was performed and 95% confidence intervals calculated as recommended when performing multiple correlations (Field, 2012).

7.3.6. Analysis of the expectations and experience of mobilisations questionnaire

At the end of the study the data gathered from the semi-structured questionnaire investigating participants' expectations and their experience of receiving a mobilisation treatment was analysed using content analysis (Bryman, 2008). The expectations and experience of receiving a mobilisation treatment were evaluated separately for treatment responders and non-responders.

7.3.7. Analysis of response to treatment

Responder's analysis was performed to explore the number of participants experiencing minimal but clinically important change. For PPT a clinically important change was determined from the SEM and MDC statistics from the reliability study (chapter 5) and improvements of or more 15% as determined previously (Salaffi et al., 2004). For VRS of pain clinically important improvement was considered to have occurred with a reduction of pain greater than 1 (on a 0-10 scale). This has been determined to represent a clinically important change in previous research (Salaffi et al., 2004). Cumulative proportion of responders analysis was used to describe the likelihood of response over a range of response levels (Farrar et al., 2006). Chi-square test was conducted on PPT measures to establish whether there was a significant effect of the duration of mobilisation treatment or of expectations of treatment on the number of responders. As previous studies have reported greater local changes in PPT following mobilisations (Pentelka et al., 2012; Willett et al., 2010) PPT responders were determined for sites local to the treatment and for the site most distant to treatment in order to compare local and systemic difference between treatment durations.

In order to explore the factors that may influence participants' response to treatment, the questionnaire results for responders and non-responders were compared using Mann-Whitney tests (for skewed data) and independent samples T-tests (for normally distributed data).

7.4. Results

Two hundred and twenty one potential participants responded to University email, advertisements in local papers and shops and via word of mouth; Ninety-four did not report any exclusion criteria and received a physiotherapy assessment. Twenty participants were excluded after the physiotherapy assessment as they did not experience pain with active movement with overpressure (14) or were taking medication (6). Seventy-four participants met the inclusion criteria and became participants in the study. One participant had an acute injury to their lower back whilst playing rugby after the first session and did not attend the 24-hour follow-up. At the end of the study, two participants revealed that they took medication and so were excluded from the analysis. A total of 72 participants data were used in the analysis. This was the minimum number suggested in the power analysis (section 7.2.3).

Fifty participants complained of symptoms contained to their low back (34 with central pain and 16 with pain to one side), 6 complained of symptoms extending into the buttocks, 14 had low back and posterior leg pain (10 of these had pain extending below the knee) and 2 had LBP and anterior thigh pain. The most symptomatic level determined through the physical examination is displayed in

Table 7.4. Thirty-nine participants received a central PA mobilisation technique and 33 participants received a unilateral PA mobilisation technique. Participant's weight, height, age and duration of symptoms are displayed in Table 7.4. There was a significant difference in the age of participants in the short and long duration treatment groups. Participants in the long duration treatment group were significantly younger t_{69}= 3.06, p<.01 (Appendix 19).

Group	Sex	Age	Height (cm)	Weight (kg)	Symptom Duration (years)	Symptomatic level (number of participants)	Treatment technique
Short duration n=33	22 male 11 female	Mean 46 SD13	Mean 175 SD8	Mean 78kg SD15	Mean 11 SD 11 Range 0.3-35	L5 (21) L4 (6) L3 (5) L2 (1)	Unilateral 17 Central 16
Long duration n=39	23 male 16 female	Mean 36 SD14	Mean 175 SD10	Mean 80kg SD16	Mean 7 SD 6 Range 0.8-31	L5 (23) L4 (11) L3 (5)	Unilateral 16 Central 23

Table 7.4. Demographic, symptom and treatment details.

One participant failed to complete the questionnaires so the questionnaire results, presented in Table 7.5 and 7.6, are for 71 participants. The 7 participants who smoked had a low mean dependency score. Most participants were in the lowest Oswestry disability scoring band (0-20%) indicating minimal disability. The range indicated that some participants fell in the moderate disability-scoring band (20-40%). The mean GHQ28 scores indicated that participants did not suffer from psychiatric distress (a GHQ28 of 5 or above indicates psychiatric distress (Richard et al., 2004)). However, eighteen of the 71 participants' scores exceeded this threshold.

There were no significant differences for questionnaire data between groups, except for the solicitude subscale of the SOPA (U= 409.50, p=.012, see Appendix 19) indicating that participants in the short duration group had significantly higher solicitude scores. The two groups were comparable on all other demographic and questionnaire results (age, hours of exercise, alcohol consumption, GHQ28, McGill, Oswestry).

	Alcohol		Smoking	Exercise per week (hours)	GHQ28	McGill	Oswestry % score
	Units	Binge score					
Short duration n=33	Mean 8 SD 6 Range 0-24	Mean 6 SD 9 Range 0-37	2 smokers Mean 3.8 Range 3-6	Mean 5 SD 4 Range 0-48 0-11	Median 2 Mean 3 SD 4 Range 0-16	Mean 17 SD 8 Range 5-37	Mean 18 SD 8 Range 8-36
Long duration n=39	Mean 7 SD 6 Range 0-21	Mean 7 SD 10 Range 0-21.5	5 smokers Mean 3.5 Range 3-6	Mean 5 SD 5 Range 0-48 0-21.5	Median 3 Mean 4 SD 5 Range 0-19	Mean 18 SD 10 Range 4-39	Mean 15 SD 6 Range 2-27

Table 7.5. Questionnaire results

	Control	Disability	Harm	Emotion	Medication	Solicitude	Medical cure
Short Duration n=33	10 (3)	6 (3)	5 (3)	5 (4)	4 (3)	6 (4)	10 (4)
Long Duration n=39	10 (4)	5 (3)	6 (4)	5 (5)	3 (3)	4 (3)	12 (4)

Table 7.6. Survey of pain attitudes raw scores. Mean (standard deviation).

The forces used in treatment are described in Table 7.7. There was no significant difference between the treatment force used in the short and long duration treatment groups t_{68} =.97, p=.34. As expected the placebo sham treatment was significantly lower than the mobilisation treatment force U=1,191.0, p<.01 (Appendix 21).

	Short duration condition, n=33		Long duration condition, n=39	
	Placebo (sham treatment)	1 minute	2 minutes	4 minutes
Mean	26	142	139	129
SD	12	54	50	57
Range	8-52	52-303	65-279	41-238

Table 7.7. The forces (in Newtons) applied in each condition.

7.4.1. Results for PPT

PPT data sets were not normally distributed and therefore the data was transformed using Logarithms (Log10). Re-testing for normality revealed that minor deviations from normality were found (see Appendix 18).

Due to random allocation to experimental groups, differences between the baseline PPT measurements were not anticipated. However observation of the data suggested that a difference might have been present. This was particularly notable at the symptomatic paravertebral level and T10 sites. No significant differences in baseline measurements were evident (see Appendix 19 for significance levels for each site).

Comparing PPT between baseline and after treatment period 1 (after 2 minute sham mobilisation and 2 minutes of mobilisation treatment), there was no significant effect of time ($F_{1,70}$ =0.06, p=.81) or condition ($F_{1,70}$ =0.28, p=.60) and no significant time*condition interaction effect ($F_{1,70}$ =3.3, p=.07). There was no 3-way interaction between condition*site*time ($F_{1,70}$ =2.1, p=.55). These results demonstrated that 2 minutes of mobilisations did not significantly change PPT, relative to placebo (Figures 7.2-7.5). See Appendix 20.

Comparing PPT between baseline and after treatment period 2 demonstrated that there was no significant effect of time ($F_{1,70}$ =0.09, p=.76), and no significant time*condition interaction effect ($F_{1,70}$ =2.78, p=.10). There was a significant interaction between condition*site *time ($F_{1,70}$ =2.71, p=.02). However post hoc analysis with adjustment for multiple comparisons found no 3-way interaction effect (See Appendix 20 for p values at each site). This demonstrated that the longer duration of mobilisations did not produce a greater change in PPT.

The difference between PPT at baseline and 24 hours revealed a significant main effect for time ($F_{1,69}$ =16.69, p<.01). There was a significant interaction between time*condition ($F_{1,69}$ =7.59, p=.01). However post hoc analysis with adjustment for multiple comparisons found that there was no two-way interaction effect (see Appendix 20). These results demonstrate that PPT were significantly reduced at 24-hour follow-up compared to baseline, but the difference between short and the long duration treatment groups failed to reach significance.

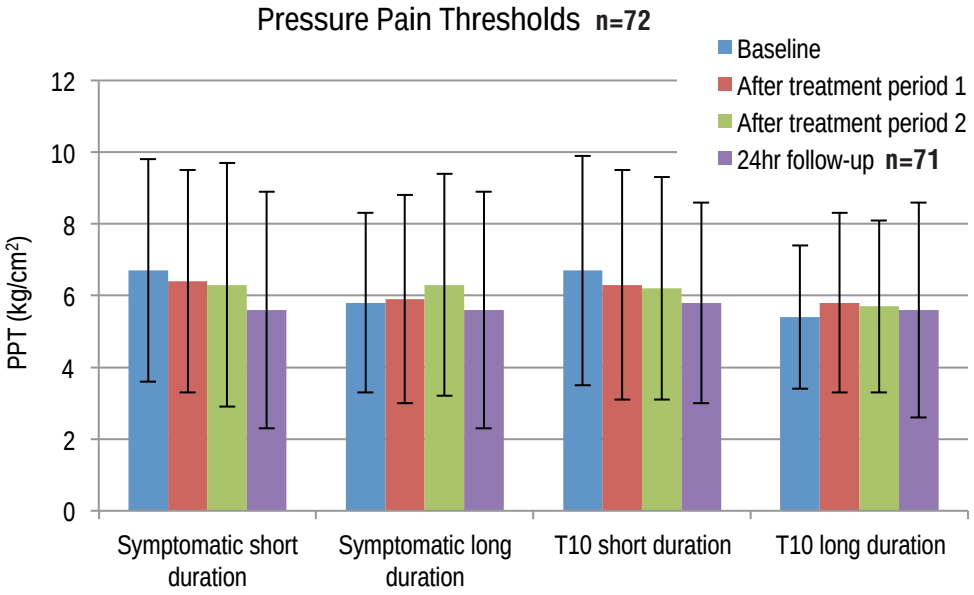


Figure 7.2. Paravertebral PPT measurements After treatment period 1: following 2 minutes sham mobilisation (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes sham mobilisation and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent +/- standard deviation.

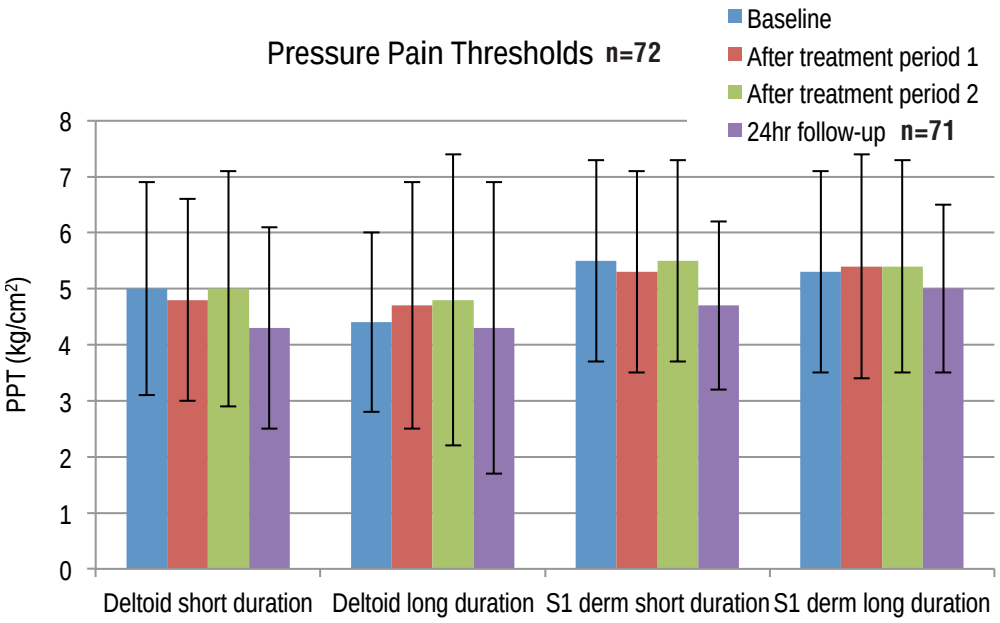


Figure 7.3. PPT measurements After treatment period 1: following 2 minutes sham mobilisation (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes sham mobilisation and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent +/- standard deviation.

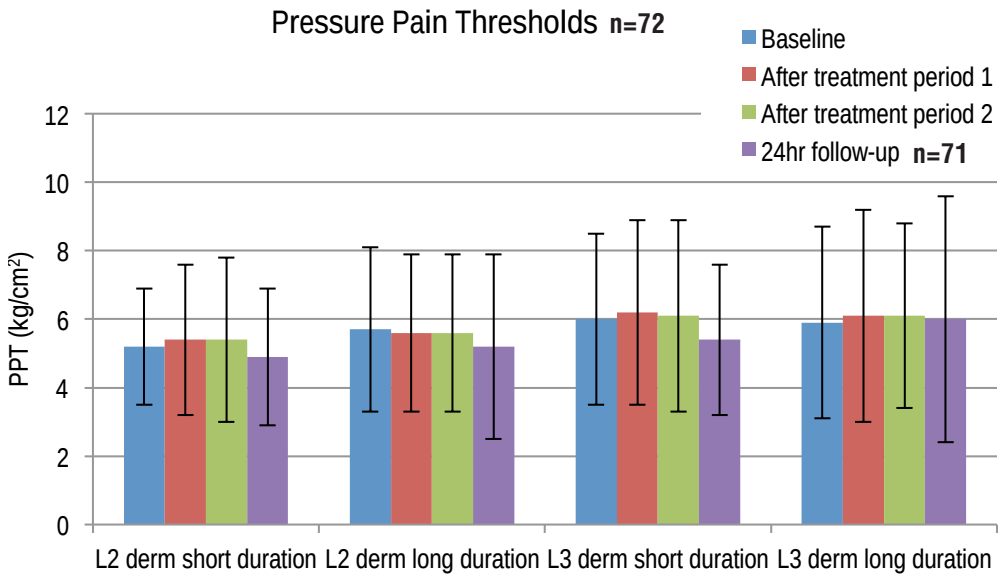


Figure 7.4. PPT measurements After treatment period 1: following 2 minutes sham mobilisation (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes sham mobilisation and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent +/- standard deviation.

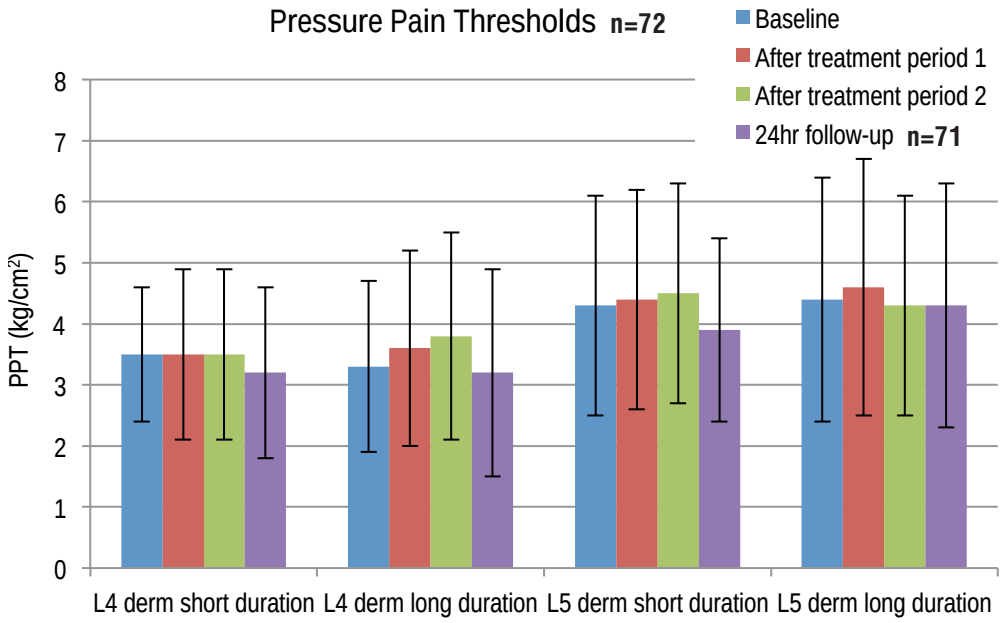


Figure 7.5. PPT measurements After treatment period 1: following 2 minutes sham mobilisation (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes sham mobilisation and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent +/- standard deviation.

Planned covariate adjustment for duration of symptoms, age, and question scores (Oswestry disability, McGill, GHQ28, SOPA) did not demonstrate any interactions. (Appendix 20). This indicated that the questionnaire data did not help to predict participants' response to mobilisations.

To enable comparison with previous studies reporting percentage change values these are presented in Table 7.8. The mean percentage differences in PPT following all treatment durations were small as depicted. The large standard deviations indicate a large variation in participants' response to mobilisation treatment. Analysis of treatment responders and non-responders is further explored in section 7.4.9.

In summary there were no difference between placebo, short and long duration of mobilisation treatment on PPT. Relative to baseline there was a significant reduction in PPT at 24 hour follow-up evident in both short and long treatment duration groups. This demonstrated that participants in both groups exhibited hyperalgesia 24-hours after the experimental session. Covariate analysis failed to identify any predictors of treatment response.

	Percentage change in Pressure Pain Threshold	
PPT Site	**Short duration group n=33**	**Long duration group n=39**
	Placebo (2 minutes sham mobilisation)	2 minutes mobilisation Rx
Symptomatic Paravertebral muscle	-4.1 (19.0)	3.2 (24.3)
T10 Paravertebral muscle	-3.7 (18.5)	8.6 (27.7)
Deltoid	-2.7 (17.7)	6.0 (22.0)
S1 Dermatome	-1.2 (21.4)	0.3 (16.8)
L2 Dermatome	4.0 (15.6)	2.1 (20.4)
L3 Dermatome	3.3 (17.7)	5.2 (19.8)
L4 Dermatome	3.3 (24.1)	12.0 (18.1)
L5 Dermatome	5.2 (21.9)	4.5 (18.6)
	Additional 1 minute mobilisation Rx	**Additional 6-minutes mobilisation Rx**
Symptomatic Paravertebral muscle	-6.1 (23.9)	7.8 (26.2)
T10 Paravertebral muscle	-6.5 (16.9)	6.9 (27.7)
Deltoid	1.6 (28.6)	7.7 (30.7)
S1 Dermatome	1.5 (20.5)	2.9 (24.5)
L2 Dermatome	2.9 (23.2)	3.5 (25.9)
L3 Dermatome	0.6 (16.0)	8.5 (23.7)
L4 Dermatome	-1.1 (24.1)	17.2 (24.6)
L5 Dermatome	8.3 (25.9)	1.1 (22.0)
	24-hour follow-up, n=33	**24-hour follow-up, n=38**
Symptomatic Paravertebral muscle	-12.9 (29.5)	-2.3 (35.2)
T10 Paravertebral muscle	-10.7 (20.4)	5.3 (38.0)
Deltoid	-12.8 (23.6)	-3.0 (35.2)
S1 Dermatome	-12.5 (20.9)	-5.5 (26.4)
L2 Dermatome	-6.7 (19.2)	-7.3 (29.1)
L3 Dermatome	-8.3 (21.1)	1.9 (27.3)
L4 Dermatome	-11.0 (24.1)	-0.5 (30.7)
L5 Dermatome	-5.9 (25.8)	-0.7 (31.0)

Table 7.8. Percentage change in PPT at each site at each measurement point. Data are mean percentage changes (standard deviation).

7.4.2. Results for verbal rating scale of pain on movement

Active movements with overpressure were applied to 64 participants. The remaining ight participants did not receive overpressures due to the severity of their symptoms (4 participants in the short duration group and 4 participants in the long duration group). Six participants had minimal symptoms so combined movements were included (2 in the short duration group and 4 in the long duration group).

Movement	Short duration group, n=33	Long duration group, n=39
	Baseline	**Baseline**
Flexion	2.7 (2.5)	1.9 (2.1)
Extension	2.8 (2.2)	2.4 (2.0)
Left lateral flexion	1.9 (2.1)	1.6 (2.0)
Right lateral flexion	2.0 (1.7)	1.5 (1.9)
Left rotation	1.1 (1.3)	0.7 (1.3)
Right rotation	1.3 (1.6)	0.6 (1.3)
	Placebo (2 minutes sham mobilisation)	**1 minute mobilisation Rx**
Flexion	2.1 (2.0)	1.8 (2.0)
Extension	2.3 (2.3)	2.0 (2.0)
Left lateral flexion	1.3 (1.9)	1.2 (1.4)
Right lateral flexion	1.8 (1.8)	1.1 (1.7)
Left rotation	0.8 (1.3)	0.6 (1.2)
Right rotation	1.1 (1.7)	0.6 (1.3)
	Additional 1 minute mobilisation Rx	**Additional 4-minutes mobilisation Rx**
Flexion	2.2 (2.3)	1.8 (2.0)
Extension	1.9 (2.1)	1.7 (1.9)
Left lateral flexion	1.3 (1.8)	1.1 (1.6)
Right lateral flexion	1.5 (1.5)	1.0 (1.5)
Left rotation	0.7 (1.2)	0.6 (1.5)
Right rotation	0.9 (1.6)	0.7 (1.3)
	24-hour follow-up, n=33	**24-hour follow-up, n=38**
Flexion	1.6 (1.8)	1.3 (2.1)
Extension	2.9 (2.6)	2.4 (1.8)
Left lateral flexion	1.6 (2.1)	1.4 (1.4)
Right lateral flexion	2.2 (2.1)	1.6 (1.5)
Left rotation	1.1 (1.8)	0.9 (1.2)
Right rotation	1.5 (2.2)	0.7 (1.0)

Table 7.9. Verbal rating scales of pain (0-10) on individual movements. Data are means (standard deviation).

Mean VRS of pain on individual movement were very low, never exceeding 3/10 (Table 7.9). There was no significant difference in the baseline measurement of VRS (combined for pain on all movements) between the long and short duration treatment groups (t_{70}= 1.148, p=.23).

Verbal rating of pain on movement data was skewed and thus transformed data was used in the analysis (Appendix 18). For two-way mixed ANOVA's for verbal rating of pain on movement (Appendix 22) there were only two time points and thus sphericity was assumed.

Comparison of verbal rating of pain on movement between baseline and after treatment period 1 (between baseline and 2 minutes sham mobilisation and baseline and 2 minutes of mobilisations) revealed a significant main effect of time ($F_{1,70}$ =30.8, p<.01), demonstrating a significant reduction in VRS of pain on movement. There was no significant main effect of condition ($F_{1,70}$ =1.29, p=.28) and there was no significant interaction effect for time*condition ($F_{1,70}$ =0.02, p=.90). These results demonstrate that there was no difference in the effects of placebo (sham mobilisation) and 2 minutes of mobilisation on verbal rating of pain on movement (see Figure 7.6).

After treatment period 2 (between baseline and 6 minutes and baseline and 1 minute (plus 2 minutes sham mobilisation)) there was a significant main effect of time ($F_{1,70}$ =45.5, p<.01), demonstrating a significant reduction in VRS of pain on movement. There was no significant main effect of condition ($F_{1,70}$ =0.55, p=.46). There was no significant interaction between condition*time ($F_{1,70}$ =0.60, p=.44). These results demonstrate that 1 minutes of mobilisations treatment did not significantly change verbal rating of pain on movement, relative to 6 minutes of mobilisation treatment (see Figure 7.6).

At 24 hour follow-up there was a significant effect of time on verbal rating of pain on movement ($F_{1,70}$ =51.3, p<.01), demonstrating that there was a significant reduction in VRS of pain on movement. There was no significant main effect of condition ($F_{1,70}$ =0.98, p=.33).There was no significant interaction between condition*time ($F_{1,70}$ =0.01, p=.94). These results demonstrate that 24 hours after treatment, 1 minute of mobilisations did not significantly change verbal rating of pain on movement, relative to 6 minutes of mobilisations (see Figure 7.6).

Covariate analysis with VRS of pain on movement did not find any interactions between the response to treatment and the questionnaire responses.

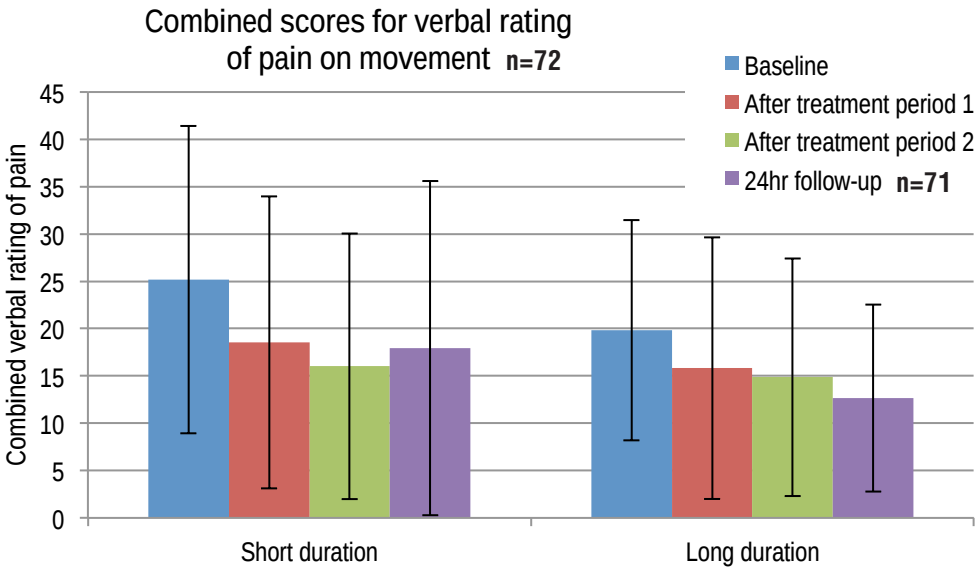


Figure 7.6. Verbal rating of pain on movement (combined for all movements). After treatment period 1: following 2 minutes placebo (sham mobilisation)(short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes placebo and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent +/- standard deviation.

In summary relative to baseline, there was an immediate decrease in verbal pain rating on movement with both treatment groups. This was also evident at 24-hour follow-up. However the difference between placebo and 2 minutes of treatment and between 1 minute and 6 minutes of treatment failed to reach significance.

7.4.3. Results for verbal rating scale of resting pain

Many participants didn't experience any resting pain (15 out of 33 in the short duration group and 24 out of 39 in the long duration group) and mean levels of resting pain were low. There were minimal variations in mean resting pain scores between time points (Figure 7.7). There was no significant difference in the baseline measurements of VRS of resting pain between the long and short duration treatment groups (t_{70}= 1.445, p=.15). Due to the low baseline scores and high number of participants with no pain at rest the data was skewed. This was not corrected with transformation of the data. However a two-way mixed ANOVA was used as there is no non-parametric equivalent and ANOVA is robust to deviations from normality.

Relative to baseline there was no significant effect of time or time*condition for resting pain after treatment periods 1 or 2 or at 24-hour follow-up (see Table 7.10 for statistical values). This indicated that relative to baseline there was no immediate or short-term effect of mobilisations on resting pain in the placebo, short, or long duration of treatment groups (Appendix 22).

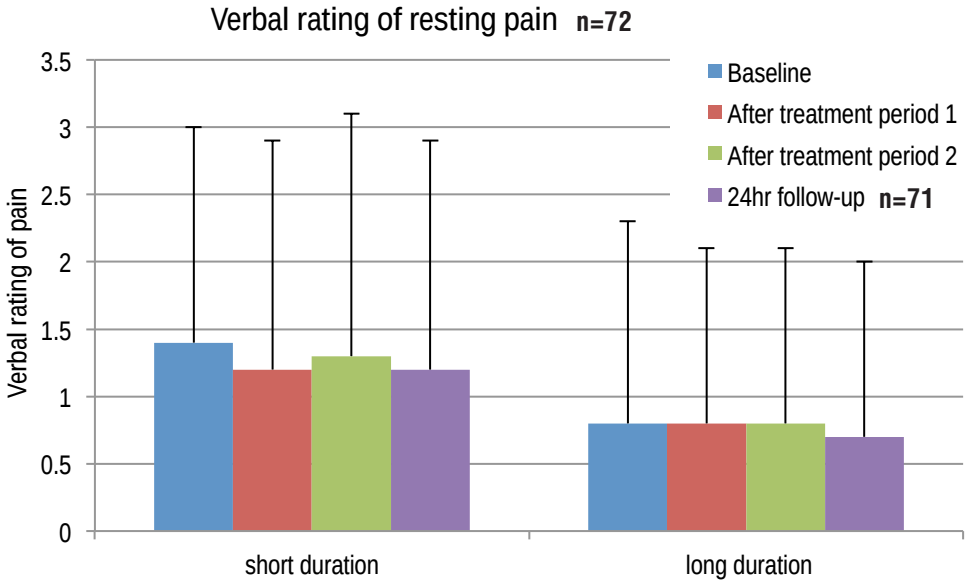


Figure 7.7. Verbal rating of resting pain After treatment period 1: following 2 minutes placebo (sham mobilisation) (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 2 minutes placebo and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent + standard deviation.

7.4.4. Results for verbal rating scale of pain on the application of PA force to the symptomatic level

The overall variations in mean verbal rating of pain scores on the application of PA force to the symptomatic level were small; the largest mean change was 0.8 on an 11-point scale (Figure 7.8). There was no significant difference in the baseline measurements of verbal rating of pain between the short duration and long duration treatment groups (t_{70}= .83, p=.41).

There was a significant main effect of time for pain on PA pressure to the symptomatic level between baseline and both time points 1 ($F_{1,70}$ =6.28, p=.02) and 2 ($F_{1,70}$ =5.67, p=.02) demonstrating that relative to baseline there was an immediate decrease in pain on the application of PA force. There was no significant main effect of condition or time*condition interaction (see Table 7.10 for statistical values) indicating that the difference between sham mobilisation and 2 minutes of mobilisation and 1 minute and 6 minutes of mobilisations failed to reach significance. The main and interaction effects at 24-hour follow-up failed to reach statistical significance (see Table 7.10 for statistical values).

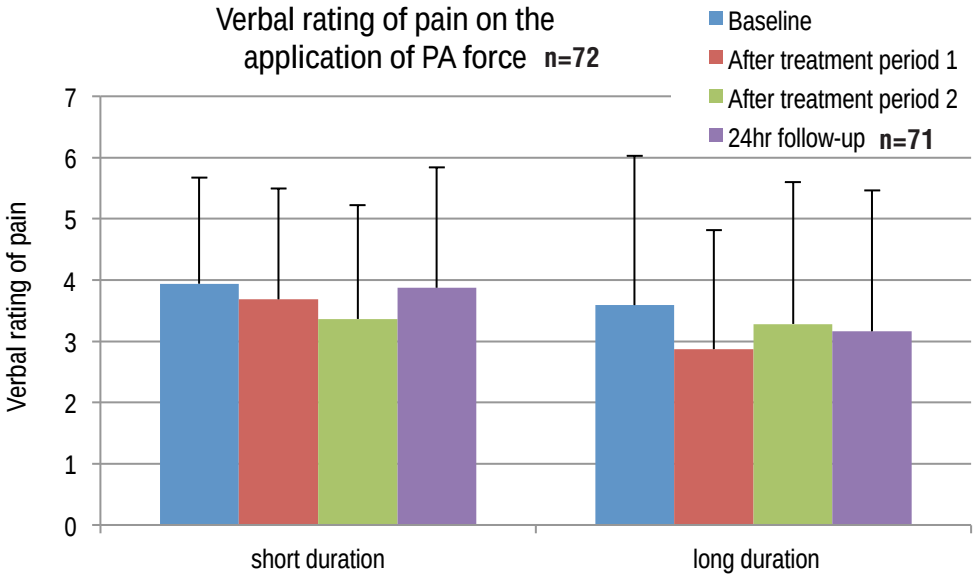


Figure 7.8. Verbal rating of pain on the application of PA force to the most symptomatic vertebral level. After treatment period 1: following 2 minutes sham mobilisation (short duration group) and following 2 minutes mobilisation treatment (long duration group). After treatment period 2: following 1 minute sham mobilisation and 1 minute mobilisation treatment (short duration group) and following 6 minutes of mobilisation treatment (long duration group). The data are means. Error bars represent + standard deviation.

Verbal rating scale	**After treatment period 1 n=72**	**After treatment period 2 n=72**	**At 24-hour follow-up n=71**
	Verbal rating of pain on movement		
Time	**$F=_{1,70}$ 30.8, $p<.01$****	**$F=_{1,70}$ 45.5, $p<.01$****	**$F=_{1,70}$ 51.3, $p<.01$****
Condition	$F=_{1,70}$ 1.29, $p=.28$	$F=_{1,70}$ 0.55, $p=.46$	$F=_{1,70}$ 0.98, $p=.33$
Time*condition	$F=_{1,70}$ 0.17, $p=.90$	$F=_{1,70}$ 0.60, $p=.44$	$F=_{1,70}$ 0.01, $p=.94$
	Verbal rating of pain resting pain		
Time	$F=_{1,70}$ 0.28, $p=.60$	$F=_{1,70}$ 0.07, $p=.79$	$F=_{1,70}$ 1.30, $p=.26$
Condition	$F=_{1,70}$ 1.96, $p=.15$	$F=_{1,70}$ 0.04, $p=.85$	$F=_{1,70}$ 2.56, $p=.11$
Time*condition	$F=_{1,70}$ 0.27, $p=.60$	$F=_{1,70}$ 2.38, $p=.13$	$F=_{1,70}$ 0.07, $p=.93$
	Verbal rating of pain on the application of PA force		
Time	**$F=_{1,70}$ 6.28, $p=.02$***	**$F=_{1,70}$ 5.67, $p=.02$***	$F=_{1,70}$ 1.77, $p=.19$
Condition	$F=_{1,70}$ 2.89, $p=.09$	$F=_{1,70}$ 0.27, $p=.61$	$F=_{1,70}$ 0.76, $p=.39$
Time*condition	$F=_{1,70}$ 2.57, $p=.11$	$F=_{1,70}$ 0.92, $p=.34$	$F=_{1,70}$ 0.01, $p=.92$

Table 7.10. Two way mixed ANOVA results for VRS of pain.
RP= resting pain; PA =PA pressure at most symptomatic level;
Bold values indicate a significant effect, *denotes $p<.05$, **denotes $p<.01$.

7.4.5. Global rating of perceived change

There was a small mean GRPC at all measurement points, greatest 24 hours after treatment (see Table 7.11). The difference in GRPC between short and long duration groups failed to reach significance (after treatment 1: $t_{70}= .399$, $p=.69$, after treatment 2: $t_{70}= .472$, $p=.64$ and at 24-hour follow-up: $t_{69}= .200$, $p=.84$). See Appendix 23.

Short duration group, n=33	Long duration group, n=39
Placebo	2 minutes mobilisation Rx
0.7 (1.7)	0.5 (1.7)
1 minute mobilisation Rx (+ 2 minutes Placebo)	6-minutes mobilisation Rx
0.6 (2.2)	0.8 (1.7)
24-hour follow-up, n=33	24-hour follow-up, n=38
1.3 (1.9)	1.2 (1.8)

Table 7.11. Global rating of perceived change (on an 11-point scale) at each measurement point (-5 = very much worse, 0 = unchanged, +5 = very much better).

In most cases GRPC scores were correlated with change in all pain measures (Table 7.12). Following treatment period 1, change in PPT and verbal rating of pain on movement were not associated with participants perceived rating of change. However there was association between GRPC and verbal rating of resting pain and pain on the application of PA force to the symptomatic level. The dissociation between GRPC and PPT and verbal rating of movement were the same for the short duration treatment group (PPT p=.12, r=.27; VRS p=.75, r=.06) and for the long duration treatment group (PPT p=.69, r=.-07; VRS p=.39, r=.14) After treatment period 2, there was association between GRPC and all pain measures, except pain on the application of PA force to the symptomatic level, where the association just failed to reach significance. At 24-hour follow-up there was significant association between GRPC and all pain measures (Table 7.12).

The associations between GRPC and change in PPT were positive associations, demonstrating that a improvement in symptoms was associated with an increase in PPT, suggesting a hypoalgesic effect (Figure 7.9). The associations between GRPC and change in verbal ratings of pain were negative associations, demonstrating that an improvement in symptoms was associated with a reduction in pain (Figure 7.10).

	PPT	Verbal rating of pain on movement	Verbal rating of resting pain	Verbal rating of pain on application of PA force
Treatment period 1, n=72	p=.47, r=.09	p=.49, r=.08	**p=.01, r=-.32****	**p=.02, r=-.27***
Treatment period 2, n=72	**p<.01, r=.35****	**p<.01, r=-.41****	**p<.01, r=-.34****	p=.06, r=-.22
24 hour follow-up, n=71	**p=.03, r=.26***	**p<.01, r=-.53****	**p=.05, r=-.24***	**p<.01, r=-.49****

Table 7.12. Spearman's correlation between change in pain and GRPC in short and long duration groups combined. PA =PA pressure at most symptomatic level. Bold values indicate a significant effect, *denotes p<.05, **denotes p<.01. (see appendix 23).

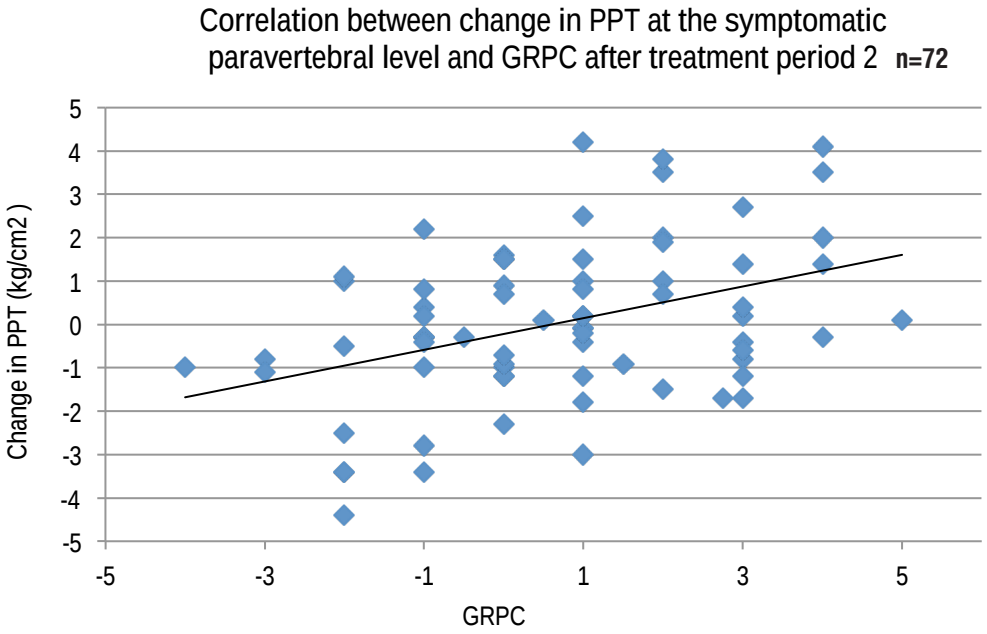


Figure 7.9. Scatter plot demonstrating positive correlation between GRPC and change in PPT at the symptomatic paravertebral level (p<.01, r=.35).

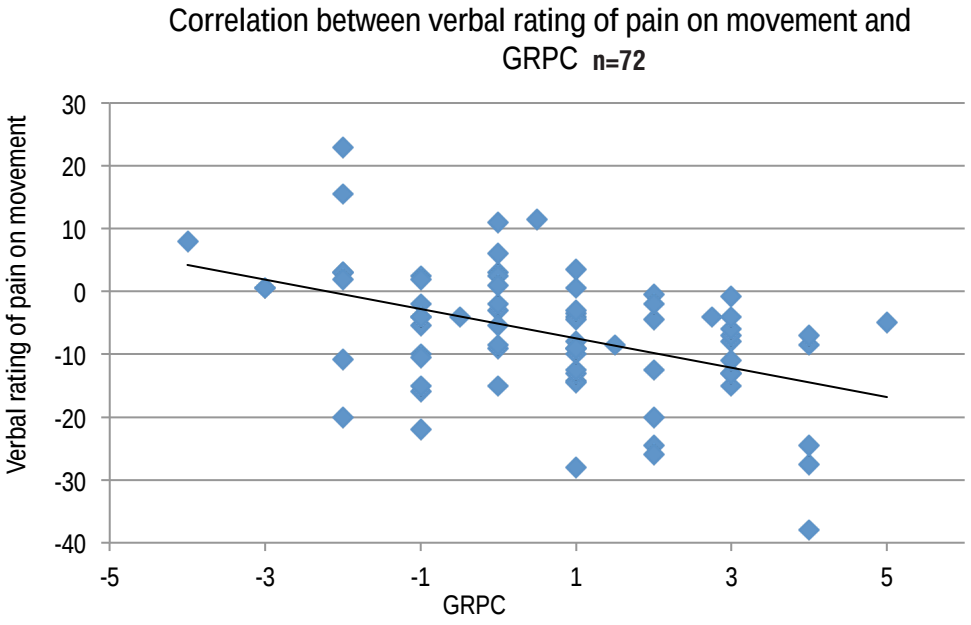


Figure 7.10. Scatter plot demonstrating negative correlation between GRPC and verbal rating of pain on movement after treatment period 2 (p=.02, r=.28).

7.4.6. Stratified analysis of force

Force of treatment varied depending on participants' clinical presentation and thus was a potential confounding or mediating variable. For stratified analysis was performed for changes at the paravertebral muscles site local to the site of treatment where the greatest changes in PPT were observed and for the Deltoid muscle site distant from the site of treatment, where less change was observed following treatment.

At the symptomatic paravertebral PPT, after treatment period 2, there was a significant mediating effect of force $F_{1,69}$ =8.32, p=.01, the R^2 (0.109) demonstrated that 11% of the variation in effect at the symptomatic paravertebral PPT site could be accounted for by force (Figure 7.11). The mediating effect of force at 24-hour follow up failed to reach significance ($F_{1,69}$ =8.32 p=.67). See Appendix 21.

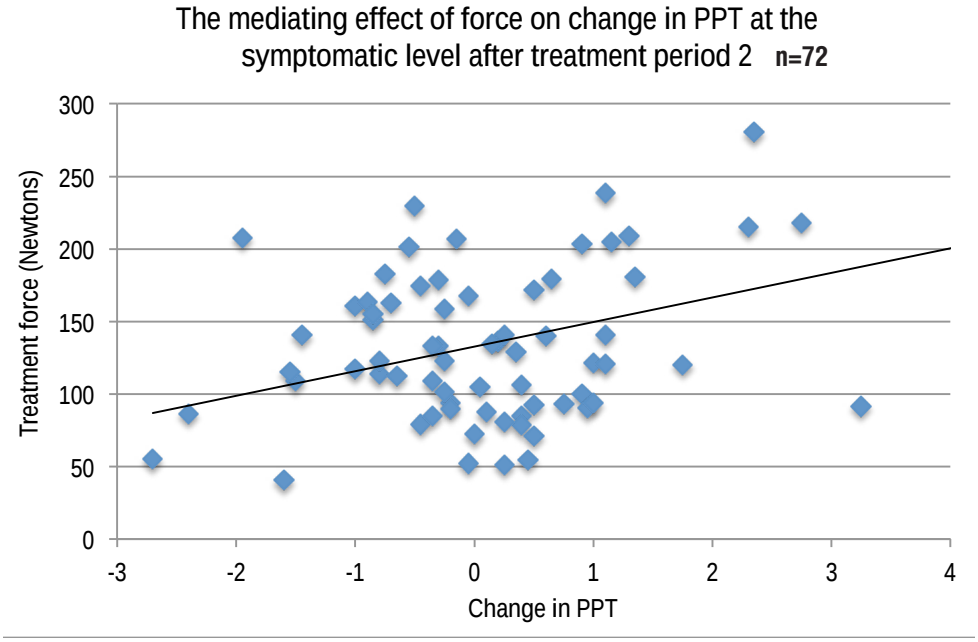


Figure 7.11. At the symptomatic paravertebral PPT, after treatment period 2, there was a significant mediating effect of force $F_{1,69}$ =8.32, p=.01, the R^2 (.109) demonstrated that 11% of the variation in effect at the symptomatic paravertebral PPT site could be accounted for by force.

The R^2 0.09 at the T10 paravertebral PPT site demonstrated that 9% of the variation in effect could be accounted for by force immediately following treatment ($F_{1,69}$ =6.81, p= .01) (Figure 7.12), indicating that force was a significant mediating factor. The mediating effect of force was not evident at the deltoid muscle PPT site R^2=.02: $F_{1,69}$ =0.88, p=.35). These results indicate that higher treatment forces result in greater increases in immediately following treatment local to the site of treatment, but not at a more distant location.

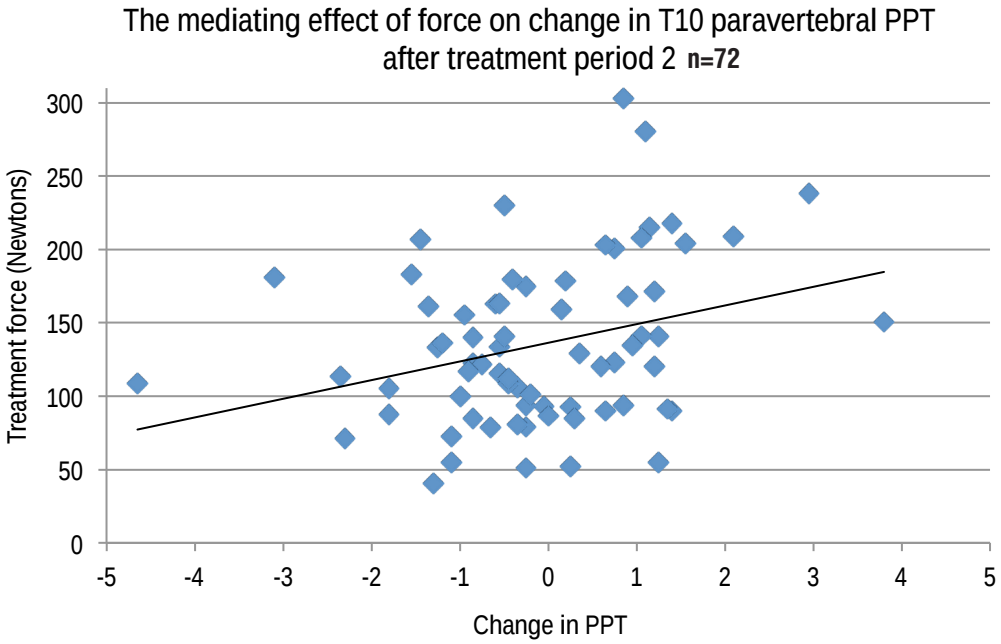


Figure 7.12. The R^2 0.09 at the T10 paravertebral PPT site demonstrated that 9% of the variation in effect could be accounted for by force immediately following treatment ($F_{1,69}$=0.89, p= .66).

Stratified analysis also found that force had a significant mediating effect on verbal rating of pain on movement ($F_{1,69}$=10.38, p<.01). The R^2 (0.132) demonstrated that 13% of the variation in effect could be accounted for by force of treatment, with higher force resulting in greater reductions in verbal rating of pain on movement (Figure 7.13). The mediating effect of treatment force on change in verbal rating of pain on movement was still evident at 24-hour follow-up ($F_{1,68}$=4.337, p=.04). The R^2 (0.06) demonstrated that the variation in effect that could be accounted for by force of treatment had reduced to 6% at this measurement point (Figure 7.14).

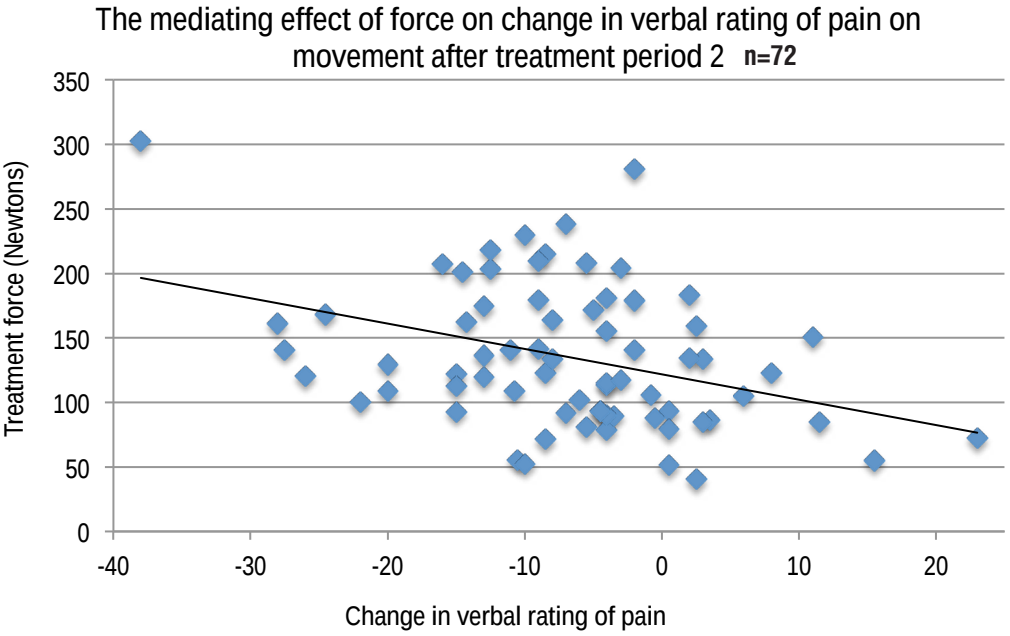


Figure 7.13. Treatment force had a significant mediating effect on verbal rating of pain on movement ($F_{1,69}$=10.38, p<.01). The R^2 (0.132) demonstrated that 13% of the variation in effect could be accounted for by force of treatment

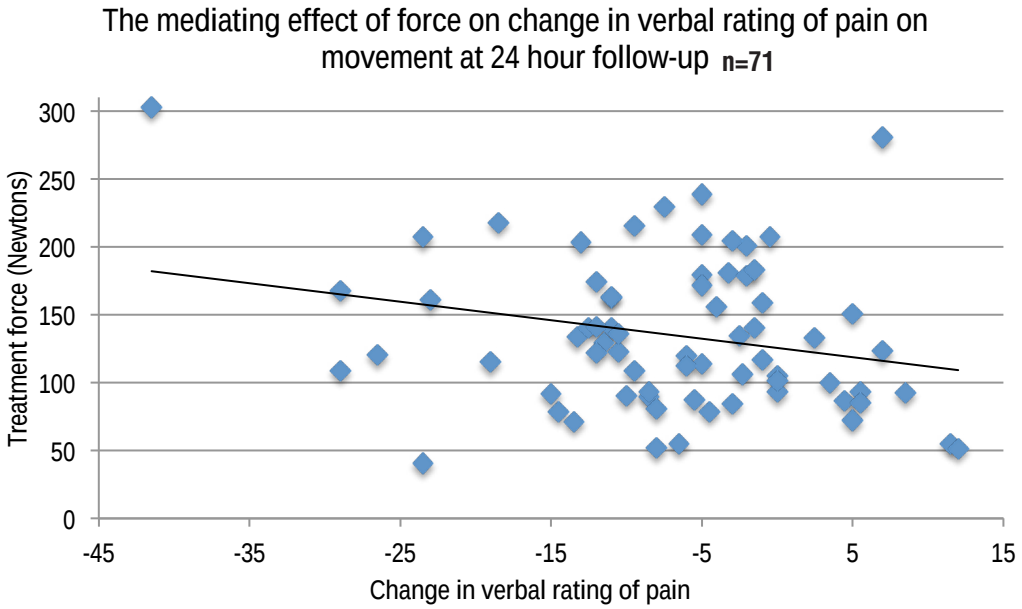


Figure 7.14. Treatment force had a significant mediating effect on verbal rating of pain on movement ($F_{1,68}$ =4.337, p=.04). The R2 (.06) demonstrated that 6% of the variation in effect could be accounted for by force of treatment.

There was no significant mediating effect of treatment force on resting pain (R^2=.03: $F_{1,69}$ =2.36, p=.13) or pain on the application of PA force to the most symptomatic level (R^2=.01: $F_{1,68}$ =0.815, p=.37).

In summary there was a significant immediate mediating effect of treatment force on PPT at the symptomatic paravertebral muscles sites and on verbal rating of pain on movement, suggesting that higher treatment forces create a greater analgesic effect. The mediating effect of force on verbal rating of pain on movement remained evident at 24-hour follow-up. There was no difference in the effect on resting pain or pain on the application of PA force to the symptomatic level.

7.4.7. The Relationship between PPT and participants' VRS.

Correlations demonstrated that there was dissociation between PPT at the symptomatic paravertebral site and VRS of pain on movement and resting pain. There was a negative correlation between PPT at the symptomatic paravertebral site and pain on the application of PA force at the symptomatic level for 2 out of the 4 time points (Table 7.13). However the effect size was small and this suggests that there is little to no association between PPT and patient reported pain measures (Appendix 24).

Correlations between participants' verbal rating of pain on movement, PA force to the symptomatic spinal level and resting pain established that there was a positive correlation between the different patient-reported pain measures on 9 out of 12

occasions (Table 7.13). These results demonstrate that higher ratings of pain on one patient reported measure are associated with higher pain ratings on other patient reported measures (see Figures 7.15 – 7.18 for examples). The r values mostly suggest medium effect sizes.

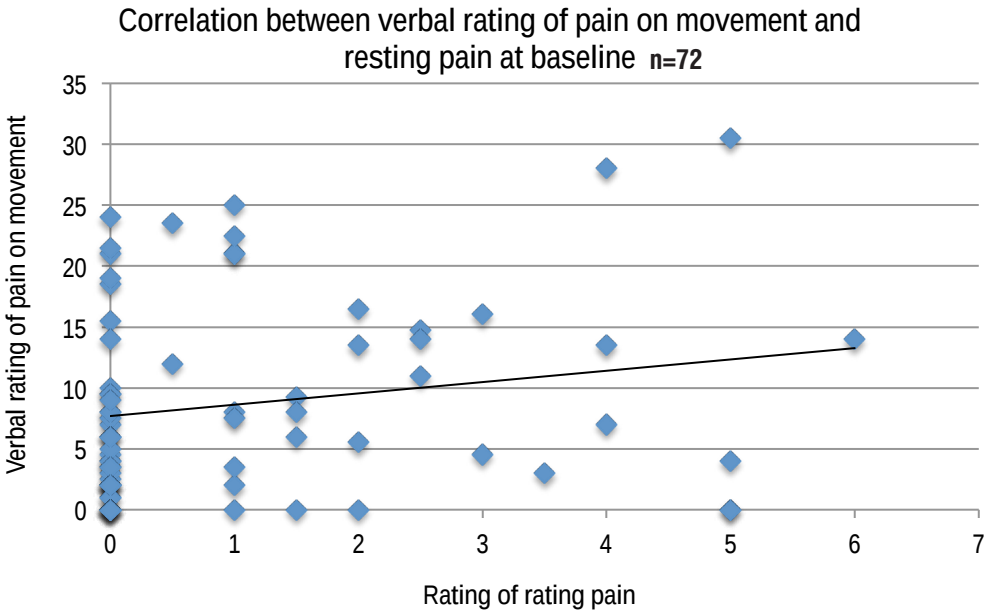


Figure 7.15. Scatter plot demonstrating positive correlation between verbal rating of pain on movement and resting pain at baseline (p=.03, r=.26, 95% CI -.00 to .49).

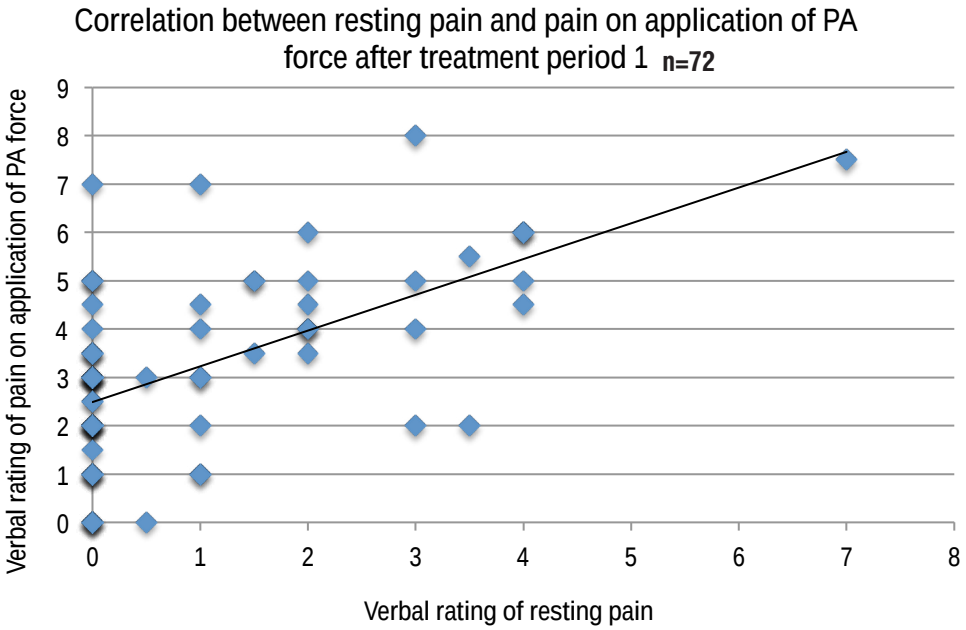


Figure 7.16. Scatter plot demonstrating positive correlation between verbal rating of resting pain and pain on the application of PA force to the most symptomatic vertebral level after treatment period 1 (p<.01, r=.55, 95% CI .36 to .71).

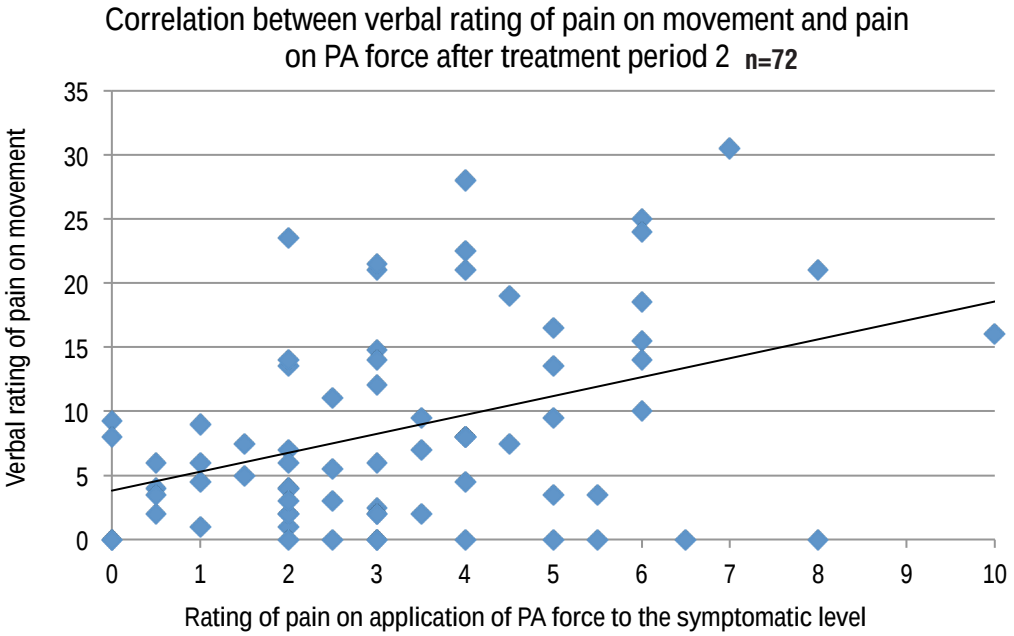


Figure 7.17. Scatter plot demonstrating positive correlation between verbal rating of pain on movement and pain on the application of PA force to the most symptomatic vertebral level after treatment period 2 (p<.01, r=.31, 95% CI -.17 to .60).

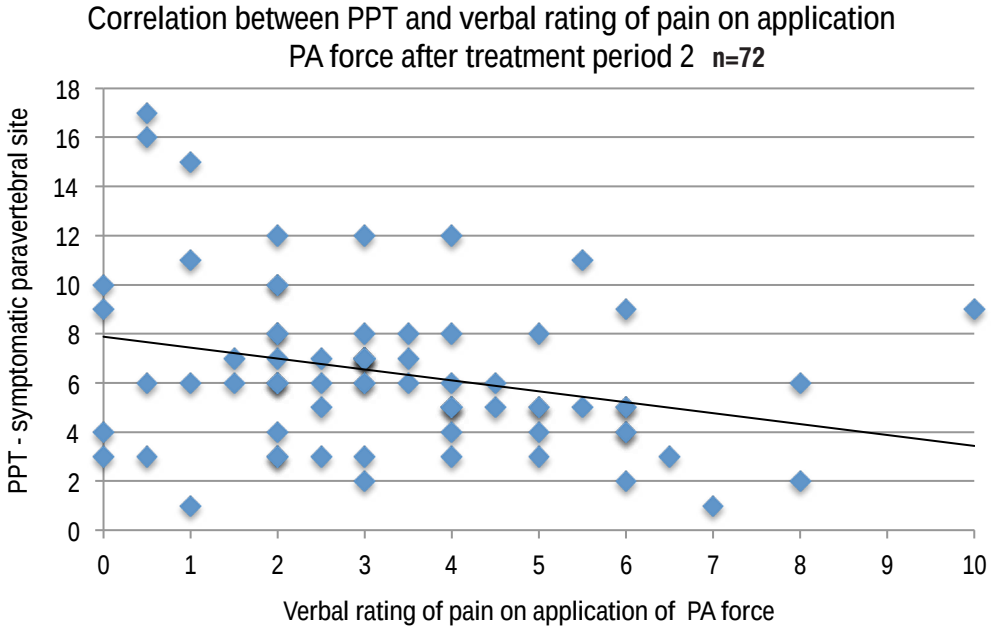


Figure 7.18. Scatter plot demonstrating negative correlation between verbal rating of pain on the application of PA force to the most symptomatic vertebral level and PPT at the symptomatic paravertebral level after treatment period 2 (p=.02, r=-.28, 95% CI -.51 to -.03).

Correlations between measures		p value	Correlation coefficient r	95% confidence interval	
				lower	upper
Correlations between Pressure pain thresholds and VRS of pain (at rest (RP), on movement (Mvt) and with PA force (PA))					
Symp PPT baseline	Mvt baseline	.45	-.09	-.15	.32
Symp PPT after treatment period 1	Mvt after treatment period 1	.93	.01	-.21	.25
Symp PPT after treatment period 2	Mvt after treatment period 2	.99	.00	-.23	.25
Symp PPT 24hr follow-up	Mvt 24hr follow-up	.99	.00	-.26	.23
Symp PPT baseline	PA baseline	.10	-.19	-.43	.04
Symp PPT after treatment period 1	PA after treatment period 1	.38	-.25	-.46	.00
Symp PPT after treatment period 2	PA after treatment period 2	**.02***	**-.28 ¢**	**-.51**	**-.03**
Symp PPT 24hr follow-up	PA 24hr follow-up	**.04***	**-.25 ¢**	**-.47**	**-.00**
Symp PPT baseline	RP baseline	.92	-.01	-.27	.22
Symp PPT after treatment period 1	RP after treatment period 1	.83	.03	-.21	.26
Symp PPT after treatment period 2	RP after treatment period 2	.08	-.21	-.43	.05
Symp PPT 24hr follow-up	RP 24hr follow-up	.85	-.02	-.29	.23
Correlations between VRS of pain at rest (RP), on movement (Mvt) and with PA force(PA).					
Mvt baseline	PA baseline	.21	.15	-.12	.39
Mvt after treatment period 1	PA after treatment period 1	**.01****	**.31 ‡**	**.09**	**-.52**
Mvt after treatment period 2	PA after treatment period 2	**.01****	**.33 ‡**	**.10**	**.55**
Mvt 24hr follow-up	PA 24hr follow-up	**.01****	**.32 ‡**	**.08**	**.65**
Mvt baseline	RP baseline	**.03***	**.26 ¢**	**-.00**	**.49**
Mvt after treatment period 1	RP after treatment period 1	**.01****	**.33 ‡**	**.06**	**.56**
Mvt after treatment period 2	RP after treatment period 2	**.01****	**.33 ‡**	**.08**	**.56**
Mvt 24hr follow-up	RP 24hr follow-up	.17	.17	-.09	.40
PA baseline	RP baseline	**.02***	**.27 ¢**	**.02**	**.49**
PA after treatment period 1	RP after treatment period 1	**.00****	**.55 §**	**.36**	**.71**
PA after treatment period 2	RP after treatment period 2	**.00****	**.40 ‡**	**-.17**	**.60**
PA 24hr follow-up	RP 24hr follow-up	.39	.10	1.15	.35

Table 7.13. Correlations between PPT at the symptomatic paravertebral site and patients VRS of pain. Symp PPT= symptomatic paravertebral muscle pressure pain threshold, Mvt= verbal rating scale of pain on movement. PA= verbal rating scale of pain on PA pressure to the symptomatic level, RP= verbal rating scale of resting pain. *denotes p<.05, **denotes p<.01. ¢ indicates small effect size r+/- .1, ‡ indicates medium effect size r+/- .3, § indicates large effect size r+/- .3 (See Appendix 24).

7.4.8. Participants' expectation and experience of receiving a mobilisation treatment

All 72 participants completed the end of study questionnaire. Thirty participants thought that the mobilisation treatment would be beneficial. Thirty-five participants did not express any expectations of mobilisations so had unknown expectations. The remaining 8 of participants thought that treatment would be of limited benefit (Figure 7.19).

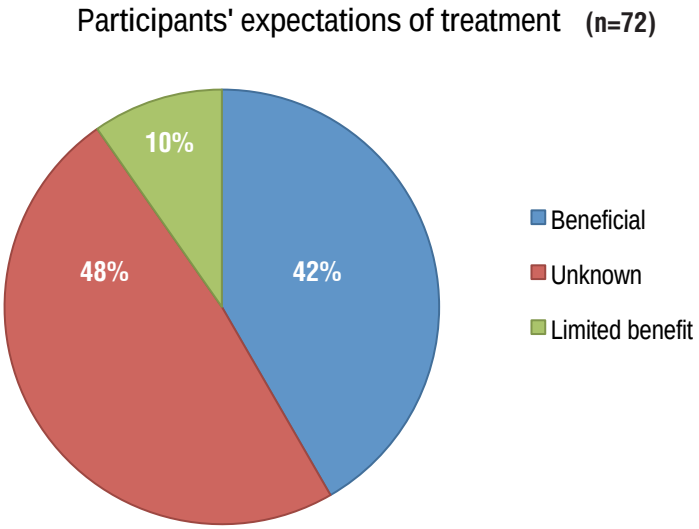


Figure 7.19. Participants' expectations were categorised in beneficial, limited benefit or unknown.

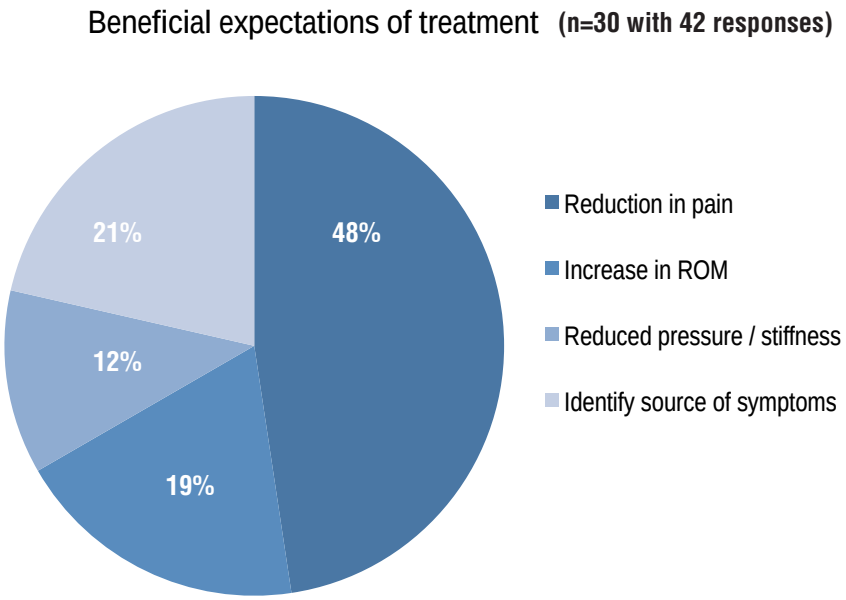


Figure 7.20. Expectations of participants who thought that mobilisation would be beneficial.

Of the 30 participants who expected the mobilisation treatment to be beneficial, some expressed more than one expected treatment outcome. Twenty participants thought that the treatment would decrease pain (n=20), Eight that it would increase range of movement and 5 that it would reduce stiffness or tension. Nine participants also expected that the treatment would identify the source of their pain (Figure 7.20).

Participants' expectations of the pain during mobilisation treatment were varied. Some participants described expecting treatment to be painful (n=7), whilst others expected pain relief (n=20). Of the 7 participants who described an expectation of pain during treatment, 2 appeared to perceive pain as a necessary component of extolling a beneficial treatment effect, of the remaining 5, two described pain during treatment as 'kill or cure' (participants 51 and 54) and the remaining 3 thought that treatment would be of limited benefit. Three participants commented that they expected the effects of mobilisations to be short-term.

Participants described a number of experiences related to receiving the mobilisation treatment. Thirty-three participants described the experience as "comfortable". Twelve participants described experiencing a sense of relaxation and even a sense of wellbeing during the application of the mobilisation treatment. Nine participants commented on the simplicity of the mobilisation technique. Sixty-eight participants experienced a change in pain associated with treatment, but the nature of this change varied between individuals (Figure 7.21). Thirty-four described feeling pain during the application of the mobilisation treatment. Ten described initial soreness followed by pain relief. Thirty-one participants felt less pain after treatment and ten described an increase in pain following treatment.

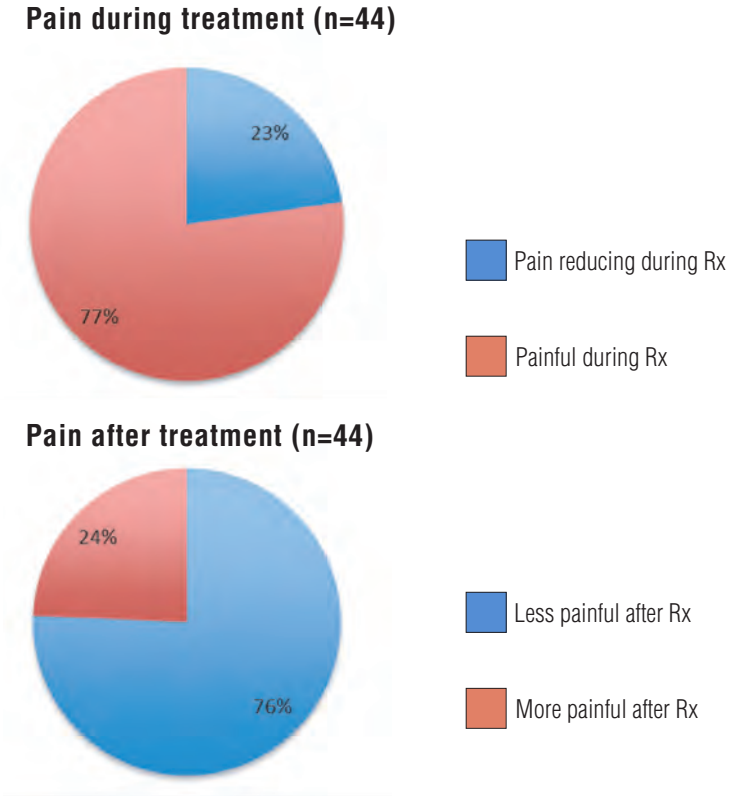


Figure 7.21. Participants had varied experience of pain associated with mobilisation treatment.

Prior to entry into this study, 26 participants had not received treatment for their symptoms. The 46 participants who had received treatment had experienced a range of interventions including exercise, massage, acupuncture, mobilisations and manipulation – from chiropractors, osteopaths and physiotherapists. Eight participants had seen 2 different professionals for their LBP (e.g. a physiotherapist and a chiropractor), and 7 had seen three different health professionals (e.g. a physiotherapist, chiropractor and an osteopath). Fifteen participants who had previously received manual therapy stated that it had helped a lot, 17 stated it helped a little, 12 said it didn't help and 2 commented that any benefits had been short term. Seventeen of the 35 participants who expressed no expectations of mobilisation had received mobilisation or manipulation in the past.

7.4.9. Analysis of treatment responders and non-responders

The cumulative portion of responders' analysis suggested that immediately following mobilisation treatment fewer participants experienced a positive response to placebo (sham mobilisation) than to 2 minutes of mobilisation (Figure 7.22).

This difference in the amount of responders' and level of response was greater immediately following 1 and 6 minutes of mobilisations, with a greater proportion of responders in the group receiving a longer duration of treatment (Figure 7.23-7.25). This response was most evident at the symptomatic paravertebral PPT, where in the short duration of treatment group 35% of participants had increased PPT immediately following treatment compared to 60% in the long duration group (Figure 7.23). In addition to more participants responding in the longer duration of treatment group, the level of response was also greater in this group.

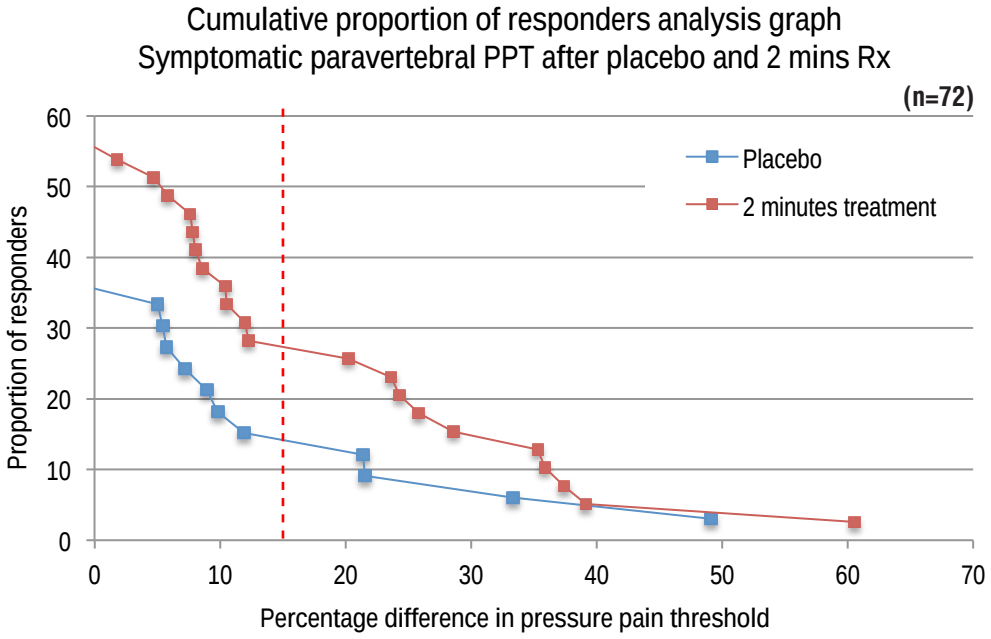


Figure 7.22. Responders' analysis at the symptomatic PPT following treatment period 1. Vertical line represents clinically relevant change (>15%).

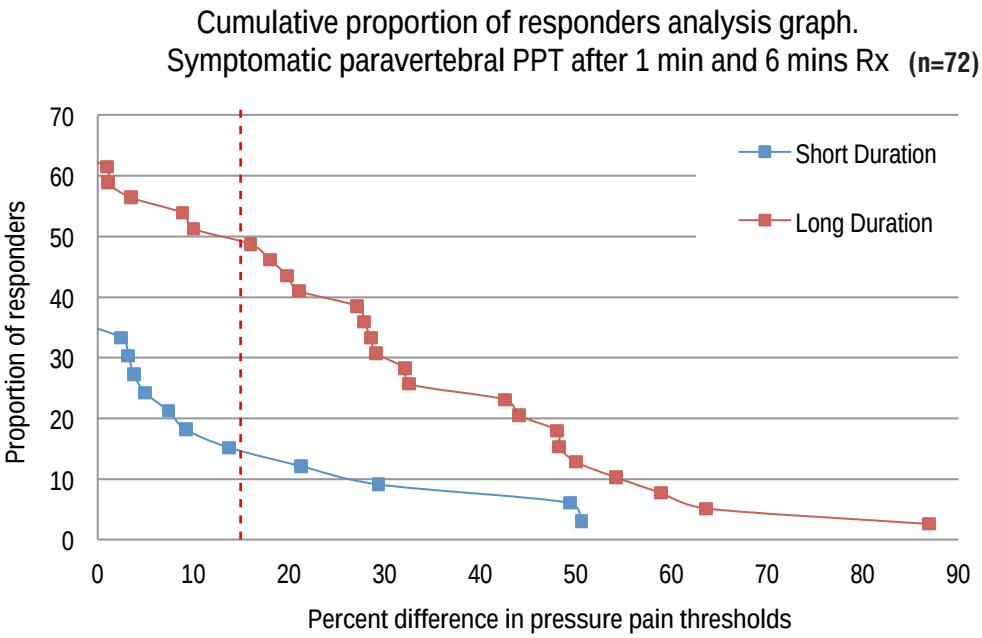


Figure 7.23. Responders' analysis at the symptomatic paravertebral PPT site following treatment period 2. Vertical line represents clinically relevant change (>15%).

A similar response was seen at the T10 paravertebral PPT site (Figure 7.24). Although a difference in response between groups was still evident at the deltoid muscle PPT site, there was a less obvious difference between treatment durations (Figure 7.25).

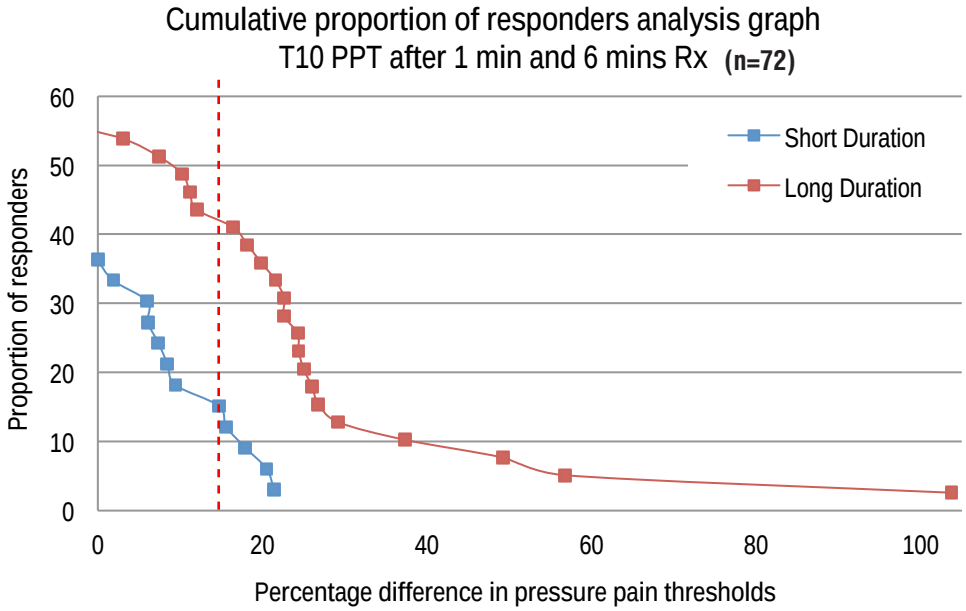


Figure 7.24. Responders' analysis at T10 paravertebral PPT site for after treatment period 2. Vertical line represents clinically relevant change (>15%).

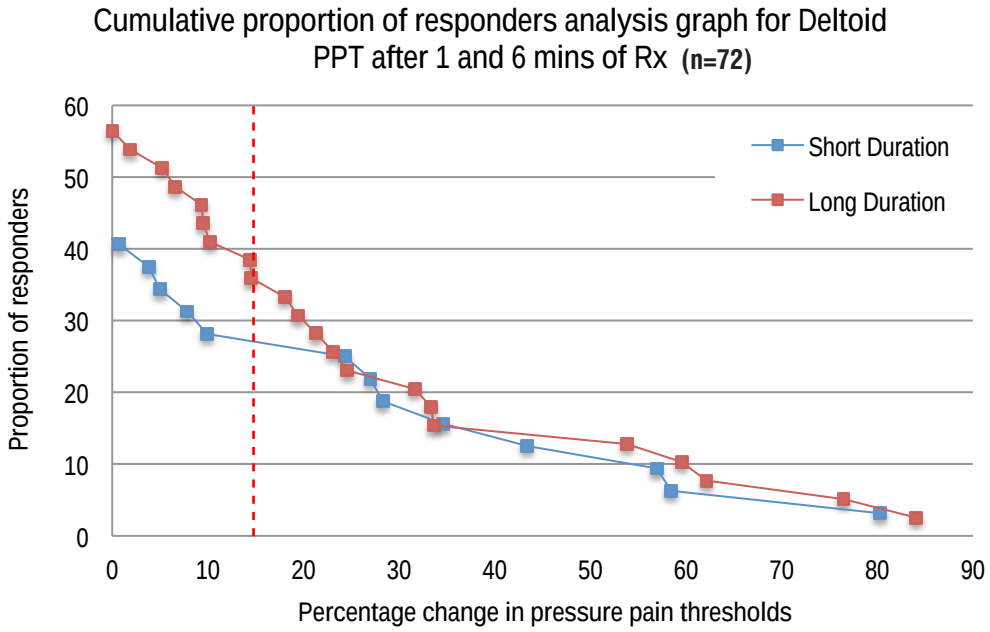


Figure 7.25. Responders' analysis at Deltoid PPT site for after treatment period 2
Vertical line represents clinically relevant change (>15%).

A similar response was seen at 24-hour follow-up, where again, the cumulative portion of responder analysis demonstrated that fewer participants experienced a positive response to the short duration of treatment at the symptomatic paravertebral PPT, 23% of the short treatment duration group had increased PPT compared to 47% in the long treatment duration group (Figure 7.26).

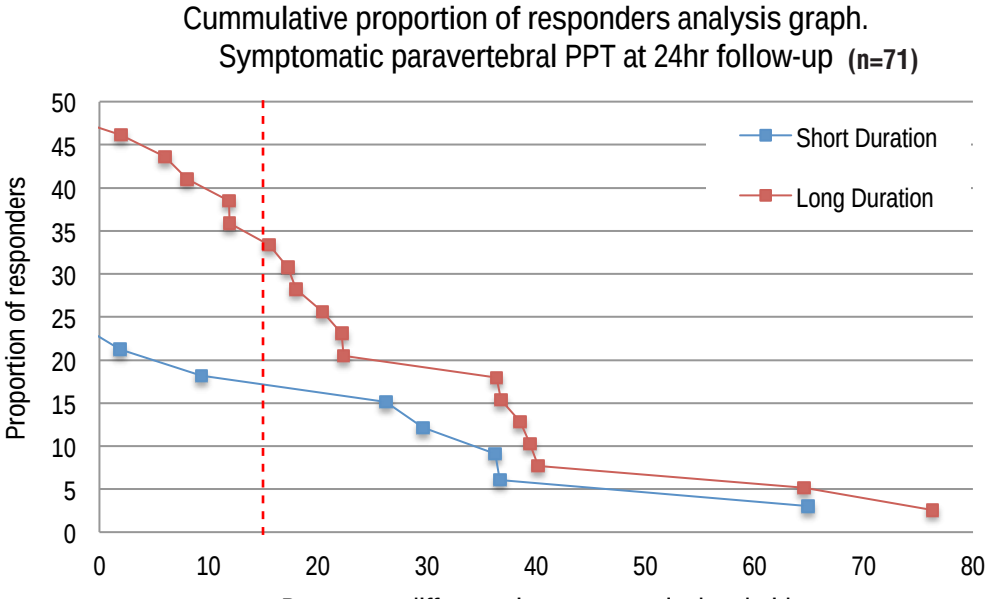


Figure 7.26. Responders' analysis at the symptomatic paravertebral PPT site at 24-hour follow-up
Vertical line represents clinically relevant change (>15%).

The number of responders for each condition, at each time point, based on changes in PPT local to the site of treatment (symptomatic paravertebral PPT), is displayed in Table 7.14. Chi-square analysis using the frequency of responders at each time point found that there was a significant association between duration of treatment and whether participants responded immediately after treatment, with significantly more responders in the long duration treatment group (Table 7.14). There was no association between response to treatment and group after placebo / 1 minute of mobilisations or at 24 hour follow-up (Appendix. 25).

	Number of participants with changes in PPT at the symptomatic paravertebral level exceeding					
	SEM	MDC	>15%	SEM	MDC	>15%
	Short duration			Long duration		
After treatment period 1 (n=72) 2 mins sham mobilisation (short) 2 mins mobilisation Rx (long)	5	2	4	7	4	10
Chi-square analysis based on SEM/MCD	x2 (1)=0.47 *p*= .50					
Chi-square analysis based on % change	x2 (1)=2.07 *p*= .15					
After treatment period 2 (n=72) 2 mins sham mobilisation + 1 min mobilisation Rx (short) 6 min mobilisation Rx (long)	2	3	4	13	8	19
Chi-square analysis based on SEM/MCD	x2 (1)=11.60 *p*= .001					
Chi-square analysis based on % change	x2 (1)=11.01 *p*= .001					
24 hour follow-up (n=71) 2 mins sham mobilisation + 1 min mobilisation Rx (short) 6 min mobilisation Rx (long)	2	3	5	6	6	13
Chi-square analysis based on SEM/MCD	x2 (1)=2.42 *p*= .12					
Chi-square analysis based on % change	x2 (1)=3.15 *p*= .08					

Table 7.14. Number of responders to treatment based on changes in symptomatic paravertebral PPT. SEM= number of participants with change from baseline greater than standard error of measurement. MDC= number of participants with change from baseline greater than minimal detectable change. >15%= number of participants with change greater than 15%.

The cumulative responders analysis for change in verbal rating of pain demonstrated that participants in the short treatment duration group exhibited a similar decrease in pain on movement (Figure 7.27). There was no significant difference in the number of responders *after treatment period 2*, when all participants had received mobilisation treatment (x^2 (1)=0.00 *p*= .99). See Table 7.15.

	Short Duration After treatment period 2 After 2 min placebo + 1 min Rx (n=33)	Long Duration After treatment period 2 After 6 min Rx (n=39)
Flexion	14	14
Extension	15	19
Right lateral flexion	15	12
Left lateral flexion	9	15
Right rotation	9	7
Left rotation	5	11
Total VRS (sum of VRS on all movements)	25	28

Table 7.15. Number of participants who had a positive response to treatment, based on changes in VRS of pain on movement of 1 or more. Numbers are shown for individual movements and for combined VRS of pain.

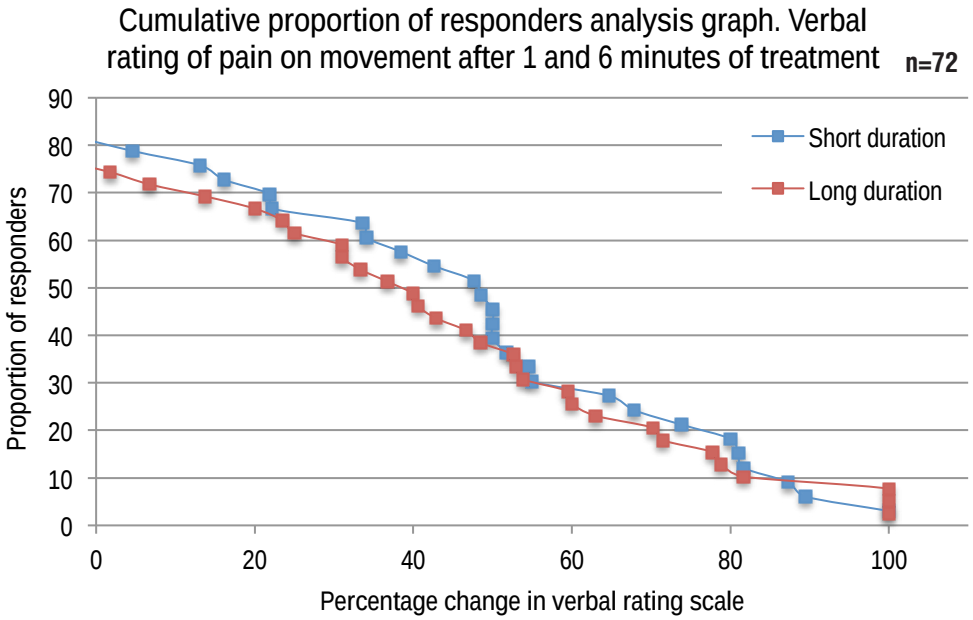


Figure 7.27. Similar amounts of participants responded in the short and long duration groups.

7.4.10. Profile of treatment responders

To investigate the profile of participants who responded to mobilisation treatment the characteristics, expectations and experience of those participants who were deemed to have responded to mobilisations based on either changes in MDC/SEM or % change in PPT at the symptomatic paravertebral muscle site were explored.

Overall 35 out of the 72 participants were considered to be responders in terms of changes in PPT at the symptomatic level (11 participants in the short duration of treatment group and 24 in the long duration group). After treatment period 2, when all participants had received mobilisation treatment, there was a significantly greater number of responders in the long duration of treatment group. At this time point, 5 participants in the short duration of treatment group and 21 in the long duration group were deemed to have responded to mobilisations in term of PPT and 53 out of the 72 participants were considered to be responders in terms of change in verbal rating of pain on movement (25 participants in the short duration of treatment group and 28 in the long duration group). Despite the high number of VRS responders, not all those participants that were classified as PPT responders were VRS responders (Tables 7.16 and 7.17). This dissociation between PPT and participants' verbal rating of pain was also evident in the main analysis.

The expectation and experience of treatment responders are summarised in Tables 7.16 and 7.17. The number of responders in terms of a minimum change in PPT at the symptomatic level, of the SEM or more, was used in further analysis. There was no difference in the expectations of treatment in responders and non-responders ($x^2(1)=.523$ $p= .77$). Appendix 25.

Short Duration Group Responders									
Participant no	**Duration of symptom (years)**	**VRS Responder (at time 2)**	**2 mins sham mob**	**1 min Rx mobilisation**	**24 Follow-up**	**Force of Rx (N)**	**Expectations**	**Experience**	**Did previous Rx help?**
1	1	Y		MDC/%	MDC/%	220	-ve	> mvt < pain	A lot
6	0.3	Y	SEM			154	Unform	Possible decrease in tension	A little
10	30	Y	SEM	MDC/%		168	+ve	Great improvement > mvt < pain	Short term
31	0.6	N	MDC/%			45	Unform	Not sure	No Rx
33	7	Y			MDC/%	93	Find source	Not sure	A lot
34	22	Y	SEM/%		SEM/%	98	Unform	Slight improvement	A little
38	0.2	Y	SEM/%	MDC/%		95	+ve	< pain	No Rx
46	3	Y	MDC/%			135	Unform	Not sure	Acupuncture helped
59	2.5	Y			MDC/%	151	Unform	Not sure	No Rx
66	1	Y	SEM	SEM		95	+ve	Slight relief	Not much
67	15	Y		SEM/%	SEM/%	128	-ve	Very good relief	A little

Table 7.16. Profile of PPT responders in the short duration of treatment group.
SEM/MDC/%: indicate changes exceeding minimal detectable change/ standard error of measurement /15% or greater (see section 7.13.1).
Y/N: represents whether participants were considered responders in terms of verbal rating of pain on movement at time-point 2.
-ve = negative; +ve = positive; Unform = unformed expectations, Rx = treatment, MVT = Movement, sham mob = sham mobilisation.

Long Duration Group – Responders									
Participant no	**Duration of symptom (years)**	**VRS Responder (at time 2)**	**2 min Rx**	**6 min Rx**	**24 Follow-up**	**Force of Rx (N)**	**Expectations**	**Experience**	**Did previous Rx help?**
3	4	Y		SEM/%		77	Find source	< tightness < pain	No Rx
7	15	N		SEM/%	MDC/%	41	Find source	< stiffness < pain	No Rx
8	12	N		SEM	MDC/%	67	+ve	> mvt < pain short term	A little
11	13	Y	MDC/%	MDC/%	SEM/%	142	Unform	Ease	A little
13	3.5	Y	MDC/%	MDC/%	MDC/%	132	Unform	Improvement	A lot
17	1.5	Y	SEM%	SEM%	SEM/%	38	+ve	Stiff and sore	Not much
22	7	N		SEM/%	%	56	Unform	Sore	No Rx
25	4	Y	MDC/%	MDC/%	MDC/%	146	+ve	Effective	A lot
28	2	N	SEM%		SEM%	31	+ve	> mvt	Didn't help
30	1	Y		SEM%		156	+ve	Not sure	Helped a lot
32	4.5	Y		MDC/%		202	+	Short term relief	GP a little
36	3.5	Y		SEM/%		60	+ve	Unusually better	A little
39	6	Y	SEM%	SEM/%	SEM%	67	+ve	Helped with daily activities	No Rx
44	2	Y		SEM/%		93	+ve	Unsure < pain short term	No Rx
47	2	Y	SEM%	MDC/%		85	+ve	< pain short term	A lot
52	31	Y		MDC/%		150	Neutral	None	A little
54	5	Y			MDC/%	76	Neutral	Not sure	No Rx
58	5	Y	SEM%	SEM%	SEM%	51	Neutral	<pain	A little
61	5	Y		SEM%		179	+ve	<pain	No Rx
64	8	Y	SEM%	MDC/%		69	Unform	Uncomfortable	Not much
65	15	N	SEM	SEM		86	+ve	Unsure	A lot
70	21	N	MDC/%	SEM%	MDC/%	101	Unform	Perhaps < pain	No help
72	11	N			SEM%	62	Neutral	More flexible, hard to tell.	A lot
73	7	Y		MDC/%		81	+ve	Ease of movement	A little

Table 7.17. Profile of PPT responders in the long duration of treatment group. SEM/MDC/%: indicate changes exceeding minimal detectable change/ standard error of measurement /15% or greater (see section 7.13.1). Y/N: represents whether participants were considered responders in terms of verbal rating of pain on movement at time-point 2. -ve = negative; +ve = positive; Unform = unformed expectations, Rx = treatment, MVT=Movement

There were no significant differences between questionnaire results for responder and non-responders (Tables 7.18 and 7.19 and Appendix 25 for statistical output) and there was no significance in the duration of symptoms or force of treatment in responders to non-responders. The only observable difference between responders and non-responders was participants' age. Responders were significantly younger than non responders U=802, *p*=.047 (Table 7.18).

	Alcohol		Age (years)	Exercise per week (hours)	GHQ28	McGill	Oswestry % score
	Units	Binge score					
Short duration responders n=11	Mean 8 SD 6	Mean 9 SD 11	Mean 41 SD 11	Mean 6 SD 4	Median 3 Mean 2 SD 4	Mean 17 SD 9	Mean 18 SD 10
Long duration responders n=24	Mean 7 SD 6	Mean 8 SD 11	Mean 35 SD 13	Mean 6 SD 5	Median 3 Mean 4 SD	Mean 18 SD 10	Mean 15 SD 6
Non-responders n=37	Mean 7 SD 6	Mean 6 SD 8	Mean 44 SD 14	Mean 4 SD 3	Median 3 Mean 4 SD 6	Mean 17 SD 9	Mean 17 SD 6

Table 7.18. Questionnaire results of responders to mobilisations

	Control	Disability	Harm	Emotion	Medication	Solicitude	Medical cure
Responders n=35	10 (3)	5 (3)	6 (4)	4 (4)	4 (3)	5 (4)	12 (4)
Non-responders n=37	11 (4)	6 (3)	5 (3)	6 (5)	4 (3)	5 (4)	10 (4)

Table 7.19. Survey of pain attitudes for responders and non-responders

A number of other factors that may have influenced the response to treatment were also examined and were similar between responders and non-responders as follows:

- There was no difference in the expectations of treatment responders (x^2 (1)=.523 *p*=.77).
- There was no significant difference in the treatment force received in responders and non-responders (U=533, *p*=.35).
- There was dissociation between change in PPT at the symptomatic paravertebral level and change in verbal rating of pain in treatment responders (PPT and verbal rating of pain on movement *p*=.06, r= -0.31 PPT and verbal rating of resting pain *p*=.63, r= -0.08 PPT and verbal rating of pain on PA force *p*=.19, r= -.022. See Appendix 24).

- Seven physiotherapists (4 students and 3 qualified) took part in the study. Three of these were classified as responders to mobilisation treatment (2 qualified and 1 student) and 4 as non-responders.
- Ten participants had pain referred below the knee. Two of these were classified as responders (one responded to placebo but not to the mobilisation intervention).
- Fifteen treatment responders received a central technique and 20 a unilateral technique.
- Responders did not necessarily perceive treatment to be beneficial, but 14 out of 35 thought that the treatment had been beneficial (see tables 7.16 and 7.17).

7.4.11. Summary of findings

- Cumulative proportion of responders' analysis suggested that there is greater immediate increase in PPT at the symptomatic paravertebral level after 6 minutes mobilisation treatment than after 1 minute of mobilisation.
- Chi-square analysis using the frequency of responders at each time point found that there was a significant association between duration of treatment and whether participants responded in terms of change in PPT immediately after treatment, with significantly more responders in the long duration treatment group.
- Responders analysis demonstrated that most participants experienced clinically significant changes in pain on movement. There was no significant difference between short and long duration groups.
- There were no immediate overall effects of sham mobilisation or mobilisation treatment on PPT,
- There was a significant reduction in PPT at 24-hour follow-up. The reduction in PPT at 24-hour follow-up was evident in both short and long duration groups. This demonstrated that participants in both groups exhibited hyperalgesia 24-hours after mobilisation treatment.
- Force of treatment had a significant mediating effect on change in PPT and change in verbal rating of pain on movement immediately after treatment. Force accounted for 9-13% of the variation in effect. Higher treatment forces were associated with a greater immediate hypoalgesic effect. The mediating effect of force for verbal rating of pain on movement remained evident at 24-hour follow-up.
- For verbal rating of pain on movement, there was a significant main effect of time, which demonstrated an immediate, and mid-term decrease in pain on movement with all conditions (placebo and short and long durations of treatment). The differences between 2 minutes sham mobilisation, 1 minute of treatment and 6 minutes of treatment failed to reach significance.

- For verbal rating of pain on the application of PA force to the symptomatic level, there was a significant main effect of time immediately following treatment, which demonstrated an immediate, decrease in pain on movement with all conditions (placebo and short and long durations of treatment). The differences between 2 minutes sham mobilisation, 1 minute of treatment and 6 minutes of treatment failed to reach significance. There was no effect of time at 24-hour follow-up demonstrating there was no short-term effect on resting pain levels.
- GRPC was improved at all time points demonstrating a significant perceived effect of treatment. The differences between placebo, 1 minute of treatment and 6 minutes of treatment failed to reach significance. There were significantly significant associations between changes in pain and participants' perception of change.
- Mobilisation treatment did not have an effect on resting pain levels in any treatment group.
- Nearly half of the participants in the study were not able or willing to express their expectations of receiving a mobilisation treatment. Most of the other participants expressed expectations of a positive outcome
- Most participants expressing an expectation thought that the treatment would reduce pain and some participants also thought that treatment would increase their movement and decrease stiffness. Seven participants expected to experience pain during the treatment.
- Most participants' experience of mobilisations was centred around pain during treatment and either increasing or decreasing pain following treatment.
- Profiling of the responders was not able to identify any characteristics that were different from the non-responders.

7.5. Discussion of findings

7.5.1. Discussion of the immediate effects of mobilisations

This study found no change in PPT immediately following sham mobilisation, 1 minute of mobilisations and 6 minutes of mobilisation in participants with LBP. This is the first study to investigate the effects of lumbar mobilisation treatment on PPT in a symptomatic population. Three previous studies have investigated the difference between lumbar mobilisation treatment doses on PPT in asymptomatic participants and contrary to the results of this study, reported significant increases in PPT following both treatment doses (Pentelka et al., 2012; Krouwel et al., 2010; Willett et al., 2010). However those studies were conducted primarily on asymptomatic physiotherapy students who may have

had expectations of a positive treatment effect, which might have enhanced the effect of treatment. Furthermore as the aim of those studies was to compare two treatment doses, rather than examine the effects of treatment per se, they did not employ a control intervention.

A number of studies of participants with neck pain have reported immediate increases in PPT following cervical mobilisations (Sterling et al., 2001; Vicenzino et al., 1998 and 1995) (section 2.9.1, page 15). All these studies have been conducted by one research group and have employed a same subject placebo controlled design. It may be that the non-significant treatment effect observed in this study is due to the spinal region treated, as it has been proposed that the lower density of mechanoreceptors in the lumbar spine might result in a reduced effect of the pain gate compared to studies performed in the cervical spine (Thomson et al., 2009)

In addition to being conducted in a different region of the spine, there are large differences in the duration of pre-existing symptoms experienced between participants in the current study and previous work. Most participants in previous studies had a mean duration of symptoms of a few months (6-8 months) (Vicenzino et al., 2001a and 1998 and 1996), as opposed to participants in the current study who reported 9 years mean duration of symptoms (range 0.3-35 years). Including participants with a greater duration of symptoms reflects patients in clinical practice, but may result in greater heterogeneity of this sample due to alteration of factors such as pain processing, pain beliefs and activity levels in chronic pain conditions. The questionnaire data identified that on the GHQ participants in the single-arm trial had lower depression / anxiety levels than those in the RCT. A number of factors where explored through covariate analysis, however, GHQ results, duration of symptoms, pain beliefs and activity levels did not alter the results of the main analysis. Furthermore in this study, duration of symptoms appeared to be no different in treatment responders and non-responders. The only factor that was different between responder and non-responders was age, with responders being significantly younger than non-responders.

Another difference between the current study and others investigating the effect of mobilisations in symptomatic participants is that previous results reported percentage change rather than actual change scores and used percentage change scores in their analysis (Sterling et al., 2001; Vicenzino et al., 2001a). Although percentages can be a useful way of presenting results descriptively, it has been suggested that percentage scores should not be entered for analysis (Vickers et al., 2001; Bonate, 2000). The use of actual change during the analysis may have altered the conclusions of those studies. However greater percentage change in PPT were reported than those seen in the present study.

Although Sterling et al., (2001) reported an immediate hypoalgesic effect of cervical mobilisations in patients with neck pain, a more recent study by the same authors reported no change in PPT following cervical mobilisations in patients with whiplash (Sterling et al., 2010). The authors proposed that these contradictory findings could be due to the greater amount of manual contact used in the more recent study, or due to the difference in musculoskeletal condition (Sterling et al., 2010). Another more recent placebo controlled study casts further doubt over previously consistent reports of increased PPT with mobilisation treatment – reporting no significant treatment effect after 3 minutes of cervical mobilisations in asymptomatic participants (Soon et al., 2010). It is a possibility that other studies reporting no treatment effect have been conducted but are not in the public domain due to a recognised publishing bias (Dechartes et al., 2013).

In addition to the measurement of PPT, this study also utilised verbal rating scales of pain and found an immediate reduction of pain on movement, pain on the application of PA force to the symptomatic level and an immediate perceived treatment change (GRPC). There was no significant difference between placebo and 2 minutes of treatment and 1 minute of treatment and 6 minutes of treatment, suggesting that the change could be attributed to the non-specific effects of treatment such as placebo or stimulation of cutaneous receptors. However, any treatment effects between groups could have been obscured by the low mean verbal rating of pain indicating low severity of symptoms and resulting in a floor effect, where low initial baseline scores make it difficult to detect a reduction in pain.

7.5.2. The effects of mobilisation treatment at 24-hour follow-up

Relative to baseline there was a significant reduction in PPT at 24-hour follow up, indicating that there was an increase in pain sensitivity. There was no significant interaction with site or condition, demonstrating that there was no difference between sites or treatment groups. It was recognised in the pilot work for this thesis that repeated testing of PPT can result in local soreness. In order to minimise this, the current study used the mean of 2 PPT measures as opposed to the mean of 3 measures at each site. However this still resulted in 6 repetitions at each site over the course of an hour. At 24-hour follow-up a number of participants complained that the testing sites ‘felt bruised from the previous days testing’. It is likely that the reduction in PPT (indicating hyperalgesia) demonstrated at 24-hour follow-up resulted from previous testing rather than a delayed effect of treatment. Alternatively they may have been suffering from ‘treatment soreness’ which is recognised to occur in some patients for 24-48 hours after treatment (Maitland et al., 2005).
At 24-hours follow-up pain on movement was significantly reduced compared to baseline and there was a significant perceived treatment change (GRPC). There were no significant difference between placebo and 2 minutes of treatment or 1 minute of

treatment and 6 minutes of treatment, so the reduction in pain on movement effects could be attributed to the non-specific effects of treatment or change over time.

There was no difference in resting pain or verbal rating of pain on PA force in any treatment group. This is somewhat contradictory to the results of the one previous study that has investigated the short-term effects of a single dose of mobilisation treatment; Vicenzino et al., (1996) reported a significant reduction in the patients' VRS of worst pain over the 24-hour period following 3 minutes of mobilisations to the cervical spine compared to placebo-controlled intervention. It may be that worst pain over a 24-hour period provides a better representation of participants' pain experience.

In this study PPT were measured immediately after treatment and 24 hours after treatment. The clinical relevance of findings would be enhanced if measures were obtained over a longer period. The mid-term and longer-term effects of mobilisation treatment are important areas for future research. The current study investigated the effects of a single treatment dose. In clinical practice patients normally receive a number of treatments over several weeks and thus investigating the possible cumulative effect of treatment is also an area for further investigation.

7.5.3. The mediating effect of treatment force on change in pain

In the current study there was a significant mediating effect of force on change in verbal rating of pain, with 13% of the variation in effect being accounted for by force. Higher treatment forces were associated with a greater immediate reduction in pain. This mediating effect of force was also evident for PPT where 9-11% of the variation in effect could be accounted for by force. The mediating effect of force was evident at PPT sites local to the treatment, but not evident at the Deltoid PPT site. These findings support previous hypotheses that local analgesic mechanisms are responsible for the analgesic effects of mobilisations. The force of treatment applied during this study was decided on based on participants' clinical presentation and thus the lack of overall effect of treatment on pain may have been due to the lower treatment forces used with some participants.

Two studies have investigated the effect of applying different percentages of the perceived maximum force during a mobilisation with movement to the elbow on pain free grip strength (PFGS) in patients with lateral epicondylalgia; Vicenzino et al., (2001b) noted that there was a threshold beyond which no further increase in force produced any further improvement of PFGS. This force was 62.2N or 50% of maximum applied force. A later study looked at applying 33%, 50%, 66% and 100% of the maximum force and found that 66% was the force threshold beyond which no further improvement in PFGS occurred (McLean et al., 2002). Interestingly the

maximum force in the later study was considerably lower, 113.2N as opposed to 134.8N in the first study, which may explain the difference in optimal percentage of perceived force between the two studies.

Current evidence suggests that the force of treatment has an influence in extolling an analgesic effect. This study provides evidence to support this whilst subsequently highlighting an area for additional research.

7.5.4. The relationship between PPT and verbal rating of pain measures

The dissociation between PPT and VRS of pain measures suggested by the responders' analysis was confirmed by further exploration of the relationship between these measures. This study found that the relationship between pain measures was variable. Mostly there was dissociation between symptomatic paravertebral PPT measures and VRS of pain (see Table 7.12). Conversely on most occasions different VRS of pain were associated with one another. One previous study explored the relationship between PPT and verbal rating of pain following mobilisation to the cervical spine and also reported dissociation (Sterling et al., 2001).

On the two occasions that there was association between PPT and verbal rating of pain, these associations were with pain on the application of PA force to the symptomatic level and verbal rating of pain on the application of force to the symptomatic spinal level. This association, albeit variable and potentially due to random error, could also be due to the fact that both these pain measures involved the application of pressure.

The other verbal ratings of pain rating used in this study were more akin to pain participants may have experienced on a daily basis, for example VRS of pain on movement and resting pain could be considered representative of a person's daily pain experience. Whereas participants are unlikely to experience pain produced in a similar manner to pain on PA force application during their daily activities. This, coupled with the fact that participants were not in control of the application of the PA force (as it was applied by a physiotherapist) may have affected the relationship with other pain measures.

PPT are often used as a measure of the hypoalgesic effect of mobilisations. PPT may represent participants' level of pain sensitivity, but this does not appear to relate to the experience of pain in participants with chronic LBP. These findings suggest that analgesia measured by these different measures may be mediated by different underlying neurobiological mechanisms.
After treatment period 1, there was a significant association between participants' perception of change and the change in verbal rating of resting pain and pain on PA force application. However there was dissociation between GRPC between

verbal rating of pain on movement and change in PPT. There was no difference in this dissociation when examined separately for placebo and 2 minutes of treatment. After treatment period 2 there was association between participants' perception of change and all pain measures except for verbal rating of pain on PA force application (p= .06, r=-.22). At 24-hour follow-up there was a strong and significant association between the change in all pain measures and participants' perception of change. These findings demonstrate that on most occasions there is an association between participants' perception of change and changes in pain.

The inclusion of PPT, verbal rating scales of pain and GRPC in future studies would provide a more complete picture of the analgesia effects of treatment.

7.5.5. Discussion of responders analysis

The difference in response of individuals as observed in the PPT results of this study can create a wash out effect, where on overall analysis those who experience soreness with treatment cancel out the beneficial effects experienced by other participants. The variability in patient's response to treatment of LBP has been widely recognised (Wand and O' Connell, 2008; Farrar et al., 2006; Childs et al., 2004). For this reason Farrar et al., (2006) recommended using cumulative proportion of responders analysis graphs in order to compare the proportion of participants responding to different treatments.

The cumulative proportion of responders analysis graphs suggested that a greater proportion of participants in the long duration treatment group respond to a greater extent than those in the short duration treatment group (Figures 7.21 and 7.22). This was evident at the symptomatic level and T10 paravertebral PPT site, but not at the Deltoid muscle PPT site suggesting that the response is mediated by local analgesic mechanisms.

Further analysis revealed that, in terms of local changes in PPT, there were significantly more responders to treatment in the long duration treatment group than the short duration treatment group (treatment responders were classified according to those who had minimally detectable change in PPT local to the site of treatment). The difference in the proportion of responders in the placebo and 2 minutes of treatment groups failed to reach significance. This suggests that longer than 2 minutes of treatment may be necessary before a treatment effect exceeding that of placebo is observed. The difference in the proportion of participants experiencing clinically important increases in PPT in the short and long duration groups appears to be short lived as the difference between groups at 24-hour follow-up failed to reach significance.

Although the responders analysis of PPT results demonstrated a difference between treatment durations, this was not evident with VRS of pain on movement. The cumulative proportion of responders analysis of verbal rating of pain on movement demonstrated a similar pattern for both treatment durations, with over 70% of participants achieving a beneficial effect of treatment. Responders analysis also revealed that a similar number of individuals experienced clinically meaningful changes in pain on movement in both short and long duration of treatment groups (Table 7.15). Profiling of responders demonstrated that those participants that were responders in terms of PPT measures were not necessarily those that responded in terms of change in verbal rating of pain on movement. This was confirmed by the dissociation between verbal rating and PPT measures of pain in treatment responders. These findings support the results of the overall analysis of the relationship between PPT and patient reported measures of pain.

In summary more participants in the long duration group had an immediate decrease in PPT than in the short duration group. The results of this study have demonstrated that responders analysis is a sensitive method of observing between group differences in analgesia. It is recommend that future studies investigating the effect of different treatments on pain consider including similar analysis.

7.5.6. Participants' expectations of mobilisation treatment

It has been demonstrated that expectation of a beneficial treatment can positively influence treatment outcomes, for example, positive association between positive expectations and good functional outcomes has been reported previously (Kalauokalani et al., 2001). Specific to manual physiotherapy treatment, one study investigated the effects of expectations on the analgesic effects of manipulation treatment and found that participants who were given negative expectations demonstrated hyperalgesia (an increase in pain) following treatment (Bialosky et al., 2008). This may suggest that those participants who had previously beneficial physiotherapy treatment may have been more likely to encounter a more positive experience on this occasion. However responders analysis in this study was not able to identify any significant influence of treatment expectations. This could be due to the study context and environment (the research study was conducted in a University laboratory) being different to that encountered during participants' previous treatment experience.

Nearly half of the participants in this study expressed neutral or unformed expectations of receiving a mobilisation treatment. An inability or unwillingness to express expectations has been described previously as unformed expectations (Thompson and Sunol 1995) and is thought to be present when an individual has no prior experience on which to form their expectations (Bialosky et al., 2010). However

a lack of previous experience does not explain the higher number of unknown expectations in this study as half of the participants who expressed no expectations had received previous treatment and all but 2 of these had received mobilisation or manipulation. The large proportion of participants expressing neutral treatment expectations could be partly due to the fact that participants in this study suffered from chronic LBP as patients with chronic conditions have been found to have lower expectations of treatment (Hills and Kitchen, 2007).

7.5.7. Predictors of response to mobilisation treatment.

Utilising symptomatic study participants adds a number of variables such as the heterogeneity of LBP, the patients' beliefs regarding their condition and their pain experience to name just a few. This adds a layer of complexity that may not be evident in studies utilising asymptomatic participants and may explain the varying response to treatment observed in the cumulative responders analysis. Studies in acute LBP have identified factors that may help to predict patient's response to manual therapy treatment but provide inconclusive evidence and require further validation before their findings can be accepted (Haskins et al., 2012 and Kamper et al., 2010). The current study included planned covariate analysis of PPT and verbal rating of pain with questionnaire data and examination findings. None of the covariates (duration of symptoms, age, GHQ, Oswestry, McGill, SOPA) significantly influenced treatment outcome. The influence of these factors was further explored in the responders analysis, but profiling of treatment responders did not identify any influence of these factors, nor of expectation or experience of treatment. Low fear avoidance, duration of symptoms of less than 16 days and pain not extending below the knee have been suggested to be predictive of a positive treatment outcome (Childs et al., 2004; Flynn et al., 2002). These factors were explored in this study, however profiling of treatment responders did not find an association with duration of symptoms, pain distribution or pain belief and treatment outcome.

Other untested factors may be useful predictors of treatment outcome, but at present these findings suggest that none of the factors investigated in this study can predict the response to treatment and highlights the complexity of predicting treatment response.

7.5.8. The extent of the analgesic effect

This study found that there was no overall site*time interaction of PPT, indicating that there was no difference between the change in PPT at different PPT sites. However, because there was no overall treatment effect of treatment no conclusions regarding the extent of the analgesic effect can be drawn from the overall analysis. However responders analysis found that there were significantly more responders in the long duration of treatment group. The effect was evident at PPT sites local

to the treatment and not at the deltoid muscle site indicating that the effects of mobilisations maybe mediated, at least in part, by a local analgesic mechanism. Further evidence of a local analgesic mechanism is provided by the mediating effect of force which was evident at local PPT site but not at the deltoid muscle site.

The local treatment effects observed in this study could be explained by the pain gate theory whereby more afferents are stimulated by larger forces applied for longer, resulting in modulation of pain in the dorsal horn of the spinal cord (Wyke, 1985). One study in rats found the analgesia resulting from mobilisations may be mediated at spinal cord level; Malisza et al., (2003) investigated the effect of knee joint mobilisations in rats and found a decrease in activity (using functional MRI) in the areas of the spinal cord associated with pain. Conversely, Sterling et al., (2001) reported concurrent sympathetic excitation and mechanical hypoalgesia observed following cervical mobilisations and claimed that this indicated that pain relief was mediated via the dorsal PAG. However the measures of SNS activity may be considered to lack validity (Arena and Hobbs, 1995) and at best provide indirect evidence of stimulation of the dorsal PAG.

Similar to the current study, previous studies have utilised a number of different PPT sites in order to gain insight into the extent of the analgesic effect of mobilisations and thus the underlying analgesic mechanisms. Significant changes have been reported at sites distant and sites local to the treatment (Pentelka et al., 2012; Willett et al., 2010). Importantly these studies also reported that changes in PPT local to the site of treatment were significantly greater than more distant sites, indicating that more than one analgesic mechanism may be responsible for the hypoalgesic effect (Pentelka et al., 2012).

In summary the findings of this study suggest that the analgesia resulting from lumbar mobilisations is at least in part, mediated via local analgesic mechanisms. However these findings remain speculative and further studies utilising functional magnetic resonance imaging or neurochemical manipulation of neurotransmitters could provide more direct evidence of the underlying mechanisms and is an area for future research.

7.5.9. Study Limitations

The current study included a placebo intervention in order to control for the non-specific effects of treatment. A structurally equivalent placebo was used in the current study as in a meta-analysis the use of structurally equivalent placebos has been shown to reduce bias (Baskin et al., 2003). However, the challenge of including a suitable placebo condition for low back pain studies is recognised (Machado et al., 2008; Hancock et al., 2009), as the effectiveness of placebo hinges on participants

believing that the treatment will be successful (Bialosky et al., 2011). Similar to this study, manual contact has been used as a placebo treatment in previous studies investigating the effects of mobilisations (Sterling et al., 2010; Vicenzino et al., 1995). In this study, the mean force of manual contact used in the placebo group was 25.6N (SD 12, range 8-52N). This force may be considered to be high for a placebo condition, but was employed to try and ensure the believability of the placebo and thus ensure blinding of participants. It is notable that there was some overlap between the force used in the placebo and treatment conditions as the lowest mean peak force used in treatment was 41 Newtons. However when inspecting the individual data the highest placebo force (52N) was applied to the participant that received the highest treatment force (303N). This was applied to a larger male participant with minimal symptoms. Conversely the lowest placebo force (8N) was applied to a small female with severe symptoms whose mean peak treatment force was 79N. It could be considered that the variability in the force used in the placebo group was appropriate for the participants in this setting. However, it is acknowledged that the influence of manual contact on cutaneous and muscle receptors (Woolf, 1983; Woolf and Wall, 1982) in the placebo condition may have an influence on pain that should not be underestimated. Future work could consider using alternative placebos, for example detuned shortwave diathermy.

One of the recruitment strategies employed in this study was advertising through the University email system. This resulted in a number of academics and research students taking part in the study. The wording of the participant information sheet (Appendix 15) was carefully considered stating the aim of the study as investigating 'the effect of different amounts of mobilisation' (this was deemed to be ethically acceptable as the placebo group went on to receive a treatment dose). Despite the fact that the participant information sheet did not describe the inclusion of a placebo group, 2 of the participants in the study asked if they would be receiving a placebo condition. The researcher explained that there were a number of stages to the study that could not be discussed until the completion of the study. Furthermore the current study did not recruit participants who were naïve to physiotherapy intervention and many had received physiotherapy, including similar techniques previously. These factors may have resulted in participants receiving the placebo intervention distinguishing this from an active treatment. Future work should consider recruiting research or physiotherapy naïve participants to ensure blinding or including an end of study debriefing, asking participants whether they thought they had received a placebo intervention and thus revealing the extent of un-blinding that occurred during the study.
All the participants receiving mobilisation treatment in the studies in this thesis received a treatment applied in neutral, prone lying position. However this does not reflect clinical practice where depending on the severity and irritability of a

patient's symptoms they may be treated in a position that either aggravates or eases their symptoms whilst the mobilisation is applied (Petty, 2011). Most elements of treatment dose in this study were applied pragmatically (grade, rate, rhythm), and for this reason the decision regarding positioning of the patient afforded extensive consideration prior to the onset of this study. Positioning participants in a symptomatic range for treatment would have created a challenge when devising a structurally equivalent placebo, as this would have required the placebo group to be positioned in symptomatic range for the same duration as the treatment condition. This was considered to be inappropriate due to the possible therapeutic effects from positioning alone. Thus, a decision was made to apply all treatment conditions in neutral. However it is recognised that positioning is an important element of treatment dose which was not incorporated into this study. Furthermore the position of prone lying may have resulted in an increase in symptoms for some participants, for example, in the subjective history several participants complained of being unable to lie prone because of their symptoms, some of the participants who were randomised to the placebo treatment, complained of increased resting pain and pain on movement which they attributed to lying prone.

In the current study participants received a physiotherapy assessment in order to identify the symptomatic level and ensure they met the inclusion criteria of experiencing pain on active movement. On completion of the study participants received advice and home exercises for their LBP. In order to tailor this advice to the needs of the individual, the initial assessment also included a full subjective examination; participant's beliefs about their symptoms were noted but not explored until the final advice and exercise session and there was no discussion regarding the cause of their symptoms until that point. Some participants displayed fear of movement and faulty movement patterns through the study but these were not addressed until the study was completed. The lack of normal communication in this study may have influenced the treatment response, as not addressing participants' beliefs may have influenced their responsiveness to treatment. It has been suggested that if patient expectations are not addressed the benefits of treatment might not be maximised (Potter et al., 2003). Furthermore, the experimental procedure prevented the therapist from demonstrating active listening skills, which have been shown to be important in communicating with patients (Potter et al., 2003). The inability of the assessing therapist to explore the participants' beliefs and expectations resulted in the treatment following a biomedical model. It is widely recognised that this does not result in optimum treatment outcomes and assuming a biopsychosocial treatment approach is considered to be an essential part of the management of low back pain (Main and George, 2011; Nicholas and George, 2011). Additionally in clinical practice the examination process itself can be used as treatment, for example, physiotherapists

may use motivational interviewing techniques to encourage normal movement. This study was designed to examine the effects of mobilisations in isolation and thus communication with the patient not necessary for the study was kept to a minimum. The effects of mobilisations may be interlinked with the communication that is associated with them and thus the effects seen in this study may not reflect those seen when they are utilised in clinical practice.

All participants in this study regardless of their findings were treated using a mobilisation standardised for experimental purpose. This does not reflect clinical practice where treatment is directed at the examination findings. Options for future work would be including participants who respond favourably to a trial treatment dose (often applied in a physiotherapy assessment in order to tailor subsequent treatment choices). An alternative strategy, that has been employed previously, in LBP studies, is to investigate the effect of manual therapy in participants who fulfilled a clinical prediction rule (Childs et al., 2004). These options were not employed in this study in order to prevent the introduction of bias.

The questionnaire on participants' expectations and experience of receiving a mobilisation treatment dose was completed at the end of the study (after participants had received a mobilisation technique). Participants were asked to recall their expectations prior to receiving the treatment, which may have been affected by their experience of receiving a mobilisation treatment as a participant in the study. The use of a semi-structured questionnaire did not enable the researcher to explore the thoughts or opinions expressed by participants. For example, 34 participants stated that they did not have any expectations of a mobilisation treatment. The use of an interview would have enabled the researcher to explore participants' initial responses. Another disadvantage of a semi-structured questionnaire as opposed to an interview was that participants were less likely to clarify the meaning of the questions and the researcher was unable to establish whether they had been misunderstood until the point of analysis.

7.6. Conclusions

In summary responders analysis demonstrated that significantly more participants experienced immediate increases in PPT local to the site of treatment following 6 minutes of lumbar mobilisation treatment than following 1 minute of treatment suggesting that longer treatment duration may have a greater hypoalgesic effect which may be mediated by local analgesic mechanism. This study identified that treatment responders were significantly younger than non-responders. No other predictors of treatment response were identified.

The overall analysis demonstrated that there was a significant change in verbal rating of pain on movement and verbal rating of pain on the application of PA force to the symptomatic level, but there was no difference between treatment and placebo

intervention, suggesting that this effect was due to natural variation or the non-specific effects of treatment. Overall, neither placebo intervention nor lumbar mobilisations changed PPT, however there was a significant mediating effect of force, with higher treatment forces being associated with greater immediate increases in PPT and decreases in pain on movement. The variability in participants' response to treatment may explain the lack of overall effect and thus responders analysis may be a more sensitive way of analysing pain relief in heterogeneous populations.

The dissociation between PPT and verbal ratings of pain reported in this study suggest that when investigating the analgesic effects of treatment it may be important to incorporate a number of pain measures in order to gain a wide appreciation of change in pain experienced by patients.

Chapter 8

Overall discussion of the thesis

This thesis has presented three main studies. The first study (chapter 5) explored the reliability of pain, ROM and stiffness measurements to be used in later studies. This was followed by a single-arm trial investigating the immediate effects of 3 and 6 minutes of lumbar mobilisations in participants with LBP. A single-arm trial (chapter 6) was employed, as this was the first study to explore the effects of mobilisation and duration of mobilisation treatment in participants with lumbar spine pain. Moreover participants had a stable condition that was being monitored within one treatment session so the natural history of the condition was unlikely to be responsible for any immediate within session changes. The final study presented in the last chapter of this thesis was an RCT. The RCT was a methodologically robust progression from the single-arm trial, which focused on both the immediate and short-term analgesic effects of mobilisation and incorporated a questionnaire asking participants about their expectations and experience of receiving mobilisation treatment.

8.1. Analysis of treatment responders

In the RCT responders analysis of PPT results identified that there were significantly more responders to 6 minutes of treatment than to 1 minute of treatment demonstrating that there were greater numbers of participants who experienced clinically important increases in PPT in the long duration of treatment group.
The difference in the proportion of responders in 3 minutes compared to 6 minutes of treatment in the single-arm trial failed to reach significance. This suggests that the difference between 3 and 6 minutes of treatment is insufficient to observe significant difference between durations but suggests that longer treatment results in greater increase in PPT in some individuals.

The difference between factors that may influence the treatment response was explored for responders and non-responders. Only one factor tested in this thesis was different between response groups with responders being significantly younger than non-responders. It is evident that responders analysis is a sensitive method for examining the analgesic effects of different treatments and it is recommended for future studies.

8.2. The effects of lumbar mobilisations on PPT

The overall analysis of PPT in the single-arm trial (chapter 6) found that both 3 and 6 minutes of lumbar mobilisation treatment resulted in a significant change in PPT. The difference between durations failed to reach statistical significance which may have been due to the study being underpowered to detect a difference between

durations. Because there was no placebo or control group claims of a hypoalgesic effect of treatment could not be fully supported. The proceeding RCT (chapter 7) found that there was no immediate analgesic effect of placebo, 1, 2 or 6 minutes of mobilisation treatment.

The lack of effect observed in the RCT is somewhat contradictory to the findings of the single-arm trial. In the single arm trial mean change in PPT at the symptomatic paravertebral muscle site after 6 minutes of treatment was 1.5kg/cm^2 and at T10 1.2 kg/cm^2; the mean differences in the RCT study were much smaller (0.3kg/cm at both of these sites). The RCT included 72 participants and thus had greater statistical power than the single-arm trial (which included 16 participants). However in a meta-epidemiological study, Dechartres et al., (2013) investigated the influence of sample size on treatment effects and found that the greatest effects were observed in small to medium sized trials as opposed to larger trials and proposed that this could due to a publication bias or the greater heterogeneity when recruiting larger samples. The participants in the single arm trial and RCT met the same inclusion and exclusion criteria and the recruitment strategy was largely the same, one notable difference was that in addition to the recruitment strategies used in the single arm trial (most participants were recruited through University email) the RCT recruited participants through advertisements in local papers. This may have resulted in a more heterogeneous group of participants in the RCT. Another difference in the inclusion criteria is that in the single-arm trial participants had to experience pain on simple movement (without overpressure). Due to difficulty recruiting participants matching these criteria the inclusion criteria in the RCT was widened to include participants who experienced pain on active movement with overpressure or combined movements. This may have resulted in participants with less severe symptoms taking part in the study and thus potentially a floor effect with smaller potential benefits making it difficult to detect a treatment effect. These factors may also explain the difference in results for verbal rating of pain on movement found in the single-arm trial and RCT.

In addition to examining the immediate effects of mobilisation, the RCT investigated the analgesic effects 24-hour after treatment. There was a significant decrease in PPT at 24-hour follow-up in both treatment groups. Due to observations from the pilot work, this was attributed to soreness from PPT testing on the previous day rather than a delayed effect of mobilisations treatment. Six PPT repetitions were performed at each site over the course of an hour and a number of participants commented that some PPT sites felt ‘bruised’ the following day. The reliability study (chapter 5) demonstrated adequate inter-day reliability of PPT measures, However, the time between days varied from 1-13 days (mean 5.45 SD 3.91) and any bruising may well have reduced over this timeframe and may not have been evident in the reliability

results. Future research should consider the number of repetitions and the time between repetitions when using PPT as an outcome measure.

8.3. The extent of the analgesic effect of mobilisations

The difference in response levels in the RCT was evident at the paravertebral muscle sites, but not at the deltoid muscle site suggesting local analgesic mechanisms (such as the pain gate theory) may be responsible for the increase in PPT. The significant difference in PPT measurements relative to baseline following both 3 and 6 minutes of treatment reported in the single-arm trial was not evident at the deltoid muscle site. This local effect was also apparent for the mediating effect of force which was evident at local sites but not at the deltoid site. This evidence combined suggests that the change in PPT is mediated by local analgesic mechanisms, however this is speculative evidence and further evidence should be sought through studies utilising functional magnetic resonance imaging or pharmacological manipulation of neurotransmitters that influence the different analgesic mechanisms.

8.4 The effects of lumbar mobilisations on verbal ratings of pain

The single-arm trial found that 6 minutes of treatment produced a significantly greater reduction in verbal rating of pain on movement than 3 minutes of treatment. Although the RCT found a significant effect of time immediately following treatment, there was no difference between placebo and 2 minute and 1 minutes and 6 minutes of treatment. Although the RCT suggests that there may be no effect on verbal rating of pain additional to those of placebo, in the single-arm trial the effects of 3 minutes of mobilisations failed to reach significance, whereas the effects of 6 minutes of mobilisation were significant, indicating that in the single arm trial the effects of treatment were more than those of just placebo. Similar to the PPT results there appeared to be less of an analgesic effect on verbal rating of pain in the RCT than in the single-arm trial. This could be explained by the difference between participants recruited in the studies as discussed in section 8.2.

8.5. The relationship between pain measures

An important finding of both the single arm trial and RCT was the dissociation between PPT and VRS measures. One other study has investigated the relationship between PPT and pain rating after cervical mobilisation and also found dissociation between measures (Sterling et al., 2001). In a study utilising asymptomatic participants Lacourt et al., (2012) reported only moderate correlation between verbal pain rating of pain experienced on PPT testing and the PPT values themselves and proposed that PPT and verbal rating of pain consist of different constructs.
The dissociation between measures as found in this study may be greater in participants with a chronic condition as rating of ‘their’ pain may be more influenced by psychosocial factors than the rating of pressure threshold.

These results suggest that different PPT and verbal ratings of pain may be mediated by different neurobiological mechanism. It is suggested that studies measuring analgesia do not use PPT in isolation and where possible patient reported pain measures are also used.

The RCT identified an association between changes in pain and participants' perception of change. It is recommended that where possible participants' perceptions of change are monitored in order to gain an appreciation of the overall pain experience.

8.6. Mediating effect of force

Treatment force had a significant mediating effect on both verbal rating of pain on movement and PPT (local to the site of treatment), with greater forces creating greater reductions in pain. The lack of overall significant findings may have been due to the lower force used in some participants. Although there was no significant difference in the treatment force received by treatment responders and non-responders. It may be that where pain allows physiotherapists should apply mobilisations using higher forces. However these findings need further investigation and thus the influence of treatment force is an important area for future research.

8.7. Predictors of response to treatment.

In the RCT, the expectations and experiences of treatment responders and non-responders were compared but there were no apparent difference between groups. This is the first study to investigate the influence of symptomatic participants' expectations of receiving a lumbar mobilisation treatment. Although 30 participants expected treatment to be beneficial, 35 were unable to express their expectations. This could be due to the chronic nature of the LBP experienced by participants in this study (mean 9 years duration), as it has been recognised that patients with chronic conditions have lower expectations of treatment (Hills and Kitchen, 2007). Treatment responders did not have different expectations to non-responders. However these results may have been influenced by the large number of participants with unknown expectations. Future research could use interviews to explore participants' expectations in greater detail and look at the relationship between treatment outcome and participants' perceived effects of treatment. Profiling of responders in this thesis did not find a relationship between expectation and experience of mobilisations and treatment response.

8.8. Stiffness measurement.

The studies presented in chapter 5 and 6 of this thesis are the first studies to compare the two methods of stiffness measurement (three-point bending and displacement); simultaneous measurements were taken using both methods in the first two studies of

this thesis. The reliability study found that within-day reliability of three-point bending was moderate and between-day reliability was poor. The within- and between-day reliability of displacement measurements of stiffness were moderate.

Observation of the three-point bending electromagnetic sensor movement and associated data highlighted potential problems with the validity of three-point bending measurements. Three-point bending measures demonstrated large between-subject variability (evident from the range and standard deviation of measurements), compared to displacement measurements.

The relationship between three-point bending and displacement methods of stiffness measurement varied. In the reliability study there was a significant and strong association between three-point bending and displacement methods of stiffness measurement demonstrating that greater stiffness measurements with one method were related to greater stiffness measurements with the other method. However, the proceeding single-arm trial found that there was dissociation between baseline measurements of three-point bending and displacement.

To gain further information about the stiffness measurements, responsiveness to change was assessed after 3 and 6 minutes of treatment. Interestingly there was dissociation of measurements after 3 minutes of treatment, but an association after 6 minutes of treatment. The varying relationship between measures suggests that three-point bending and displacement are not necessarily measuring the same behaviour. This, coupled with concerns about sensor movement and the theory underpinning three-point bending, casts doubt over its usefulness in future work. The displacement method has greater face validity as it is similar to the stiffness assessment performed by physiotherapists in clinical practice, however, the reliability values reported in chapter 5 suggest that neither method (using manually applied force) is ideal for measuring stiffness changes resulting from mobilisations.

Neither 3 nor 6 minutes of mobilisations resulted in immediate changes in three-point bending or displacement stiffness measurements. This is in agreement with the majority of studies investigating the effect of mobilisations on lumbar spine stiffness.

8.9. The effects of lumbar mobilisations on range of movement

Although on initial appraisal, the ICC's for ROM could be regarded as acceptable, the real change value indicated that a large difference would need to have occurred before it could be attributed to a treatment effect. For example in the case of flexion, treatment would need to produce a 15.41 degrees change in ROM to be sure that a treatment effect had occurred, this is approaching an increase of nearly 1/3 of the total range. The single-arm trial (chapter 6) found that neither 3 nor 6 minutes of mobilisations

resulted in immediate changes in ROM in participants with chronic LBP. This is in agreement with the majority of studies reporting no change in ROM with mobilisations treatment. Two studies employing longer durations of treatment have reported increased ROM immediately following treatment (McCollam and Benson, 1993 and Powers et al., 2008). The findings of the single-arm trial suggest that the longer treatment duration employed does not explain the change in ROM reported in these studies.

8.10. Summary of limitations

- The single-arm trial in this thesis investigated the difference between treatment durations. A single arm trial is a quasi-experimental design that cannot rule out bias, natural improvement or regression to the mean. It was used as a precursor to an RCT as an RCT is not usually the first step in studying an intervention (Chin and Lee, 1996). It is acknowledged that in the RCT, the inclusion of a third group receiving placebo condition only would have been a preferable study design, but the number of participants required for a third group was not feasible within the duration of the study.

- It is acknowledged that positioning is a component of mobilisation treatment that was not incorporated into the treatment periods and may have influenced the study outcomes.

- The final study sought to compare participants' response to treatment to their expectations and experience of receiving a mobilisation treatment. A questionnaire was used in order to categorise their responses. However, the use of a questionnaire did not enable exploration of their responses and nearly half of the participants did not express any expectations of treatment.

- It is recognised that patients respond differently to treatment. However none of the potential predictors of treatment outcome tested in this thesis significantly altered the results of the main analysis. This may have been due to lack of statistical power as the power analysis was calculated on the 2-way interaction between time and condition and may have been underpowered to detect subgroup effects. Research trials sufficiently powered to detect differences in subgroup is an important continued focus for future work.

8.11. Research questions addressed in the studies in this thesis

This thesis set out to address a number of research questions (page 44). The findings relating to each of these questions is summarised below:

What is the test-retest reliability and measurement error of ROM (using an electromagnetic tracking device), stiffness (using three-point bending and displacement methods) and PPT measurements?

The test-retest reliability of lateral flexion range of movement measurements was good to excellent, as was within-day reliability of extension. However within- and between-day reliability of flexion and between-day reliability of extension were only fair. Furthermore the MDC statistic indicated that large changes in range of movement would need to occur in order to be sure that a change was due to treatment. Within-day reliability of stiffness measurements was good to excellent. Between-day reliability for displacement measurements was good, but for three-point bending was poor. Both between- and within-day reliability of PPTs measurements was good to excellent (depending on the site of PPT measurement).

Which is the most valid and reliable method for measuring the effects of mobilisation on lumbar stiffness?

Observation of the sensor movement occurring during testing cast doubt over the validity of three-point bending measurements. The concerns regarding the movement of the sensors and the safety of the assumption underpinning three-point bending theory suggest that the displacement method of stiffness measurement is preferable for future research. Furthermore the three-point bending method of stiffness measurement does not represent how physiotherapists assess stiffness and in terms of measuring the stiffness that therapist perceive it lacks face validity. These results suggest that further investigation of the three-point bending method of stiffness is necessary before it is used in future work.

The displacement measurements of stiffness demonstrated good reliability both within- and between-day. However the reliability of stiffness was lower than in previous studies. This is largely explained by the use of a manually applied indenter in this study. It is recommended that future work uses a mechanically driven indenter to standardise the application of force

What are the immediate effects of lumbar mobilisations on pain, stiffness and ROM in patients with chronic non-specific LBP?

The single arm trial found no significant change in ROM or stiffness relative to baseline with either 3 or 6 minutes of treatment. However relative to baseline there was a significant increase in PPTs following mobilisations (indicating a hypoalgesic effect). Because this was not compared to a control intervention this findings

could be due to natural variation over time. The single arm trial found that relative to baseline there was a significant increase in verbal rating of pain on movement following 6 minutes of mobilisations. Although this was not compared to a control intervention no significant difference in PPT was found after 3 minutes of treatment, suggesting that a treatment effect had occurred following 6 minutes of treatment.

The RCT found no overall change in PPT immediately following sham mobilisation, 1 minute of mobilisations and 6 minutes of mobilisation in participants with LBP demonstrating that there was no overall effect of treatment. However there were significantly more responders to 6 minutes of treatment than 1 minute of treatment. The difference in the number of treatment responders following 2 minutes of mobilisation treatment and 2 minutes of sham mobilisation (the placebo intervention) failed to reach statistical significance suggesting that 2 minutes of mobilisations may not be long enough duration to exceed the benefits of the non-specific effects of placebo. Overall these findings highlight the variability in participants' response to treatment and demonstrate that significantly more participants respond to a longer duration of mobilisation treatment.

There was a significant change in verbal rating of pain on movement and verbal rating of pain, but the difference between treatment and placebo intervention failed to reach significance, suggesting that this change was due to natural variation or the non-specific effects of treatment.

What are the short-term effects of lumbar mobilisations on pain, stiffness and ROM in patients with chronic non-specific LBP?

Relative to baseline there was a significant reduction in PPT at 24-hour follow up, indicating that there was an increase in pain sensitivity. It is likely that this reduction in PPT's (indicating hyperalgesia) resulted from previous testing rather than a delayed effect of treatment.

At 24-hours follow-up pain on movement was significantly reduced compared to baseline. However there were no significant difference between placebo and 2 minutes of treatment or 1 minute of treatment and 6 minutes of treatment, so the reduction in pain on movement effects could be attributed to the non-specific effects of treatment or natural variation over time. There was no difference in resting pain or verbal rating of pain on PA.

What is the effect of a longer duration of mobilisation treatment on ROM, stiffness and pain in patients with chronic non-specific low back pain?

The single-arm trial found that relative to baseline VRS of pain on movement was significantly greater following 6 minutes of treatment but not following 3 minutes of treatment.

The RCT found no overall change in PPT immediately following sham mobilisation, 1 minute of mobilisations and 6 minutes of mobilisation in participants with LBP demonstrating that there was no overall effect of treatment. However significantly more participants experienced immediate increases in PPT local to the site of treatment following 6 minutes of lumbar mobilisation treatment than following 1 minute of treatment. The difference in the number of treatment responders following 2 minutes of mobilisation treatment and 2 minutes of sham mobilisation (the placebo intervention) failed to reach statistical significance demonstrating that 2 minutes of mobilisations may not be long enough duration to exceed the benefits of the non-specific effects of placebo. Overall these findings highlight the variability in participants' response to treatment and demonstrate that significantly more participants respond to a longer duration of mobilisation treatment.

These are the first studies to compare the effect of different durations of mobilisations in a symptomatic population and suggest that there may be a beneficial effect of applying longer durations of treatment than those advocated in clinical texts or investigated in previous research.

What is the relationship between PPT's and VRS of pain?

There was dissociation between PPT and verbal ratings of pain reported in both the single-arm trial and RCT. These finding suggest that change in PPT and change in verbal rating of pain may be mediated by different neurobiological mechanisms.

8.12. Recommendations for future work

The results presented in this thesis have highlighted some important areas for future work, which are discussed below.

- Although there was no overall difference in PPT between treatment conditions, responders analysis found that significantly more participants in the longer duration treatment group experienced clinically meaningful changes in PPT. The responder analysis appeared to provide a sensitive way at exploring the difference in effect between different treatments. The inclusion of responders analysis is recommended for future studies.
- The final study in this thesis found that force had a mediating effect of treatment, with greater forces extolling a greater analgesic effect. The current thesis explored the 24-hour effects of a single mobilisation treatment dose. Longer–term follow up (for example 48 or 72 hours post treatment) from a single treatment could be explored in future research.
- Dissociation was found between PPT measures and VRS of pain. Further investigation is needed to explore the clinical relevance of changes in PPT.

It is recommended that future studies incorporated a number of pain related outcome measures.

- A number of individuals responded immediately to mobilisation treatment. Although research developing clinical prediction rules for patients with acute LBP is on-going area, it may prove to be too complex to predict response in patients with a condition as heterogeneous as chronic LBP. In clinical practice the immediate effects of mobilisations are assessed using a 'trial dose' and decisions regarding whether to employ mobilisations as a treatment option are often based on this. It would be useful to isolate those individuals who would have had an immediately favourable response to a trial mobilisation dose and evaluate the effects over a course of mobilisation treatments. An alternative strategy, that has been employed previously, in LBP studies, is to investigate the effect of manual therapy in participants who fulfilled a clinical prediction rule (Childs et al., 2004). These options were not employed in this study in order to prevent the introduction of bias.

- Future studies could investigate the use of therapist selected techniques or multimodal treatment.

- Further exploration of patients' experiences of receiving mobilisations could be achieved using interviews or focus groups.

- Communication with participants was kept to a minimum during the course of the studies in this thesis and their beliefs and expectations were not explored at the time of the physiotherapy assessment, which may have influenced the response to treatment. One area for future study is to explore how communication with participants influences the clinical response to mobilisations.

- Pilot work suggested that the instructions given to participants during PPT might affect measurement reliability. An area for future work is to investigate the influence of instructions on the reliability of PPT. For example using the words 'discomfort' or 'pain', or emphasising to participants that this is not a measure of tolerance may influence reliability of PPT measures (using instructions such as 'it is important that you do not try and tolerate any pain what so ever and that you indicate AS SOON AS the feeling changes from one of just pressure').

- Most previous studies measuring stiffness have employed the displacement method using a mechanically driven device that standardises the maximum force and rate

of application. It appears from this work that the interpretation of the method used by Owen et al., (2007a+b) used in the studies contained in this thesis have some deficiencies. For this reason it might be preferable for mechanical indentation devices to be used in future work measuring lumbar stiffness

8.13. Original contribution to knowledge

- The reliability study in this thesis provided comprehensive reliability of stiffness, ROM and PPT measurements, including the calculation of MDC and SEM which enabled responders analysis to be performed in later studies.

- This is the first study to compare the two different methods of stiffness measurement that are reported in the literature.

- This thesis is the first to report responders analysis for the analgesic effects of mobilisations and highlights a method of analysis useful for future studies.

- The single arm trial and the RCT were the first to investigate the effects of different durations of lumbar mobilisations in participants with low back pain. These findings add to the evidence aiding clinicians in their decision-making when selecting mobilisation treatment dose.

- This is the first study to highlight the potential influence of mobilisation force on the analgesic effect of mobilisations.

- This is the first study to investigate the extent of the analgesic effect in participants with LBP and provides speculative evidence that the pain relief from mobilisation is mediated by a local analgesic mechanism.

- The studies in this thesis have found dissociation between PPT and verbal ratings of pain. This suggests that changes in PPT may not reflect changes in participants' clinical presentations and thus the clinical meaningfulness of studies reporting PPT in isolation should be questioned.
- The studies in this thesis suggest that changes in PPT and changes in verbal rating of pain may be mediated via different analgesic mechanisms.

- This study was the first to ask participants about their expectations and experience of mobilisation treatment and to compare these to treatment outcome.

8.14. Conclusions

The reliability study (chapter 5) found that within-day reliability of PPT measures was excellent and between-day reliability of PPT measures was good to excellent. The reliability of range of movement measurements was good to excellent within-day, but only fair between-days. The CI's suggested that on other occasions reliability may be insufficient and the MDC indicated that in some cases a large difference would need to have occurred before it could be attributed to a treatment effect.

Within-day reliability of three-point bending stiffness measurements was excellent, but between-day reliability was only fair. Observation of the sensor movement occurring during testing cast doubt over the validity of three-point bending measurements. These results suggest that further investigation of the three-point bending method of stiffness is necessary before it is used in future work. The displacement measurements of stiffness showed good reliability. The reliability of stiffness is lower than in previous studies. This is largely explained by the use of a manually applied indenter in this study. It is recommended that future work uses a mechanically driven indenter to standardise the application of force.

The single-arm trial (chapter 6) demonstrated that relative to baseline VRS of pain on movement was significantly greater with 6 minutes of treatment than with 3 minutes of treatment. Both 3 and 6 minutes of mobilisations resulted in a significant increase in PPT local to the site of treatment and in the signature zones of most lower limb dermatomes but not at a site unrelated to treatment. These findings suggest that the change in PPT is mediated via a local, as opposed to systemic, analgesic mechanism. The results of this study suggested that there may be a beneficial effect of applying longer durations of treatment than those advocated in clinical texts or investigated in previous research.

The single arm trial found that neither 3 nor 6 minutes of mobilisations had an effect on range of movement and stiffness. This suggests that the immediate effects of mobilisations may be predominantly neurophysiological.

In the RCT (chapter 7) responders analysis demonstrated that significantly more participants experienced immediate increases in PPT local to the site of treatment following 6 minutes of lumbar mobilisation treatment than following one minute of treatment. This suggests that a longer treatment duration may have a greater hypoalgesic effect, which may be mediated by a local analgesic mechanism. This study identified that treatment responders were significantly younger than non-responders. No other predictors of treatment response were identified.

The overall analysis demonstrated that there was a significant change in verbal rating of pain on movement and verbal rating of pain on the application of PA force to the symptomatic level, but there was no difference between treatment and placebo intervention, suggesting that this effect was due to natural variation or the non-specific effects of treatment. Overall, neither placebo intervention nor lumbar mobilisations changed PPT, however there was a significant mediating effect of force, with higher treatment forces being associated with greater immediate increases in PPT and decreases in pain on movement. The variability in participants' responses to treatment may explain the lack of overall effect and thus responders analysis may be a more sensitive way of analysing pain relief in heterogeneous populations.

The dissociation between PPT and verbal ratings of pain reported in both the single-arm trial and RCT suggest that when investigating the analgesic effects of treatment it may be useful to incorporate a number of pain measures in order to gain a wide appreciation of changes in pain experienced by patients.

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Appendices

Appendix 1.

Clair Hebron Publications and presentations

Publications

Hebron, C., Morris, J., (2013). 'Spurring you on' – The values of group research projects. *Journal of Peer Learning*, 5, 65-77.

Pentelka, L., Hebron, C., Shapleski, R., Goldshtein, I. (2012)The effect of increasing sets (within one treatment session) and different set durations (between treatment sessions) of lumbar spine posteroanterior mobilisations on pressure pain thresholds. *Manual Therapy*, 17, 6, 526-530.

Krouwel, O., Hebron, C., Willett, E., (2009) An Investigation into the Potential Hypoalgesic Effects of Different Amplitudes of PA Mobilisations on the Lumbar Spine as Measured by Pressure Pain Thresholds (PPT). *Manual Therapy*, 15,1 7-12.

Willett E, Hebron C, Krouwel O. (2009) The Initial Effects of different rates of Lumbar Mobilisations on Pressure Pain Thresholds in asymptomatic subjects *Manual Therapy*, 15, 2, 173-178.

Poster presentations

Hebron, C., Moore, A., Saber-Sheikh, K., Jackson, A. (2012). The immediate effects of 3 and 6 minutes of lumbar mobilisations on pain, ROM and stiffness in patients with low back pain: *IFOMPT, the World Congress of Manual/Musculoskeletal Physiotherapy*. September 30 to October 5, Quebec City, Canada.

Krouwel O and Hebron C. An Investigation into the Potential Hypoalgesic Effects of Different Amplitudes of PA Mobilisations on the Lumbar Spine as Measured by Pressure Pain Thresholds (PPT). *7th Interdisciplinary World Conference on Low Back and Pelvic Pain.* 9th -12th November 2010, Los Angeles, USA.

Conference presentations

Ward, J., Hebron, C., Conrad, P., Hill., V., 2013. A revised three-point grading system for accessory joint mobilisations tested on the ankle. *Physiotherapy UK*. 11-12 October 2013, Birmingham, UK.

Hebron, C., Moore, A., Saber-Sheikh, K., Jackson , A. (2012). A comparison of three-point bending and displacement methods of stiffness measurements in the lumbar spine: *IFOMPT, the World Congress of Manual/Musculoskeletal Physiotherapy*. September 30 to October 5, Quebec City, Canada.

Pentelka,L., Hebron, C., Shapleski, R., Goldshtein, I. (2012). The effect of increasing sets (within one treatment session) and different set durations (between treatment sessions) of lumbar spine posteroanterior mobilisations on pressure pain thresholds: *IFOMPT, the World Congress of Manual/Musculoskeletal Physiotherapy*. September 30 to October 5, Quebec City, Canada.

Pentelka L, Hebron C, Shapleski R. The effect of different durations of lumbar spine posteroanterior mobilisations on pressure pain thresholds. *The 11th Israel National Physiotherapy Conference*: 17th May 2011, Airport City, Israel.

Hebron C, Morris J, Cage M. 'Spurring you on' – The values of group research projects. *Teachers Symposium IFOMPT, ECE Meeting*. 25th November 2010, Zaragoza, Spain.

Hebron C, Morris J, Cage M. 'Spurring you on' – The values of group research projects. *Teaching and Learning Conference, Brighton University*, July 2010

Willett E and Hebron C. The Initial Effects of different rates of Lumbar Mobilisations on Pressure Pain Thresholds in asymptomatic subjects. *Society of Back Pain Research*: 6th and 7th November 2008, Keele, UK.

Willett E and Hebron C. The Initial Effects of different rates of Lumbar Mobilisations on Pressure Pain Thresholds in asymptomatic subjects. *KC/MACP Conference*: 30th October -1st November 2009, Edinburgh, UK.

Willett E and Hebron C. The Initial Effects of different rates of Lumbar Mobilisations on Pressure Pain Thresholds in asymptomatic subjects. *ACPSM Conference*: Belfast 2008.

Appendix 2: Ethical Approval

Ethical approval for: The reliability of pressure pain threshold, ROM and stiffness measurements of the lumbar spine.

Subject:
Faculty of Health and Social Science Research Ethics and Governance Committee - Decision on Manuscript ID FREGC-10-046.R1
Body:
@@date to be populated upon sending@@

Dear Mrs. Hebron:

It is a pleasure to approve your application entitled "The reliability of pressure pain threshold, ROM and stiffness measurements of the lumbar spine."

Thank you for your correspondence and discussion on the phone today in which you clarified that you would take the additional precaution of using a trusted and suitably competent colleague to inform and consent students into the study for whom you have either course responsibility or, for whom you assume a direct personal tutor role.

I have made this exception because I have been convinced that the opportunity to participate in this research will serve as a pedagogic opportunity to both role model research in physiotherapy to students, and to use the experience of participation to engage students in research and thinking critically about the research process. These benefits seem to outweigh any possible risk of coercion in recruiting students within one's own field of practice - especially as the research is low risk and consent is to be gained by a suitably competent colleague. I feel it would be helpful to identify on the information sheet to whom a student might make a complaint (as an additional precaution). This person should be a neutral party and I would recommend this either be the Head of School or myself if this would be acceptable to you and your supervisors.

I wish you well with your research. Please notify the Committee of any changes to the design of your study and report any adverse incidents immediately.

Sincerely,
Prof. Julie Scholes
Chair, Faculty of Health and Social Science Research Ethics and Governance Committee
J.Scholes@brighton.ac.uk

Ethical approval for: A single-arm trial investigating the immediate effects of duration of lumbar mobilisation treatment on pain, stiffness and ROM in patients with chronic LBP

Faculty of Health

University of Brighton

01273 644763

Mrs C L Hebron
80 Ocklynge Road
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East Sussex
BN21 1QA

6th January 2010

Clinical Research Centre
For Health Professions
Professor Ann Moore PhD GradDipPhys
FCSP DipTP CertEd MMACP
Director of Centre

Aldro Building
49 Darley Road
Eastbourne BN20 7UR
Telephone 01273 643647
Fax 01273 643944

Dear Clair

Title of Proposal: The Relationship between treatment dose, pain and stiffness with lumbar mobilisations
FREGC Application Number: 07/12a

We are writing to confirm that the above-mentioned proposal has been approved by the Research Ethics and Governance Committee of the Faculty of Health and Social Science (FREGC) after an independent scientific and ethics review.

Although approval has been given to start the research work, it is the ultimate responsibility of the researchers to ensure that the work is conducted within the Research Ethics and Governance Framework of the University of Brighton, and if applicable, those of the Department of Health and any funding body. Approval of project is given for the duration of the research indicated in the application form, although FREGC may review this decision at any time and has the right to suspend or terminate this approval.

You are required to notify the Committee in writing if there any substantial changes in the research methodology or any serious adverse events or accidents during the conduct of the study. As a requirement of the Governance Framework, please submit annual progress and completion reports to the Committee. You may not be need to prepare a separate progress report for the Committee as we would be happy to receive a copy of annual report submitted to funding body, NHS or other relevant body to satisfy this requirement. Please see the Guidance Notes of the Application Pack (Section 7) for further information.

Yours sincerely

Professor Julie Scholes PhD
Chair of Faculty of Health Research Ethics & Governance Committee
www.brighton.ac.uk/sohp/research/

27-Jun-2012

Dear Mrs. Hebron:

It is a pleasure to approve your application entitled "The immediate and mid-term effects of 1 and 6 minutes of lumbar mobilisations on pressure pain thresholds and patient reported pain measures." which has been approved by the Faculty of Health and Social Science Research Ethics and Governance Committee. The comments of the reviewer(s) who reviewed your manuscript are included at the foot of this letter.

Please notify The Chair of FREGC immediately if you experience an adverse incident whilst undertaking the research or if you need to make amendments to the original application.

We shall shortly issue letters of sponsorship and insurance for appropriate external agencies as necessary.

We wish you well with your research. Please remember to send annual updates on the progress of your research or an end of study summary of your research.

Sincerely,
Prof. Julie Scholes
Chair, Faculty of Health and Social Science Research Ethics and Governance Committee J.Scholes@brighton.ac.uk

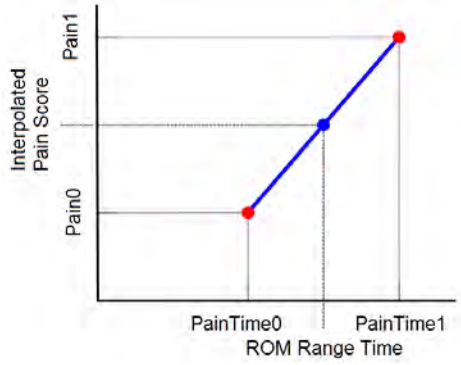
Appendix 3: Batch process procedure for processing ROM and stiffness data.

Excel files with Macro were created to make use of Microsoft VBA (Visual Basic for Applications) and automatically batch process relevant raw data files for data analysis. The following appendix explains the process used in all studies. References to processing of pain button data refer only to study 2 and beyond.

ROM (ROM) batch processing

The content of the ROM (ROM) batch process VBA code

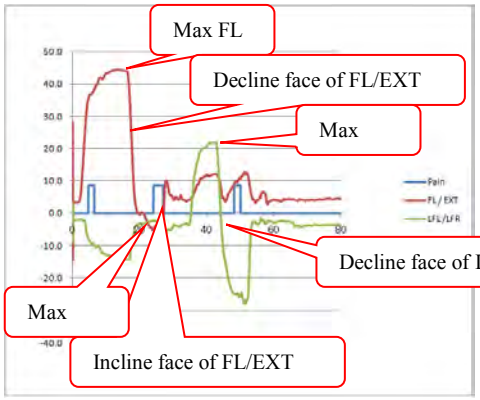
VBA identified which raw data files (ROMP, ROM, ROMplot, ROMraw) to copy onto which worksheet in the ROM template file. Linear interpolation of Pain button measurement (force plate) occurred in accordance to ROM range (fastrak).



Linear Interpolation Equation

$$\text{Interpolated Pain Score} = \text{Pain0} + (\text{ROM Range Time} - \text{PainTime0}) \frac{(\text{Pain1} - \text{Pain0})}{(\text{PainTime1} - \text{PainTime0})}$$

The ROM sample of the first 2seconds was used to correct the measurement offset.
Then the maximum and minimum values for both FL/EXT and LFL/LFR waves are identified.
This was followed by identifying the ROM at the onset of P1. In order to identify the right pain button at the right movement, several points were identified:



Points at max FL, max EXT, and max LFL
Point somewhere at the decline face of FL/EXT wave after max FL
Point somewhere at the incline face of FL/EXT wave after max EXT
Point somewhere at the decline face of LFL/LFR wave after max LFL

Then it is assumed that:
P1FL will happen before decline face of FL/EXT; **P1EXT** is after max FL and before incline face of FL/EXT;
P1LFL is after incline face of FL/EXT and before decline face of LFL/LFR; **P1LFR** is after decline face of LFL/LFR.
If pain button was not pressed during a movement, then "-" is noted for P1 of that movement.

Stiffness (PA) Batch Processing

A Macro written in Visual Basics A (VBA). Force plate files show the forces in the X,Y and Z axis. Vertical forces are those in the Z axis and are shown separately for the two force plates and are shown in column D (Z axis force plate one) and J (Z axis for force plate two). The Macro calculated the sum of D and J columns of the Force plate file to calculate the total force applied over the two force plates.

The Fastrak files required a timeline to be inserted. This was interpolated to the time line for the force plates.

The Fastrak motion tracking system was set up with sensors 1 and 2 placed on the sacrum and L1 respectively. The column showing movement of sensor one in relation to sensor 2 was plotted against the sum of the forces in the Z axis to produce a force angle graph. A third sensor was mounted on top of the indenter used to apply the PA pressure to the spine during stiffness testing in order to measure vertical displacement. The macro separated the Fastrak data from the different sensors (from the raw file). The data for sensor was in inches. This was multiplied by 25.4 to convert into millimetre to allow comparison with previous studies. Vertical displacement data was plotted against the force data to produce a force displacement graph.

This data and the force displacement and force displacement graphs were transferred onto a template document to allow the data to be inspected visually to check for any problems.

A second Macro was then used to calculate stiffness using both force angle and force displacement data using linear interpolation of the slope of the force displacement graph between 30-100N. The second part of this section calculates the slope of force-displacement curve (i.e., spinal stiffness) of the loading phase of each cycle. By default, VBA is set to calculate slope between Force of 30 and 100N, or if 100N was not reached, then max force of the cycle.

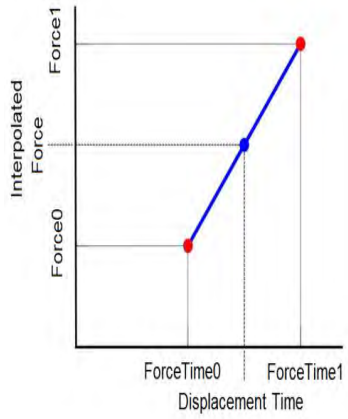
<u>The Content of the PA Batch Process VBA code</u>

Measurements were converted to appropriate units:

Displacement from FT Sensor 3 was converted from inch to mm (divided by -0.03947)

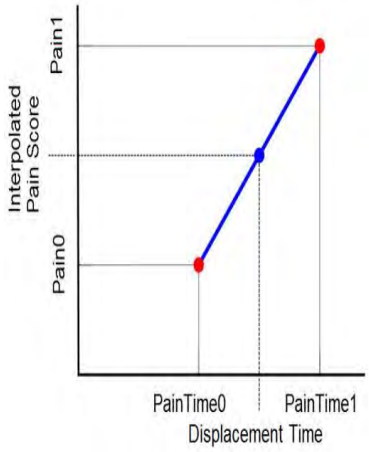
Original measurement for bending angle is in degree; then was formulated to radian ("=RADIAN")

This section also includes the linear interpolation of Force and Pain button measurements (force plate) in accordance to displacement range (Fastrak).



Linear Interpolation Equation

$$\text{Interpolated Force} = \text{Force0} + (\text{Displacement Time} - \text{ForceTime0})\frac{(\text{Force1} - \text{Force0})}{(\text{ForceTime1} - \text{ForceTime0})}$$



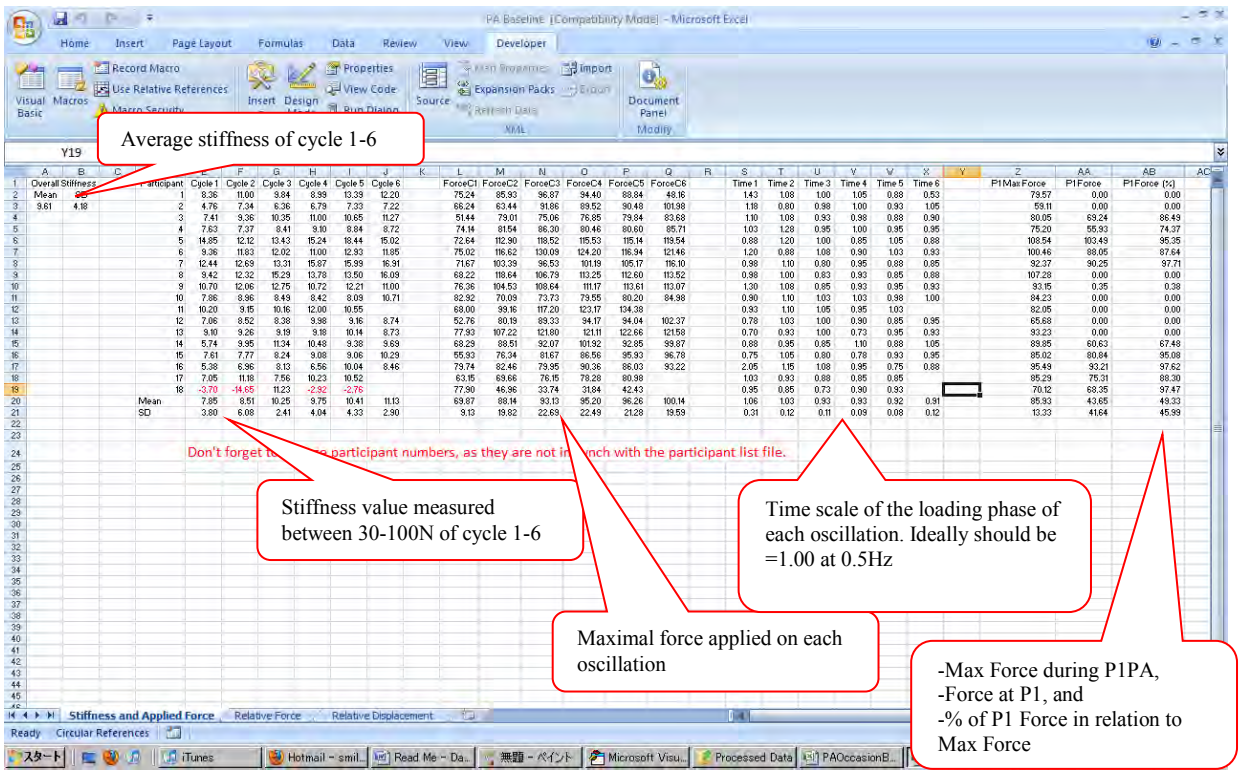
Linear Interpolation Equation

$$\text{Interpolated Pain Score} = \text{Pain0} + (\text{Displacement Time} - \text{PainTime0})\frac{(\text{Pain1} - \text{Pain0})}{(\text{PainTime1} - \text{PainTime0})}$$

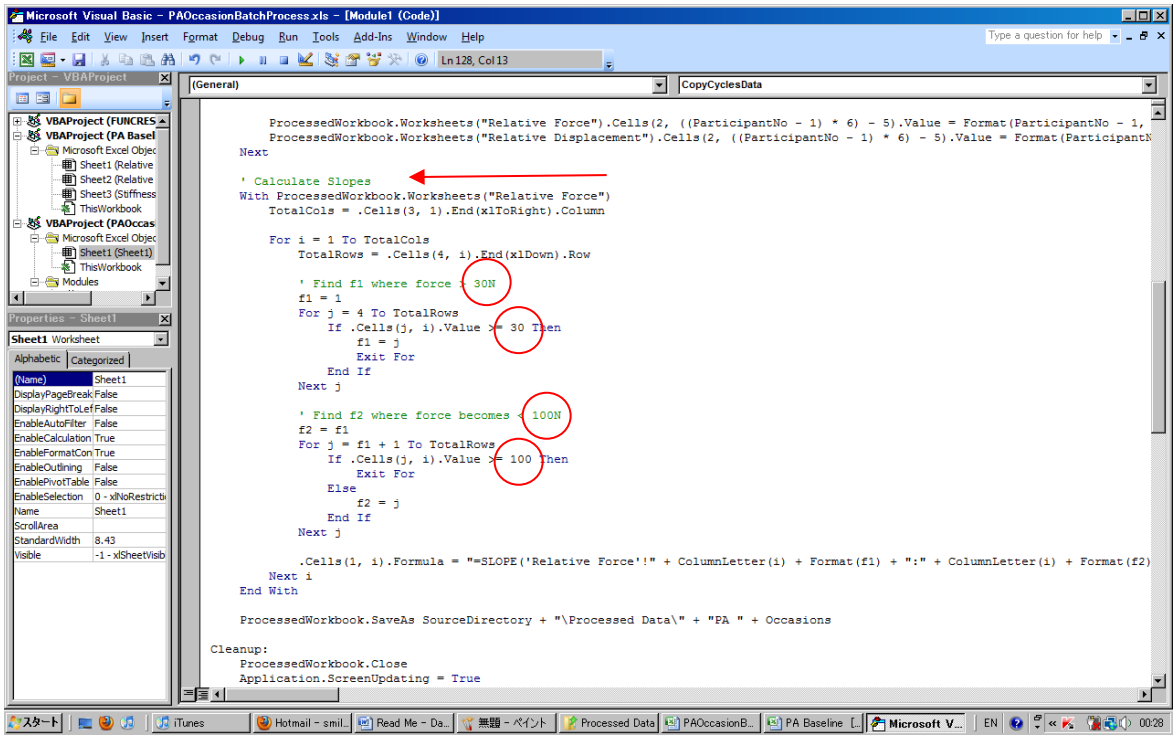
The following part calculates the Force sample of 0-0.4seconds to correct the measurement offset.
Then the Force at P1 during the first PA is identified by tracing the initial spike in the Pain column (value > 8).

Function CopyCycle() section identifies the first PA and 6 consecutive PA Force application. This is done by first identifying the inclining face of Force on each oscillation and selecting the range of Min and Max Force on each cycle.
Each strip of cycle is then copied onto subsequent worksheets.

PA Occasion Batch Processing: The Content of the PAOccasionBatchProcess VBA code



The second part of this section calculates the slope of force-displacement curve (i.e., spinal stiffness) of the loading phase of each cycle. By default, VBA was set to calculate slope between Force of 30 and 100N, or if 100N was not reached, then max force of the cycle.



Sub CopyCyclesData() section simply copies the force and displacement strips of each cycle from participant's processed file to the PAOccasion template file.

This section also copies P1PA measurements. If pain button was not pressed during the initial PA, then the data is shown as "0.00" under P1Force, resulting in P1Force(%) to be also "0.00"

This is repeated for all three occasions, each set of data saved on separate files.

Appendix 4

Reliability study. Normality testing for pressure pain threshold, ROM and stiffness data.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Flex2	.190	15	.150	.950	15	.526
Ext2	.140	15	.200*	.968	15	.822
LLF2	.167	15	.200*	.941	15	.389
RLF2	.139	15	.200*	.975	15	.928
Flex3	.106	15	.200*	.976	15	.933
Ext3	.140	15	.200*	.897	15	.087
LLF3	.122	15	.200*	.950	15	.523
RLF3	.191	15	.146	.831	15	.009
Flex4	.117	15	.200*	.941	15	.399
Ext4	.218	15	.053	.859	15	.024
LLF4	.174	15	.200*	.950	15	.532
RLF4	.158	15	.200*	.949	15	.502
Flex5	.150	15	.200*	.895	15	.080
Ext5	.235	15	.025	.883	15	.053
LLF5	.169	15	.200*	.910	15	.135
RLF5	.195	15	.128	.885	15	.057
Flex6	.197	15	.121	.959	15	.676
Ext6	.142	15	.200*	.921	15	.202
LLF6	.158	15	.200*	.953	15	.570
RLF6	.094	15	.200*	.972	15	.880

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Def1	.109	15	.200*	.973	15	.905
Angle1	.151	15	.200*	.931	15	.278
Def2	.227	15	.036	.797	15	.003
Angle2	.287	15	.002	.808	15	.005
Def3	.105	15	.200*	.952	15	.560
Angle3	.305	15	.001	.611	15	.000
Def4	.198	15	.116	.940	15	.383
Angle4	.123	15	.200*	.952	15	.562
Def5	.168	15	.200*	.873	15	.037
Angle5	.131	15	.200*	.977	15	.944
Def6	.202	15	.101	.881	15	.050
Angle6	.261	15	.007	.775	15	.002

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
L4sp1	.089	20	.200*	.977	20	.884
L4sp2	.116	20	.200*	.943	20	.268
L4sp3	.148	20	.200*	.966	20	.672
L4sp4	.124	20	.200*	.964	20	.617
L4sp5	.154	20	.200*	.942	20	.267
L4sp6	.147	20	.200*	.937	20	.213
T101	.105	20	.200*	.976	20	.871
T102	.119	20	.200*	.963	20	.602
T103	.140	20	.200*	.974	20	.833
T104	.100	20	.200*	.981	20	.945
T105	.144	20	.200*	.941	20	.253
T106	.143	20	.200*	.938	20	.216
Deltoid1	.129	20	.200*	.969	20	.733
Deltoid2	.139	20	.200*	.965	20	.650
Deltoid3	.121	20	.200*	.957	20	.478
Deltoid4	.148	20	.200*	.944	20	.283
Deltoid5	.134	20	.200*	.958	20	.506
Deltoid6	.165	20	.155	.960	20	.539
S11	.151	20	.200*	.946	20	.317
S12	.210	20	.021	.910	20	.063
S13	.167	20	.145	.937	20	.210
S14	.124	20	.200*	.956	20	.476
S15	.122	20	.200*	.954	20	.435
S16	.115	20	.200*	.981	20	.949
L21	.151	20	.200*	.946	20	.317
L22	.210	20	.021	.910	20	.063
L23	.167	20	.145	.937	20	.210
L24	.124	20	.200*	.956	20	.476
L25	.122	20	.200*	.954	20	.435
L26	.115	20	.200*	.981	20	.949
L31	.141	20	.200*	.903	20	.048
L32	.083	20	.200*	.985	20	.980
L33	.114	20	.200*	.974	20	.832
L34	.166	20	.149	.933	20	.173
L35	.138	20	.200*	.945	20	.300
L36	.139	20	.200*	.955	20	.443
L41	.140	20	.200*	.963	20	.597
L42	.116	20	.200*	.946	20	.316
L43	.156	20	.200*	.932	20	.171
L44	.181	20	.083	.922	20	.107
L45	.180	20	.088	.935	20	.191
L46	.224	20	.010	.877	20	.015
L51	.146	20	.200*	.952	20	.402
L52	.165	20	.154	.919	20	.094
L53	.188	20	.063	.871	20	.012
L54	.115	20	.200*	.967	20	.687
L55	.146	20	.200*	.957	20	.492
L56	.162	20	.179	.953	20	.413

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
L4sp1	.089	20	.200*	.977	20	.884
L4sp2	.116	20	.200*	.943	20	.268
L4sp3	.148	20	.200*	.966	20	.672
L4sp4	.124	20	.200*	.964	20	.617
L4sp5	.154	20	.200*	.942	20	.267
L4sp6	.147	20	.200*	.937	20	.213
T101	.105	20	.200*	.976	20	.871
T102	.119	20	.200*	.963	20	.602
T103	.140	20	.200*	.974	20	.833
T104	.100	20	.200*	.981	20	.945
T105	.144	20	.200*	.941	20	.253
T106	.143	20	.200*	.938	20	.216
Deltoid1	.129	20	.200*	.969	20	.733
Deltoid2	.139	20	.200*	.965	20	.650
Deltoid3	.121	20	.200*	.957	20	.478
Deltoid4	.148	20	.200*	.944	20	.283
Deltoid5	.134	20	.200*	.958	20	.506
Deltoid6	.165	20	.155	.960	20	.539
S11	.151	20	.200*	.946	20	.317
S12	.210	20	.021	.910	20	.063
S13	.167	20	.145	.937	20	.210
S14	.124	20	.200*	.956	20	.476
S15	.122	20	.200*	.954	20	.435
S16	.115	20	.200*	.981	20	.949
L21	.151	20	.200*	.946	20	.317
L22	.210	20	.021	.910	20	.063
L23	.167	20	.145	.937	20	.210
L24	.124	20	.200*	.956	20	.476
L25	.122	20	.200*	.954	20	.435
L26	.115	20	.200*	.981	20	.949
L31	.141	20	.200*	.903	20	.048
L32	.083	20	.200*	.985	20	.980
L33	.114	20	.200*	.974	20	.832
L34	.166	20	.149	.933	20	.173
L35	.138	20	.200*	.945	20	.300
L36	.139	20	.200*	.955	20	.443
L41	.140	20	.200*	.963	20	.597
L42	.116	20	.200*	.946	20	.316
L43	.156	20	.200*	.932	20	.171
L44	.181	20	.083	.922	20	.107
L45	.180	20	.088	.935	20	.191
L46	.224	20	.010	.877	20	.015
L51	.146	20	.200*	.952	20	.402
L52	.165	20	.154	.919	20	.094
L53	.188	20	.063	.871	20	.012
L54	.115	20	.200*	.967	20	.687
L55	.146	20	.200*	.957	20	.492
L56	.162	20	.179	.953	20	.413

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Appendix 5

Correlation between three-point bending and displacement methods of stiffness measurements

Reliability study. Correlation between three-point bending and displacement data at baseline on occasion 1.

Correlations

			def1notlog	agle1notlog
Spearman's rho	def1notlog	Correlation Coefficient	1.000	.643**
		Sig. (2-tailed)	.	.010
		N	15	15
	agle1notlog	Correlation Coefficient	.643**	1.000
		Sig. (2-tailed)	.010	.
		N	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

Reliability study. Correlation between three-point bending and displacement data at baselines on the second occasion.

Correlations

			def4notlog	angle4notlog
Spearman's rho	def4notlog	Correlation Coefficient	1.000	.704**
		Sig. (2-tailed)	.	.003
		N	15	15
	angle4notlog	Correlation Coefficient	.704**	1.000
		Sig. (2-tailed)	.003	.
		N	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 6

A vignette of how a diagnosis of symptomatic level is made for a patient with non-specific LBP.

A patient presents with left sided LBP referring to their left posterior thigh. The patient complains of pain aggravated by activities involving physiological flexion. Physical examination confirms that both the LBP and left posterior thigh pain are reproduced on flexion; the symptoms increase further with the addition of right lateral flexion (a regular stretch pattern (Edwards, 1992). Passive accessory intervertebral movements (PAIVM's) are assessed with the patient in their symptomatic position of flexion / right lateral flexion. A unilateral posteroanterior mobilisation on L4 on the left reproduces the patients LBP, when the mobilisation is directed with a cephalad inclination (towards the head) the LBP increases and the posterior thigh pain is reproduced. The physiotherapist diagnoses the left L4/5 as the symptomatic level. The cephalic inclination of the posterioanterior force produces the similar relative movement of local structure as the patient's painful movement of flexion and right lateral flexion. The movements of flexion and right lateral flexion and the mobilisation force may affect all the local structures simultaneously; it is therefore not possible to determine the anatomical structure at fault and thus a diagnosis of symptomatic level as opposed to a structural diagnosis is given.

Physiotherapy diagnosis of symptomatic level

In the majority of patients with LBP it is not possible to diagnose a structural cause for their symptoms and these patients are diagnosed as suffering from non-specific LBP. In these patients physiotherapist will not make a structural diagnosis but will diagnose symptomatic level. There is evidence that therapists can accurately diagnose symptomatic level. Jull et al., (1988) diagnosed symptomatic level in 20 participants, (5 asymptomatic and 15 with neck pain) the findings of the physiotherapist were compared to radiologically controlled diagnostic block. There was 100% agreement on the symptomatic level and all asymptomatic participants were correctly identified, resulting in 100% sensitivity and specificity. Similar results were found in a study on the lumbar spine where 2 physiotherapists correctly identified the symptomatic level in 94% of patients and correctly identified 100% of asymptomatic participants (Phillips and Twomey, 1993). Both these studies investigated the accuracy of experienced physiotherapists in diagnosing symptomatic level, which may not reflect the ability of a wider population.

In the study by Phillips and Twomey (1993) a further 23 participants were assessed by the physiotherapist retrospectively, lower sensitivity 61% was found in this group but can be explained by the time interval between diagnostic block and manual examination (a mean of 156 days). In this study the physiotherapists were prevented from observing the patients' posture or general mobility, which may have further hindered their ability to diagnose symptomatic level. Further evidence of physiotherapists' ability to diagnose symptomatic level can be found in studies investigating the agreement between therapists; it has been shown that there is acceptable

agreement between physiotherapists when deciding on the level to treat. In one study 6 experienced manual therapists examined the upper cervical spine (as they deemed appropriate) in 40 patients with neck pain and headaches, there was 70% agreement on the level of symptoms (Jull et al., 1997).

Appendix 7:
Questionnaires.

McGILL PAIN QUESTIONNAIRE

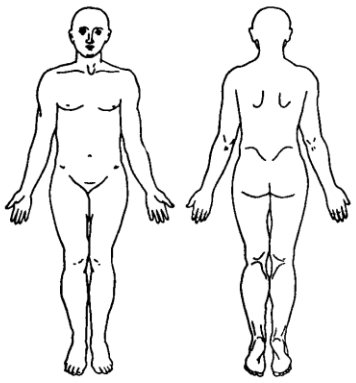
RONALD MELZACK

Patient's Name _____ Date _____ Time _____ am/pm

PRI: S _____ (1-10) A _____ (11-15) E _____ (16) M _____ (17-20) PRI(T) _____ (1-20) PPI _____

1 FLICKERING QUIVERING PULSING THROBBING BEATING POUNDING	11 TIRING EXHAUSTING	
2 JUMPING FLASHING SHOOTING	12 SICKENING SUFFOCATING	
3 PRICKING BORING DRILLING STABBING LANCINATING	13 FEARFUL FRIGHTFUL TERRIFYING	
4 SHARP CUTTING LACERATING	14 PUNISHING GRUELLING CRUEL VICIOUS KILLING	
5 PINCHING PRESSING GNAWING CRAMPING CRUSHING	15 WRETCHED BLINDING	
6 TUGGING PULLING WRENCHING	16 ANNOYING TROUBLESOME MISERABLE INTENSE UNBEARABLE	
7 HOT BURNING SCALDING SEARING	17 SPREADING RADIATING PENETRATING PIERCING	
8 TINGLING ITCHY SMARTING STINGING	18 TIGHT NUMB DRAWING SQUEEZING TEARING	
9 DULL SORE HURTING ACHING HEAVY	19 COOL COLD FREEZING	
10 TENDER TAUT RASPING SPLITTING	20 NAGGING NAUSEATING AGONIZING DREADFUL TORTURING	
	PPI 0 NO PAIN 1 MILD 2 DISCOMFORTING 3 DISTRESSING 4 HORRIBLE 5 EXCRUCIATING	

BRIEF	RHYTHMIC	CONTINUOUS
MOMENTARY	PERIODIC	STEADY
TRANSIENT	INTERMITTENT	CONSTANT



E = EXTERNAL
I = INTERNAL

COMMENTS:

SURVEY OF PAIN ATTITUDES, SHORT VERSION

SOPA-32

Instructions: Please indicate how much you agree with each of the following statements about your pain problem by using the following scale:

0 = This is very untrue for me.
1 = This is somewhat untrue for me.
2 = This is neither true nor untrue for me (or it does not apply to me).
3 = This is somewhat true for me.
4 = This is very true for me.

_____

1. There are many times when I can influence the amount of pain I feel.. 0 1 2 3 4
2. I will probably always have to take pain medications 0 1 2 3 4
3. When I hurt, I want my family to treat me better 0 1 2 3 4
4. I expect a medical cure for my pain..... 0 1 2 3 4
5. I have had the most relief from pain with the use of medications 0 1 2 3 4
6. Anxiety increases the pain I feel..... 0 1 2 3 4
7. When I am hurting, people should treat me with care and concern..... 0 1 2 3 4
8. I have given up my search for the complete elimination of my pain through the work of the medical profession 0 1 2 3 4
9. It is the responsibility of my loved ones to help me when I feel pain.... 0 1 2 3 4
10. Stress in my life increases my pain..... 0 1 2 3 4
11. Exercise and movement are good for my pain problem..... 0 1 2 3 4
12. Just by concentrating or relaxing, I can "take the edge" off of my pain 0 1 2 3 4
13. Medicine is one of the best treatments for chronic pain..... 0 1 2 3 4
14. My family needs to learn how to take better care of me when I am in pain 0 1 2 3 4
15. Depression increases the pain I feel..... 0 1 2 3 4
16. If I exercise, I could make my pain problem much worse..... 0 1 2 3 4
17. I believe that I can control how much pain I feel by changing my thoughts 0 1 2 3 4
18. Often I need more tender loving care that I am now getting when I am in pain 0 1 2 3 4
19. Something is wrong with my body which prevents much movement or exercise..... 0 1 2 3 4
20. I have learned to control my pain..... 0 1 2 3 4
21. I trust that the medical profession can cure my pain 0 1 2 3 4
22. I know for sure I can learn to manage my pain 0 1 2 3 4
23. My pain does not stop me from leading a physically active life..... 0 1 2 3 4
24. My physical pain will eventually be cured..... 0 1 2 3 4
25. There is a strong connection between my emotions and my pain level . 0 1 2 3 4
26. I can do nearly everything as well as I could before I had a pain problem 0 1 2 3 4
27. If I do not exercise regularly, my pain problem will continue to get worse..... 0 1 2 3 4
28. Exercise can decrease the amount of pain I experience 0 1 2 3 4
28. I'm convinced that there is no medical procedure that will help my pain..... 0 1 2 3 4
30. My pain would stop anyone from leading an active life 0 1 2 3 4
31. Pain means that my body is being harmed 0 1 2 3 4
32. If my pain continues at its present level, I will be unable to work..... 0 1 2 3 4

Oswestry Pain Questionnaire

This questionnaire has been designed to give information as to how your pain has affected your ability to manage in everyday life. Please answer every section, and mark in each section **ONLY ONE BOX** which applies to you. We realize you may consider that two of the statements in any one section relate to you, but please just mark the box which *most closely* describes your problem.

Section 1 -- Pain Intensity
o I can tolerate the pain I have without having to use pain killers
o The pain is bad but I manage without taking painkillers.
o Pain killers give complete relief from pain
o Pain killers give moderate relief from pain
o Pain killers give very little relief from pain
o Pain killers have no effect on the pain and I do not use them

Section 2 - - Personal Care (Washing, Dressing, etc)
o I can look after myself normally without causing extra pain.
o I can look after myself normally but it causes extra pain
o It is painful to look after myself and I am slow and careful
o I need some help but manage most of my personal care
o I need help every day in most aspects of self care
o I do not get dressed, wash with difficulty and stay in bed

Section 3 - - Lifting
o I can lift heavy weights without extra pain
o I can lift heavy weights but it gives extra pain
o Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, e.g. on a table.
o Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are Conveniently positioned
o I can lift only very light weights
o I cannot lift or carry anything at all

Section 4 - - Walking
o Pain does not prevent me from walking any distance
o Pain prevents me from walking more than 1 mile
o Pain prevents me from walking more than 1/2 mile
o Pain prevents me from walking more than 1/4 mile
o I can only walk using a stick or crutches
o I am in bed most of the time and have to crawl to the toilet

Section 5 - - Sitting
o I can sit in any chair as long as I like
o I can only sit in my favorite chair as long as I like
o Pain prevents me from sitting more than 1 hour
o Pain prevents me from sitting more than 1/2 hour
o Pain prevents me from sitting more than 10 minutes
o Pain prevents me from sitting at all

Section 6 - - Standing
o I can stand as long as I want without extra pain
o I can stand as long as I want but it gives me extra pain
o Pain prevents me from standing more than 1 hour
o Pain prevents me from standing more than 1/2 hour
o Pain prevents me from standing more than 10 minutes
o Pain prevents me from standing at all

Section 7 - - Sleeping
o Pain does not prevent me from sleeping
o I can sleep well only by using tablets
o Even when I take tablets I have less than six hours sleep
o Even when I take tablets I have less than four hours sleep
o Even when I take tablets I have less than two hours sleep
o Pain prevents me from sleeping at all

Section 8 - - Sex Life
o My sex life is normal and causes no extra pain
o My sex life is normal but causes some extra pain
o My sex life is nearly normal but is very painful
o My sex life is severely restricted by pain

o My sex life is nearly absent because of pain
o Pain prevents any sex life at all

S e c t i o n 9 - - S o c i a l L i f e
o My social life is normal and gives me no extra pain
o My social life is normal but increases the degree of pain
o Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g. dancing, etc.
o Pain has restricted my social life and I do not go out asoften.
o Pain has restricted my social life to my home
o I have no social life because of pain

S e c t i o n 1 0 - - T r a v e l i n g
o I can travel anywhere without extra pain
o I can travel anywhere but it gives me extra pain
o Pain is bad but I manage journeys over two hours
o Pain restricts me to journeys of less than one hour
o Pain restricts me to short necessary journeys under 30 minutes
o Pain prevents me from traveling except to the doctor or hospital

Number of Points: _____
Total Possible: _____
Score: _____%

Demographic Questionnaire

What is your date of birth?

What is your primary language?

- English
- Spanish
- Other

What is the highest level of education you have completed?

- O levels / GCSE's
- A level
- Vocational course
- BTech
- Bachelor's degree
- Master's degree
- Doctoral degree
- Professional degree (MD, JD, etc.)
- Other

How would you classify yourself?

- White
- Asian
- Black
- Multiracial
- Would rather not say
- Other

What is your current marital status?

- Divorced

- Living with another
- Married
- Separated
- Single
- Widowed
- Would rather not say

Describe your current job

What is your current household income ?

- Under £10,000
- £10,000 - £19,999
- £20,000 - £29,999
- £30,000 - £39,999
- £40,000 - £49,999
- £50,000 - £74,999
- £75,000 - £99,999
- £100,000 - £150,000
- Over £150,000
- Would rather not say

Have you had previous treatment for your low back pain?

- Yes
- No

Who treated you?

- GP
- Physiotherapist
- Chiropractor
- Osteopath
- Other

Did the treatment help?

- Yes, a lot
- Yes, a little
- Not much
- Not at all

Describe the treatment you received.

Please outline your exercise levels

Type of exercise	Duration of exercise	Number of times per week

Appendix 8

Normality testing for – A single-arm trial investigating the immediate effects of duration of lumbar mobilisation treatment on pain, stiffness and ROM in patients with chronic LBP

Normality testing for ROM data.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Flex	.133	17	.200*	.957	17	.568
Ext	.197	17	.078	.936	17	.277
LLF	.113	17	.200*	.967	17	.758
RLF	.112	17	.200*	.963	17	.680
Flex2	.108	17	.200*	.977	17	.930
Ext2	.113	17	.200*	.926	17	.188
LLF2	.135	17	.200*	.964	17	.708
RLF2	.271	17	.002	.667	17	.000
Flex3	.136	17	.200*	.964	17	.716
Ext3	.154	17	.200*	.944	17	.375
LLF3	.178	17	.158	.9.23	17	.166
RFL3	.143	17	.200*	.911	17	.104

Normality testing for stiffness data.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
def	.166	15	.200*	.914	15	.155
angle	.148	15	.200*	.911	15	.140
def1	.143	15	.200*	.937	15	.352
angle1	.175	15	.200*	.908	15	.125
def2	.163	15	.200*	.942	15	.404
angle2	.180	15	.200*	.931	15	.279

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Normality testing of PPT data.

Tests of Normality

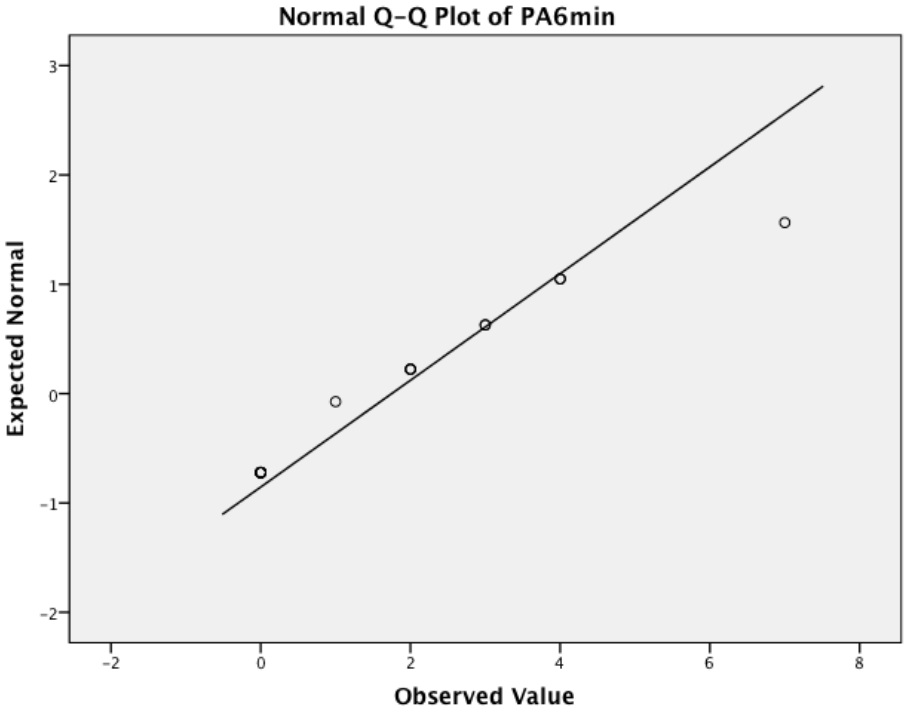
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
symp1	.249	16	.009	.818	16	.005
sympt2	.228	16	.026	.886	16	.048
sympt3	.217	16	.043	.878	16	.037
T10	.281	16	.001	.887	16	.050
T102	.094	16	.200*	.964	16	.732
T103	.109	16	.200*	.977	16	.937
delt1	.098	16	.200*	.960	16	.671
delt2	.147	16	.200*	.941	16	.364
delt3	.178	16	.189	.943	16	.382
S1	.157	16	.200*	.956	16	.593
S12	.133	16	.200*	.944	16	.401
S13	.211	16	.054	.922	16	.179
L2	.236	16	.018	.845	16	.012
L22	.180	16	.177	.900	16	.081
L23	.184	16	.149	.909	16	.111
L3	.310	16	.000	.647	16	.000
L32	.148	16	.200*	.929	16	.231
L33	.142	16	.200*	.904	16	.094
L4	.189	16	.131	.934	16	.284
L42	.123	16	.200*	.955	16	.571
L43	.114	16	.200*	.951	16	.501
L5	.180	16	.176	.906	16	.100
L52	.245	16	.011	.840	16	.010
L53	.207	16	.065	.883	16	.044

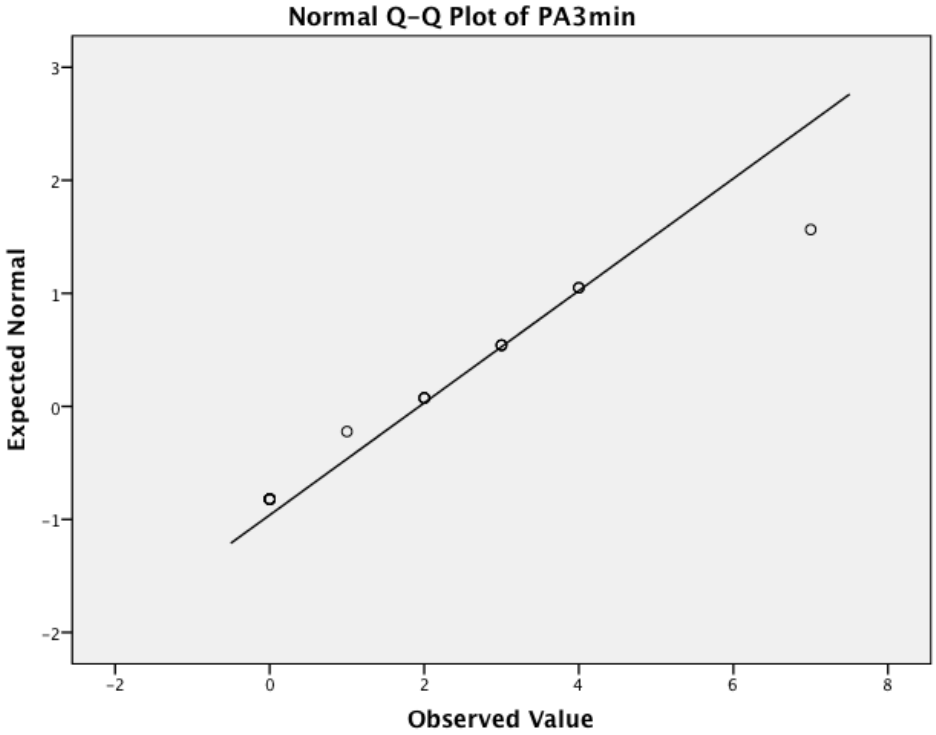
Normality testing of VRS data.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
baselineVRSmvt	.107	16	.200*	.955	16	.581
VRS3mvt	.148	16	.200*	.924	16	.195
VRS6mvt	.188	16	.134	.856	16	.017
PAbaseline	.233	16	.020	.875	16	.033
PA3min	.207	16	.066	.860	16	.019
PA6min	.241	16	.014	.827	16	.006

*. This is a lower bound of the true significance.


Normal Q-Q Plot of PA6min
Expected Normal
Observed Value
3
2
1
0
-1
-2
-2
0
2
4
6
8


Normal Q-Q Plot of PA3min
Expected Normal
Observed Value
3
2
1
0
-1
-2
-2
0
2
4
6
8

Appendix 9.

Analysis of variance for: A single-arm trial investigating the immediate effects of duration of lumbar mobilisation treatment on pain, stiffness and ROM in patients with chronic LBP.

Two-way ANOVA for ROM.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
duration	Sphericity Assumed	83.218	2	41.609	.886	.422
	Greenhouse-Geisser	83.218	1.391	59.845	.886	.391
	Huynh-Feldt	83.218	1.481	56.183	.886	.396
	Lower-bound	83.218	1.000	83.218	.886	.360
Error(duration)	Sphericity Assumed	1502.085	32	46.940		
	Greenhouse-Geisser	1502.085	22.249	67.513		
	Huynh-Feldt	1502.085	23.699	63.381		
	Lower-bound	1502.085	16.000	93.880		
Movement	Sphericity Assumed	27121.111	3	9040.370	47.154	.000
	Greenhouse-Geisser	27121.111	1.991	13621.440	47.154	.000
	Huynh-Feldt	27121.111	2.273	11929.719	47.154	.000
	Lower-bound	27121.111	1.000	27121.111	47.154	.000
Error(Movement)	Sphericity Assumed	9202.605	48	191.721		
	Greenhouse-Geisser	9202.605	31.857	288.873		
	Huynh-Feldt	9202.605	36.375	252.996		
	Lower-bound	9202.605	16.000	575.163		
duration * Movement	Sphericity Assumed	466.409	6	77.735	1.992	.074
	Greenhouse-Geisser	466.409	2.414	193.174	1.992	.142
	Huynh-Feldt	466.409	2.874	162.282	1.992	.131
	Lower-bound	466.409	1.000	466.409	1.992	.177
Error(duration* Movement)	Sphericity Assumed	3745.486	96	39.015		
	Greenhouse-Geisser	3745.486	38.631	96.955		
	Huynh-Feldt	3745.486	45.985	81.450		
	Lower-bound	3745.486	16.000	234.093		

One-way ANOVA for stiffness measurements.

Tests of Within-Subjects Effects –three-point bending

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
duration	Sphericity Assumed	2.293	2	1.147	.014	.986
	Greenhouse-Geisser	2.293	1.954	1.173	.014	.984
	Huynh-Feldt	2.293	2.000	1.147	.014	.986
	Lower-bound	2.293	1.000	2.293	.014	.906
Error(duration)	Sphericity Assumed	2057.039	26	79.117		
	Greenhouse-Geisser	2057.039	25.407	80.964		
	Huynh-Feldt	2057.039	26.000	79.117		
	Lower-bound	2057.039	13.000	158.234		

Tests of Within-Subjects Effects – displacement

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
duration	Sphericity Assumed	12.175	2	6.087	2.393	.111
	Greenhouse-Geisser	12.175	1.537	7.923	2.393	.127
	Huynh-Feldt	12.175	1.702	7.152	2.393	.121
	Lower-bound	12.175	1.000	12.175	2.393	.146
Error(duration)	Sphericity Assumed	66.148	26	2.544		
	Greenhouse-Geisser	66.148	19.977	3.311		
	Huynh-Feldt	66.148	22.130	2.989		
	Lower-bound	66.148	13.000	5.088		

Appendix 10

Correlation between three-point bending and displacement methods of stiffness measurements

Pearson's correlation between three-point bending and displacement data at baseline.

Correlations

		Angle	Def
Angle	Pearson Correlation	1	.376
	Sig. (2-tailed)		.167
	N	15	15
Def	Pearson Correlation	.376	1
	Sig. (2-tailed)	.167	
	N	15	15

Pearson's correlation between percentage change in three-point bending and displacement after 3 minutes of treatment.

Correlations

		perchndis3	perchang3
perchndis3	Pearson Correlation	1	.090
	Sig. (2-tailed)		.751
	N	15	15
perchang3	Pearson Correlation	.090	1
	Sig. (2-tailed)	.751	
	N	15	15

Pearson's correlation between percentage change in three-point bending and displacement after 6 minutes of treatment.

Correlations

		perchdis6	perchanang6
perchdis6	Pearson Correlation	1	.693**
	Sig. (2-tailed)		.004
	N	15	15
perchanang6	Pearson Correlation	.693**	1
	Sig. (2-tailed)	.004	
	N	15	15

Appendix 11
ANOVA and ANCOVA for pain measures

Two-way ANOVA for PPT (with subjects factors of site and duration).

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	1.753	7	.250	8.887	.000
	Greenhouse-Geisser	1.753	4.105	.427	8.887	.000
	Huynh-Feldt	1.753	5.845	.300	8.887	.000
	Lower-bound	1.753	1.000	1.753	8.887	.009
Error(site)	Sphericity Assumed	2.959	105	.028		
	Greenhouse-Geisser	2.959	61.574	.048		
	Huynh-Feldt	2.959	87.671	.034		
	Lower-bound	2.959	15.000	.197		
duration	Sphericity Assumed	.491	2	.246	19.019	.000
	Greenhouse-Geisser	.491	1.721	.286	19.019	.000
	Huynh-Feldt	.491	1.922	.256	19.019	.000
	Lower-bound	.491	1.000	.491	19.019	.001
Error(duration)	Sphericity Assumed	.388	30	.013		
	Greenhouse-Geisser	.388	25.808	.015		
	Huynh-Feldt	.388	28.836	.013		
	Lower-bound	.388	15.000	.026		
site * duration	Sphericity Assumed	.092	14	.007	1.787	.042
	Greenhouse-Geisser	.092	6.262	.015	1.787	.107
	Huynh-Feldt	.092	11.236	.008	1.787	.058
	Lower-bound	.092	1.000	.092	1.787	.201
Error(site*duration)	Sphericity Assumed	.770	210	.004		
	Greenhouse-Geisser	.770	93.924	.008		
	Huynh-Feldt	.770	168.541	.005		
	Lower-bound	.770	15.000	.051		

Pairwise Comparisons

Measure: MEASURE_1

(I) duration	(J) duration	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.067*	.013	.000	-.102	-.032
	3	-.082*	.017	.001	-.128	-.037
2	1	.067*	.013	.000	.032	.102
	3	-.015	.012	.721	-.048	.018
3	1	.082*	.017	.001	.037	.128
	2	.015	.012	.721	-.018	.048

Post Hoc testing for the effects of duration of treatment on PPT's with Bonferroni pairwise comparisons

Pairwise Comparisons

Measure: MEASURE_1

site	(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
1	1	2	-.103*	.029	.003	-.164	-.041
		3	-.140*	.038	.002	-.221	-.060
	2	1	.103*	.029	.003	.041	.164
		3	-.038	.021	.086	-.082	.006
	3	1	.140*	.038	.002	.060	.221
		2	.038	.021	.086	-.006	.082
2	1	2	-.083*	.029	.011	-.144	-.022
		3	-.116*	.028	.001	-.175	-.056
	2	1	.083*	.029	.011	.022	.144
		3	-.033	.023	.162	-.081	.015
	3	1	.116*	.028	.001	.056	.175
		2	.033	.023	.162	-.015	.081
3	1	2	-.025	.022	.285	-.072	.023
		3	-.067	.032	.055	-.135	.002
	2	1	.025	.022	.285	-.023	.072
		3	-.042	.020	.059	-.086	.002
	3	1	.067	.032	.055	-.002	.135
		2	.042	.020	.059	-.002	.086
4	1	2	-.043	.030	.181	-.107	.022
		3	-.039	.030	.213	-.103	.025
	2	1	.043	.030	.181	-.022	.107
		3	.004	.011	.757	-.020	.028
	3	1	.039	.030	.213	-.025	.103
		2	-.004	.011	.757	-.028	.020
5	1	2	-.056*	.021	.018	-.101	-.011
		3	-.059*	.021	.014	-.104	-.014
	2	1	.056*	.021	.018	.011	.101
		3	-.003	.019	.865	-.045	.038
	3	1	.059*	.021	.014	.014	.104
		2	.003	.019	.865	-.038	.045
6	1	2	-.050	.025	.061	-.103	.003
		3	-.074*	.024	.007	-.125	-.024
	2	1	.050	.025	.061	-.003	.103
		3	-.024	.014	.104	-.054	.006
	3	1	.074*	.024	.007	.024	.125
		2	.024	.014	.104	-.006	.054
7	1	2	-.074*	.017	.001	-.110	-.037
		3	-.060*	.025	.032	-.114	-.006
	2	1	.074*	.017	.001	.037	.110
		3	.014	.018	.462	-.025	.053
	3	1	.060*	.025	.032	.006	.114
		2	-.014	.018	.462	-.053	.025
8	1	2	-.105*	.021	.000	-.151	-.060
		3	-.103*	.028	.002	-.164	-.043
	2	1	.105*	.021	.000	.060	.151
		3	.002	.025	.928	-.050	.055
	3	1	.103*	.028	.002	.043	.164
		2	-.002	.025	.928	-.055	.050

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

ANCOVA analysis for PPT's and Questionnaires – single-arm trial

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.455	7	.065	2.607	.017
	Greenhouse-Geisser	.455	3.566	.128	2.607	.055
	Huynh-Feldt	.455	5.682	.080	2.607	.027
	Lower-bound	.455	1.000	.455	2.607	.132
site * **GHQ**	Sphericity Assumed	.295	7	.042	1.692	.122
	Greenhouse-Geisser	.295	3.566	.083	1.692	.175
	Huynh-Feldt	.295	5.682	.052	1.692	.140
	Lower-bound	.295	1.000	.295	1.692	.218
Error(site)	Sphericity Assumed	2.095	84	.025		
	Greenhouse-Geisser	2.095	42.793	.049		
	Huynh-Feldt	2.095	68.188	.031		
	Lower-bound	2.095	12.000	.175		
Duration	Sphericity Assumed	.046	2	.023	1.740	.197
	Greenhouse-Geisser	.046	1.557	.030	1.740	.205
	Huynh-Feldt	.046	1.895	.024	1.740	.199
	Lower-bound	.046	1.000	.046	1.740	.212
Duration * **GHQ**	Sphericity Assumed	.004	2	.002	.148	.863
	Greenhouse-Geisser	.004	1.557	.003	.148	.812
	Huynh-Feldt	.004	1.895	.002	.148	.853
	Lower-bound	.004	1.000	.004	.148	.707
Error(Duration)	Sphericity Assumed	.317	24	.013		
	Greenhouse-Geisser	.317	18.681	.017		
	Huynh-Feldt	.317	22.745	.014		
	Lower-bound	.317	12.000	.026		
site * Duration	Sphericity Assumed	.039	14	.003	.926	.532
	Greenhouse-Geisser	.039	6.932	.006	.926	.490
	Huynh-Feldt	.039	14.000	.003	.926	.532
	Lower-bound	.039	1.000	.039	.926	.355
site * Duration * GHQ	Sphericity Assumed	.043	14	.003	1.026	.430
	Greenhouse-Geisser	.043	6.932	.006	1.026	.419
	Huynh-Feldt	.043	14.000	.003	1.026	.430
	Lower-bound	.043	1.000	.043	1.026	.331
Error(site*Duration)	Sphericity Assumed	.504	168	.003		
	Greenhouse-Geisser	.504	83.182	.006		
	Huynh-Feldt	.504	168.000	.003		
	Lower-bound	.504	12.000	.042		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.561	7	.080	3.122	.005
	Greenhouse-Geisser	.561	3.590	.156	3.122	.027
	Huynh-Feldt	.561	5.511	.102	3.122	.011
	Lower-bound	.561	1.000	.561	3.122	.101
site * Oswestry	Sphericity Assumed	.129	7	.018	.720	.655
	Greenhouse-Geisser	.129	3.590	.036	.720	.569
	Huynh-Feldt	.129	5.511	.023	.720	.623
	Lower-bound	.129	1.000	.129	.720	.412
Error(site)	Sphericity Assumed	2.334	91	.026		
	Greenhouse-Geisser	2.334	46.676	.050		
	Huynh-Feldt	2.334	71.644	.033		
	Lower-bound	2.334	13.000	.180		
Duration	Sphericity Assumed	.092	2	.046	3.954	.032
	Greenhouse-Geisser	.092	1.480	.062	3.954	.047
	Huynh-Feldt	.092	1.753	.053	3.954	.038
	Lower-bound	.092	1.000	.092	3.954	.068
Duration * Oswestry	Sphericity Assumed	.020	2	.010	.846	.441
	Greenhouse-Geisser	.020	1.480	.013	.846	.413
	Huynh-Feldt	.020	1.753	.011	.846	.429
	Lower-bound	.020	1.000	.020	.846	.375
Error(Duration)	Sphericity Assumed	.304	26	.012		
	Greenhouse-Geisser	.304	19.237	.016		
	Huynh-Feldt	.304	22.791	.013		
	Lower-bound	.304	13.000	.023		
site * Duration	Sphericity Assumed	.051	14	.004	1.096	.364
	Greenhouse-Geisser	.051	6.458	.008	1.096	.373
	Huynh-Feldt	.051	14.000	.004	1.096	.364
	Lower-bound	.051	1.000	.051	1.096	.314
site * Duration * Oswestry	Sphericity Assumed	.024	14	.002	.511	.925
	Greenhouse-Geisser	.024	6.458	.004	.511	.811
	Huynh-Feldt	.024	14.000	.002	.511	.925
	Lower-bound	.024	1.000	.024	.511	.487
Error(site*Duration)	Sphericity Assumed	.602	182	.003		
	Greenhouse-Geisser	.602	83.958	.007		
	Huynh-Feldt	.602	182.000	.003		
	Lower-bound	.602	13.000	.046		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.161	7	.023	.902	.509
	Greenhouse-Geisser	.161	3.640	.044	.902	.463
	Huynh-Feldt	.161	5.620	.029	.902	.494
	Lower-bound	.161	1.000	.161	.902	.360
site * Control	Sphericity Assumed	.137	7	.020	.764	.619
	Greenhouse-Geisser	.137	3.640	.038	.764	.543
	Huynh-Feldt	.137	5.620	.024	.764	.593
	Lower-bound	.137	1.000	.137	.764	.398
Error(site)	Sphericity Assumed	2.327	91	.026		
	Greenhouse-Geisser	2.327	47.324	.049		
	Huynh-Feldt	2.327	73.065	.032		
	Lower-bound	2.327	13.000	.179		
Duration	Sphericity Assumed	.068	2	.034	2.849	.076
	Greenhouse-Geisser	.068	1.554	.044	2.849	.092
	Huynh-Feldt	.068	1.862	.037	2.849	.081
	Lower-bound	.068	1.000	.068	2.849	.115
Duration * Control	Sphericity Assumed	.012	2	.006	.520	.601
	Greenhouse-Geisser	.012	1.554	.008	.520	.558
	Huynh-Feldt	.012	1.862	.007	.520	.588
	Lower-bound	.012	1.000	.012	.520	.484
Error(Duration)	Sphericity Assumed	.311	26	.012		
	Greenhouse-Geisser	.311	20.207	.015		
	Huynh-Feldt	.311	24.211	.013		
	Lower-bound	.311	13.000	.024		
site * Duration	Sphericity Assumed	.026	14	.002	.582	.877
	Greenhouse-Geisser	.026	6.232	.004	.582	.750
	Huynh-Feldt	.026	13.516	.002	.582	.872
	Lower-bound	.026	1.000	.026	.582	.459
site * Duration * Control	Sphericity Assumed	.039	14	.003	.862	.601
	Greenhouse-Geisser	.039	6.232	.006	.862	.530
	Huynh-Feldt	.039	13.516	.003	.862	.597
	Lower-bound	.039	1.000	.039	.862	.370
Error(site*Duration)	Sphericity Assumed	.587	182	.003		
	Greenhouse-Geisser	.587	81.014	.007		
	Huynh-Feldt	.587	175.708	.003		
	Lower-bound	.587	13.000	.045		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.744	7	.106	4.102	.001
	Greenhouse-Geisser	.744	3.660	.203	4.102	.008
	Huynh-Feldt	.744	5.663	.131	4.102	.002
	Lower-bound	.744	1.000	.744	4.102	.064
site * disability	Sphericity Assumed	.106	7	.015	.584	.767
	Greenhouse-Geisser	.106	3.660	.029	.584	.661
	Huynh-Feldt	.106	5.663	.019	.584	.732
	Lower-bound	.106	1.000	.106	.584	.458
Error(site)	Sphericity Assumed	2.357	91	.026		
	Greenhouse-Geisser	2.357	47.577	.050		
	Huynh-Feldt	2.357	73.622	.032		
	Lower-bound	2.357	13.000	.181		
Duration	Sphericity Assumed	.141	2	.071	5.695	.009
	Greenhouse-Geisser	.141	1.595	.089	5.695	.015
	Huynh-Feldt	.141	1.923	.074	5.695	.010
	Lower-bound	.141	1.000	.141	5.695	.033
Duration * disability	Sphericity Assumed	.001	2	.000	.032	.969
	Greenhouse-Geisser	.001	1.595	.000	.032	.944
	Huynh-Feldt	.001	1.923	.000	.032	.965
	Lower-bound	.001	1.000	.001	.032	.862
Error(Duration)	Sphericity Assumed	.323	26	.012		
	Greenhouse-Geisser	.323	20.736	.016		
	Huynh-Feldt	.323	24.993	.013		
	Lower-bound	.323	13.000	.025		
site * Duration	Sphericity Assumed	.051	14	.004	1.116	.346
	Greenhouse-Geisser	.051	6.497	.008	1.116	.360
	Huynh-Feldt	.051	14.000	.004	1.116	.346
	Lower-bound	.051	1.000	.051	1.116	.310
site * Duration * disability	Sphericity Assumed	.031	14	.002	.686	.786
	Greenhouse-Geisser	.031	6.497	.005	.686	.673
	Huynh-Feldt	.031	14.000	.002	.686	.786
	Lower-bound	.031	1.000	.031	.686	.422
Error(site*Duration)	Sphericity Assumed	.594	182	.003		
	Greenhouse-Geisser	.594	84.466	.007		
	Huynh-Feldt	.594	182.000	.003		
	Lower-bound	.594	13.000	.046		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.792	7	.113	4.383	.000
	Greenhouse-Geisser	.792	3.643	.217	4.383	.005
	Huynh-Feldt	.792	5.625	.141	4.383	.001
	Lower-bound	.792	1.000	.792	4.383	.056
site * Harm	Sphericity Assumed	.115	7	.016	.635	.726
	Greenhouse-Geisser	.115	3.643	.032	.635	.626
	Huynh-Feldt	.115	5.625	.020	.635	.692
	Lower-bound	.115	1.000	.115	.635	.440
Error(site)	Sphericity Assumed	2.349	91	.026		
	Greenhouse-Geisser	2.349	47.353	.050		
	Huynh-Feldt	2.349	73.129	.032		
	Lower-bound	2.349	13.000	.181		
Duration	Sphericity Assumed	.132	2	.066	5.392	.011
	Greenhouse-Geisser	.132	1.604	.082	5.392	.018
	Huynh-Feldt	.132	1.936	.068	5.392	.012
	Lower-bound	.132	1.000	.132	5.392	.037
Duration * Harm	Sphericity Assumed	.005	2	.003	.223	.801
	Greenhouse-Geisser	.005	1.604	.003	.223	.753
	Huynh-Feldt	.005	1.936	.003	.223	.794
	Lower-bound	.005	1.000	.005	.223	.644
Error(Duration)	Sphericity Assumed	.318	26	.012		
	Greenhouse-Geisser	.318	20.852	.015		
	Huynh-Feldt	.318	25.165	.013		
	Lower-bound	.318	13.000	.024		
site * Duration	Sphericity Assumed	.037	14	.003	.794	.675
	Greenhouse-Geisser	.037	6.389	.006	.794	.584
	Huynh-Feldt	.037	14.000	.003	.794	.675
	Lower-bound	.037	1.000	.037	.794	.389
site * Duration * Harm	Sphericity Assumed	.025	14	.002	.540	.907
	Greenhouse-Geisser	.025	6.389	.004	.540	.787
	Huynh-Feldt	.025	14.000	.002	.540	.907
	Lower-bound	.025	1.000	.025	.540	.475
Error(site*Duration)	Sphericity Assumed	.601	182	.003		
	Greenhouse-Geisser	.601	83.060	.007		
	Huynh-Feldt	.601	182.000	.003		
	Lower-bound	.601	13.000	.046		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	1.466	7	.209	9.662	.000
	Greenhouse-Geisser	1.466	3.626	.404	9.662	.000
	Huynh-Feldt	1.466	5.590	.262	9.662	.000
	Lower-bound	1.466	1.000	1.466	9.662	.008
site * Emotion	Sphericity Assumed	.490	7	.070	3.231	.004
	Greenhouse-Geisser	.490	3.626	.135	3.231	.023
	Huynh-Feldt	.490	5.590	.088	3.231	.008
	Lower-bound	.490	1.000	.490	3.231	.096
Error(site)	Sphericity Assumed	1.973	91	.022		
	Greenhouse-Geisser	1.973	47.143	.042		
	Huynh-Feldt	1.973	72.665	.027		
	Lower-bound	1.973	13.000	.152		
Duration	Sphericity Assumed	.293	2	.146	12.233	.000
	Greenhouse-Geisser	.293	1.556	.188	12.233	.001
	Huynh-Feldt	.293	1.864	.157	12.233	.000
	Lower-bound	.293	1.000	.293	12.233	.004
Duration * Emotion	Sphericity Assumed	.013	2	.006	.525	.598
	Greenhouse-Geisser	.013	1.556	.008	.525	.555
	Huynh-Feldt	.013	1.864	.007	.525	.586
	Lower-bound	.013	1.000	.013	.525	.482
Error(Duration)	Sphericity Assumed	.311	26	.012		
	Greenhouse-Geisser	.311	20.225	.015		
	Huynh-Feldt	.311	24.237	.013		
	Lower-bound	.311	13.000	.024		
site * Duration	Sphericity Assumed	.069	14	.005	1.562	.094
	Greenhouse-Geisser	.069	6.040	.011	1.562	.169
	Huynh-Feldt	.069	12.730	.005	1.562	.103
	Lower-bound	.069	1.000	.069	1.562	.233
site * Duration * Emotion	Sphericity Assumed	.051	14	.004	1.151	.317
	Greenhouse-Geisser	.051	6.040	.008	1.151	.341
	Huynh-Feldt	.051	12.730	.004	1.151	.321
	Lower-bound	.051	1.000	.051	1.151	.303
Error(site*Duration)	Sphericity Assumed	.575	182	.003		
	Greenhouse-Geisser	.575	78.521	.007		
	Huynh-Feldt	.575	165.494	.003		
	Lower-bound	.575	13.000	.044		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	1.144	7	.163	6.718	.000
	Greenhouse-Geisser	1.144	3.483	.328	6.718	.000
	Huynh-Feldt	1.144	5.281	.217	6.718	.000
	Lower-bound	1.144	1.000	1.144	6.718	.022
site * Medication	Sphericity Assumed	.250	7	.036	1.470	.188
	Greenhouse-Geisser	.250	3.483	.072	1.470	.231
	Huynh-Feldt	.250	5.281	.047	1.470	.208
	Lower-bound	.250	1.000	.250	1.470	.247
Error(site)	Sphericity Assumed	2.213	91	.024		
	Greenhouse-Geisser	2.213	45.285	.049		
	Huynh-Feldt	2.213	68.647	.032		
	Lower-bound	2.213	13.000	.170		
Duration	Sphericity Assumed	.116	2	.058	4.902	.016
	Greenhouse-Geisser	.116	1.545	.075	4.902	.025
	Huynh-Feldt	.116	1.849	.063	4.902	.018
	Lower-bound	.116	1.000	.116	4.902	.045
Duration * Medication	Sphericity Assumed	.016	2	.008	.683	.514
	Greenhouse-Geisser	.016	1.545	.010	.683	.480
	Huynh-Feldt	.016	1.849	.009	.683	.504
	Lower-bound	.016	1.000	.016	.683	.424
Error(Duration)	Sphericity Assumed	.307	26	.012		
	Greenhouse-Geisser	.307	20.089	.015		
	Huynh-Feldt	.307	24.037	.013		
	Lower-bound	.307	13.000	.024		
site * Duration	Sphericity Assumed	.051	14	.004	1.091	.368
	Greenhouse-Geisser	.051	6.272	.008	1.091	.375
	Huynh-Feldt	.051	13.687	.004	1.091	.368
	Lower-bound	.051	1.000	.051	1.091	.315
site * Duration * Medication	Sphericity Assumed	.023	14	.002	.504	.929
	Greenhouse-Geisser	.023	6.272	.004	.504	.811
	Huynh-Feldt	.023	13.687	.002	.504	.926
	Lower-bound	.023	1.000	.023	.504	.490
Error(site*Duration)	Sphericity Assumed	.603	182	.003		
	Greenhouse-Geisser	.603	81.539	.007		
	Huynh-Feldt	.603	177.933	.003		
	Lower-bound	.603	13.000	.046		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.805	7	.115	4.370	.000
	Greenhouse-Geisser	.805	3.646	.221	4.370	.005
	Huynh-Feldt	.805	5.632	.143	4.370	.001
	Lower-bound	.805	1.000	.805	4.370	.057
site * Solicitude	Sphericity Assumed	.069	7	.010	.372	.916
	Greenhouse-Geisser	.069	3.646	.019	.372	.810
	Huynh-Feldt	.069	5.632	.012	.372	.885
	Lower-bound	.069	1.000	.069	.372	.552
Error(site)	Sphericity Assumed	2.395	91	.026		
	Greenhouse-Geisser	2.395	47.395	.051		
	Huynh-Feldt	2.395	73.220	.033		
	Lower-bound	2.395	13.000	.184		
Duration	Sphericity Assumed	.398	2	.199	20.208	.000
	Greenhouse-Geisser	.398	1.599	.249	20.208	.000
	Huynh-Feldt	.398	1.928	.207	20.208	.000
	Lower-bound	.398	1.000	.398	20.208	.001
Duration * Solicitude	Sphericity Assumed	.067	2	.034	3.413	.048
	Greenhouse-Geisser	.067	1.599	.042	3.413	.061
	Huynh-Feldt	.067	1.928	.035	3.413	.050
	Lower-bound	.067	1.000	.067	3.413	.088
Error(Duration)	Sphericity Assumed	.256	26	.010		
	Greenhouse-Geisser	.256	20.781	.012		
	Huynh-Feldt	.256	25.060	.010		
	Lower-bound	.256	13.000	.020		
site * Duration	Sphericity Assumed	.070	14	.005	1.562	.094
	Greenhouse-Geisser	.070	6.211	.011	1.562	.167
	Huynh-Feldt	.070	13.427	.005	1.562	.098
	Lower-bound	.070	1.000	.070	1.562	.233
site * Duration * Solicitude	Sphericity Assumed	.042	14	.003	.935	.522
	Greenhouse-Geisser	.042	6.211	.007	.935	.477
	Huynh-Feldt	.042	13.427	.003	.935	.520
	Lower-bound	.042	1.000	.042	.935	.351
Error(site*Duration)	Sphericity Assumed	.584	182	.003		
	Greenhouse-Geisser	.584	80.740	.007		
	Huynh-Feldt	.584	174.555	.003		
	Lower-bound	.584	13.000	.045		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	.528	7	.075	3.185	.005
	Greenhouse-Geisser	.528	3.543	.149	3.185	.026
	Huynh-Feldt	.528	5.407	.098	3.185	.010
	Lower-bound	.528	1.000	.528	3.185	.098
site * medcure	Sphericity Assumed	.307	7	.044	1.850	.087
	Greenhouse-Geisser	.307	3.543	.087	1.850	.142
	Huynh-Feldt	.307	5.407	.057	1.850	.109
	Lower-bound	.307	1.000	.307	1.850	.197
Error(site)	Sphericity Assumed	2.156	91	.024		
	Greenhouse-Geisser	2.156	46.053	.047		
	Huynh-Feldt	2.156	70.294	.031		
	Lower-bound	2.156	13.000	.166		
Duration	Sphericity Assumed	.026	2	.013	1.103	.347
	Greenhouse-Geisser	.026	1.554	.017	1.103	.336
	Huynh-Feldt	.026	1.862	.014	1.103	.344
	Lower-bound	.026	1.000	.026	1.103	.313
Duration * medcure	Sphericity Assumed	.015	2	.008	.642	.534
	Greenhouse-Geisser	.015	1.554	.010	.642	.499
	Huynh-Feldt	.015	1.862	.008	.642	.524
	Lower-bound	.015	1.000	.015	.642	.437
Error(Duration)	Sphericity Assumed	.308	26	.012		
	Greenhouse-Geisser	.308	20.206	.015		
	Huynh-Feldt	.308	24.209	.013		
	Lower-bound	.308	13.000	.024		
site * Duration	Sphericity Assumed	.044	14	.003	.980	.475
	Greenhouse-Geisser	.044	6.128	.007	.980	.445
	Huynh-Feldt	.044	13.086	.003	.980	.473
	Lower-bound	.044	1.000	.044	.980	.340
site * Duration * medcure	Sphericity Assumed	.040	14	.003	.891	.570
	Greenhouse-Geisser	.040	6.128	.007	.891	.507
	Huynh-Feldt	.040	13.086	.003	.891	.564
	Lower-bound	.040	1.000	.040	.891	.362
Error(site*Duration)	Sphericity Assumed	.586	182	.003		
	Greenhouse-Geisser	.586	79.666	.007		
	Huynh-Feldt	.586	170.114	.003		
	Lower-bound	.586	13.000	.045		

Appendix 12

ANOVA and ANCOVA Verbal rating of pain on movement – single arm trial

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	131.760	2	65.880	7.091	.003
	Greenhouse-Geisser	131.760	1.632	80.749	7.091	.006
	Huynh-Feldt	131.760	1.803	73.064	7.091	.004
	Lower-bound	131.760	1.000	131.760	7.091	.018
Error(Duration)	Sphericity Assumed	278.740	30	9.291		
	Greenhouse-Geisser	278.740	24.476	11.388		
	Huynh-Feldt	278.740	27.050	10.304		
	Lower-bound	278.740	15.000	18.583		

Pairwise Comparisons

Measure: MEASURE_1

(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.250	1.309	1.000	-2.275	4.775
	3	3.969*	.954	.003	1.400	6.537
2	1	-1.250	1.309	1.000	-4.775	2.275
	3	2.719*	.929	.031	.217	5.220
3	1	-3.969*	.954	.003	-6.537	-1.400
	2	-2.719*	.929	.031	-5.220	-.217

Based on estimated marginal means

Analysis of covariance (ANCOVA) Pain on movement and questionnaires

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	107.561	2	53.780	1.597	.309
	Greenhouse-Geisser	107.561	1.005	106.991	1.597	.334
	Huynh-Feldt	107.561	2.000	53.780	1.597	.309
	Lower-bound	107.561	1.000	107.561	1.597	.334
Duration * GHQ	Sphericity Assumed	141.274	22	6.422	.191	.996
	Greenhouse-Geisser	141.274	11.059	12.775	.191	.975
	Huynh-Feldt	141.274	22.000	6.422	.191	.996
	Lower-bound	141.274	11.000	12.843	.191	.975
Error(Duration)	Sphericity Assumed	134.667	4	33.667		
	Greenhouse-Geisser	134.667	2.011	66.977		
	Huynh-Feldt	134.667	4.000	33.667		
	Lower-bound	134.667	2.000	67.333		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	17.589	2	8.794	.944	.402
	Greenhouse-Geisser	17.589	1.651	10.652	.944	.388
	Huynh-Feldt	17.589	2.000	8.794	.944	.402
	Lower-bound	17.589	1.000	17.589	.944	.349
Duration * Oswestry	Sphericity Assumed	34.515	2	17.258	1.853	.177
	Greenhouse-Geisser	34.515	1.651	20.902	1.853	.185
	Huynh-Feldt	34.515	2.000	17.258	1.853	.177
	Lower-bound	34.515	1.000	34.515	1.853	.197
Error(Duration)	Sphericity Assumed	242.107	26	9.312		
	Greenhouse-Geisser	242.107	21.466	11.278		
	Huynh-Feldt	242.107	26.000	9.312		
	Lower-bound	242.107	13.000	18.624		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	2.368	2	1.184	.115	.892
	Greenhouse-Geisser	2.368	1.566	1.512	.115	.844
	Huynh-Feldt	2.368	1.880	1.260	.115	.881
	Lower-bound	2.368	1.000	2.368	.115	.740
Duration * Control	Sphericity Assumed	8.792	2	4.396	.427	.657
	Greenhouse-Geisser	8.792	1.566	5.613	.427	.610
	Huynh-Feldt	8.792	1.880	4.677	.427	.645
	Lower-bound	8.792	1.000	8.792	.427	.525
Error(Duration)	Sphericity Assumed	267.831	26	10.301		
	Greenhouse-Geisser	267.831	20.362	13.153		
	Huynh-Feldt	267.831	24.439	10.959		
	Lower-bound	267.831	13.000	20.602		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	21.927	2	10.964	1.082	.354
	Greenhouse-Geisser	21.927	1.630	13.455	1.082	.344
	Huynh-Feldt	21.927	1.974	11.108	1.082	.353
	Lower-bound	21.927	1.000	21.927	1.082	.317
Duration * disability	Sphericity Assumed	13.158	2	6.579	.649	.531
	Greenhouse-Geisser	13.158	1.630	8.074	.649	.502
	Huynh-Feldt	13.158	1.974	6.666	.649	.529
	Lower-bound	13.158	1.000	13.158	.649	.435
Error(Duration)	Sphericity Assumed	263.464	26	10.133		
	Greenhouse-Geisser	263.464	21.185	12.436		
	Huynh-Feldt	263.464	25.661	10.267		
	Lower-bound	263.464	13.000	20.266		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	28.223	2	14.112	1.351	.277
	Greenhouse-Geisser	28.223	1.592	17.728	1.351	.276
	Huynh-Feldt	28.223	1.918	14.715	1.351	.277
	Lower-bound	28.223	1.000	28.223	1.351	.266
Duration * Harm	Sphericity Assumed	5.096	2	2.548	.244	.785
	Greenhouse-Geisser	5.096	1.592	3.201	.244	.736
	Huynh-Feldt	5.096	1.918	2.657	.244	.776
	Lower-bound	5.096	1.000	5.096	.244	.630
Error(Duration)	Sphericity Assumed	271.527	26	10.443		
	Greenhouse-Geisser	271.527	20.696	13.120		
	Huynh-Feldt	271.527	24.934	10.890		
	Lower-bound	271.527	13.000	20.887		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	64.150	2	32.075	3.241	.055
	Greenhouse-Geisser	64.150	1.666	38.514	3.241	.066
	Huynh-Feldt	64.150	2.000	32.075	3.241	.055
	Lower-bound	64.150	1.000	64.150	3.241	.095
Duration * Emotion	Sphericity Assumed	19.298	2	9.649	.975	.391
	Greenhouse-Geisser	19.298	1.666	11.586	.975	.379
	Huynh-Feldt	19.298	2.000	9.649	.975	.391
	Lower-bound	19.298	1.000	19.298	.975	.341
Error(Duration)	Sphericity Assumed	257.325	26	9.897		
	Greenhouse-Geisser	257.325	21.653	11.884		
	Huynh-Feldt	257.325	26.000	9.897		
	Lower-bound	257.325	13.000	19.794		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	40.704	2	20.352	1.956	.162
	Greenhouse-Geisser	40.704	1.626	25.028	1.956	.171
	Huynh-Feldt	40.704	1.969	20.672	1.956	.163
	Lower-bound	40.704	1.000	40.704	1.956	.185
Duration * Medication	Sphericity Assumed	6.066	2	3.033	.291	.750
	Greenhouse-Geisser	6.066	1.626	3.730	.291	.705
	Huynh-Feldt	6.066	1.969	3.081	.291	.746
	Lower-bound	6.066	1.000	6.066	.291	.598
Error(Duration)	Sphericity Assumed	270.556	26	10.406		
	Greenhouse-Geisser	270.556	21.143	12.797		
	Huynh-Feldt	270.556	25.598	10.570		
	Lower-bound	270.556	13.000	20.812		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	92.926	2	46.463	4.615	.019
	Greenhouse-Geisser	92.926	1.615	57.526	4.615	.028
	Huynh-Feldt	92.926	1.953	47.588	4.615	.020
	Lower-bound	92.926	1.000	92.926	4.615	.051
Duration * Solicitude	Sphericity Assumed	14.850	2	7.425	.737	.488
	Greenhouse-Geisser	14.850	1.615	9.193	.737	.463
	Huynh-Feldt	14.850	1.953	7.605	.737	.485
	Lower-bound	14.850	1.000	14.850	.737	.406
Error(Duration)	Sphericity Assumed	261.773	26	10.068		
	Greenhouse-Geisser	261.773	21.000	12.465		
	Huynh-Feldt	261.773	25.385	10.312		
	Lower-bound	261.773	13.000	20.136		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	28.474	2	14.237	1.447	.254
	Greenhouse-Geisser	28.474	1.639	17.370	1.447	.255
	Huynh-Feldt	28.474	1.988	14.321	1.447	.254
	Lower-bound	28.474	1.000	28.474	1.447	.250
Duration * medcure	Sphericity Assumed	20.838	2	10.419	1.059	.361
	Greenhouse-Geisser	20.838	1.639	12.712	1.059	.351
	Huynh-Feldt	20.838	1.988	10.481	1.059	.361
	Lower-bound	20.838	1.000	20.838	1.059	.322
Error(Duration)	Sphericity Assumed	255.784	26	9.838		
	Greenhouse-Geisser	255.784	21.310	12.003		
	Huynh-Feldt	255.784	25.848	9.896		
	Lower-bound	255.784	13.000	19.676		

Appendix 13

ANOVA / ANCOVA Pain on PA force application

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	6.792	2	3.396	6.159	.006
	Greenhouse-Geisser	6.792	1.201	5.654	6.159	.019
	Huynh-Feldt	6.792	1.248	5.443	6.159	.018
	Lower-bound	6.792	1.000	6.792	6.159	.025
Error(Duration)	Sphericity Assumed	16.542	30	.551		
	Greenhouse-Geisser	16.542	18.018	.918		
	Huynh-Feldt	16.542	18.718	.884		
	Lower-bound	16.542	15.000	1.103		

Pairwise Comparisons

Measure: MEASURE_1

(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.688	.270	.067	-.039	1.414
	3	.875	.340	.064	-.041	1.791
2	1	-.688	.270	.067	-1.414	.039
	3	.188	.136	.564	-.179	.554
3	1	-.875	.340	.064	-1.791	.041
	2	-.188	.136	.564	-.554	.179

ANCOVA Pain on PA force application

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	2.753	2	1.376	2.902	.074
	Greenhouse-Geisser	2.753	1.232	2.235	2.902	.104
	Huynh-Feldt	2.753	1.416	1.944	2.902	.096
	Lower-bound	2.753	1.000	2.753	2.902	.114
Duration * GHQ	Sphericity Assumed	1.426	2	.713	1.503	.243
	Greenhouse-Geisser	1.426	1.232	1.157	1.503	.246
	Huynh-Feldt	1.426	1.416	1.007	1.503	.246
	Lower-bound	1.426	1.000	1.426	1.503	.244
Error(Duration)	Sphericity Assumed	11.384	24	.474		
	Greenhouse-Geisser	11.384	14.783	.770		
	Huynh-Feldt	11.384	16.991	.670		
	Lower-bound	11.384	12.000	.949		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	2.020	2	1.010	1.917	.167
	Greenhouse-Geisser	2.020	1.204	1.678	1.917	.186
	Huynh-Feldt	2.020	1.361	1.484	1.917	.183
	Lower-bound	2.020	1.000	2.020	1.917	.190
Duration * Oswestry	Sphericity Assumed	.387	2	.194	.367	.696
	Greenhouse-Geisser	.387	1.204	.322	.367	.592
	Huynh-Feldt	.387	1.361	.284	.367	.617
	Lower-bound	.387	1.000	.387	.367	.555
Error(Duration)	Sphericity Assumed	13.702	26	.527		
	Greenhouse-Geisser	13.702	15.646	.876		
	Huynh-Feldt	13.702	17.691	.775		
	Lower-bound	13.702	13.000	1.054		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	2.093	2	1.046	2.059	.148
	Greenhouse-Geisser	2.093	1.243	1.684	2.059	.169
	Huynh-Feldt	2.093	1.416	1.478	2.059	.165
	Lower-bound	2.093	1.000	2.093	2.059	.175
Duration * Control	Sphericity Assumed	.876	2	.438	.862	.434
	Greenhouse-Geisser	.876	1.243	.705	.862	.391
	Huynh-Feldt	.876	1.416	.619	.862	.403
	Lower-bound	.876	1.000	.876	.862	.370
Error(Duration)	Sphericity Assumed	13.213	26	.508		
	Greenhouse-Geisser	13.213	16.158	.818		
	Huynh-Feldt	13.213	18.404	.718		
	Lower-bound	13.213	13.000	1.016		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	.776	2	.388	.733	.490
	Greenhouse-Geisser	.776	1.211	.641	.733	.430
	Huynh-Feldt	.776	1.371	.566	.733	.445
	Lower-bound	.776	1.000	.776	.733	.408
Duration * disability	Sphericity Assumed	.324	2	.162	.306	.739
	Greenhouse-Geisser	.324	1.211	.267	.306	.631
	Huynh-Feldt	.324	1.371	.236	.306	.658
	Lower-bound	.324	1.000	.324	.306	.590
Error(Duration)	Sphericity Assumed	13.765	26	.529		
	Greenhouse-Geisser	13.765	15.742	.874		
	Huynh-Feldt	13.765	17.824	.772		
	Lower-bound	13.765	13.000	1.059		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	.777	2	.388	.755	.480
	Greenhouse-Geisser	.777	1.185	.655	.755	.420
	Huynh-Feldt	.777	1.335	.582	.755	.434
	Lower-bound	.777	1.000	.777	.755	.401
Duration * Harm	Sphericity Assumed	.711	2	.355	.691	.510
	Greenhouse-Geisser	.711	1.185	.600	.691	.443
	Huynh-Feldt	.711	1.335	.532	.691	.458
	Lower-bound	.711	1.000	.711	.691	.421
Error(Duration)	Sphericity Assumed	13.378	26	.515		
	Greenhouse-Geisser	13.378	15.407	.868		
	Huynh-Feldt	13.378	17.359	.771		
	Lower-bound	13.378	13.000	1.029		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	1.037	2	.519	.987	.386
	Greenhouse-Geisser	1.037	1.226	.846	.987	.354
	Huynh-Feldt	1.037	1.392	.745	.987	.363
	Lower-bound	1.037	1.000	1.037	.987	.339
Duration * Emotion	Sphericity Assumed	.433	2	.217	.413	.666
	Greenhouse-Geisser	.433	1.226	.354	.413	.571
	Huynh-Feldt	.433	1.392	.311	.413	.595
	Lower-bound	.433	1.000	.433	.413	.532
Error(Duration)	Sphericity Assumed	13.655	26	.525		
	Greenhouse-Geisser	13.655	15.935	.857		
	Huynh-Feldt	13.655	18.093	.755		
	Lower-bound	13.655	13.000	1.050		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	.195	2	.097	.213	.809
	Greenhouse-Geisser	.195	1.212	.160	.213	.697
	Huynh-Feldt	.195	1.373	.142	.213	.726
	Lower-bound	.195	1.000	.195	.213	.652
Duration * Medication	Sphericity Assumed	2.231	2	1.116	2.446	.106
	Greenhouse-Geisser	2.231	1.212	1.840	2.446	.134
	Huynh-Feldt	2.231	1.373	1.625	2.446	.128
	Lower-bound	2.231	1.000	2.231	2.446	.142
Error(Duration)	Sphericity Assumed	11.858	26	.456		
	Greenhouse-Geisser	11.858	15.762	.752		
	Huynh-Feldt	11.858	17.852	.664		
	Lower-bound	11.858	13.000	.912		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	1.626	2	.813	1.501	.242
	Greenhouse-Geisser	1.626	1.226	1.326	1.501	.245
	Huynh-Feldt	1.626	1.392	1.168	1.501	.245
	Lower-bound	1.626	1.000	1.626	1.501	.242
Duration * Solicitude	Sphericity Assumed	.005	2	.003	.005	.995
	Greenhouse-Geisser	.005	1.226	.004	.005	.968
	Huynh-Feldt	.005	1.392	.004	.005	.979
	Lower-bound	.005	1.000	.005	.005	.945
Error(Duration)	Sphericity Assumed	14.083	26	.542		
	Greenhouse-Geisser	14.083	15.940	.884		
	Huynh-Feldt	14.083	18.099	.778		
	Lower-bound	14.083	13.000	1.083		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Duration	Sphericity Assumed	.026	2	.013	.024	.976
	Greenhouse-Geisser	.026	1.229	.021	.024	.917
	Huynh-Feldt	.026	1.396	.018	.024	.937
	Lower-bound	.026	1.000	.026	.024	.878
Duration * medcure	Sphericity Assumed	.432	2	.216	.411	.667
	Greenhouse-Geisser	.432	1.229	.352	.411	.572
	Huynh-Feldt	.432	1.396	.310	.411	.597
	Lower-bound	.432	1.000	.432	.411	.532
Error(Duration)	Sphericity Assumed	13.657	26	.525		
	Greenhouse-Geisser	13.657	15.973	.855		
	Huynh-Feldt	13.657	18.145	.753		
	Lower-bound	13.657	13.000	1.051		

Appendix 14

Correlations between PPT and VRS – single arm trial

Correlations

		VRSchange12	sympchange12
VRSchange12	Pearson Correlation	1	.057
	Sig. (2-tailed)		.834
	N	16	16
sympchange12	Pearson Correlation	.057	1
	Sig. (2-tailed)	.834	
	N	16	16

Correlations

		VRSchange23	sympchang23
VRSchange23	Pearson Correlation	1	.141
	Sig. (2-tailed)		.603
	N	16	16
sympchang23	Pearson Correlation	.141	1
	Sig. (2-tailed)	.603	
	N	16	16

Correlations

		VRSchange13	symptchnage13
VRSchange13	Pearson Correlation	1	-.325
	Sig. (2-tailed)		.219
	N	16	16
symptchnage13	Pearson Correlation	-.325	1
	Sig. (2-tailed)	.219	
	N	16	16

Appendix 15

Participant information sheet

THE UNIVERSITY OF BRIGHTON
School of Health Professions

For a study in part fulfilment for a PhD entitled:

The effects of lumbar mobilisations on pain sensitivity and pain levels in low back pain patients.

Clair Hebron, Professor Ann Moore, Dr Anne Jackson, Dr Kambiz Saber-Sheikh, Dr Nikki Petty.

PARTICIPANT INFORMATION SHEET

1 **Study title**

The perceived effects of different amounts of mobilisation for people with low back pain.

2 **Invitation paragraph**

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

3 **What is the purpose of the study?**

The purpose of this study is to explore the perceived effects of different amounts of mobilisation for people with low back pain.

4 **Why have I been chosen?**

You have been chosen as you have experienced low back pain for three months or longer and experience this pain when you move. However you have not received treatment for these symptoms within the last 3 months.

5 **Do I have to take part?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

6 **What will happen to me if I take part?**

If you agree to take part in this study you will be required to attend the human movement laboratory on three occasions, the first attendance will take approximately 60 minutes. The second and third attendance will each take approximately 40 minutes. On each occasion you will be asked to undress to shorts and for female participants' shorts and bra.

On the first occasion a physiotherapist will perform an examination of your spine to establish the area from which your symptoms are arising. This assessment would be typical of the assessment that you would receive on your first appointment with a physiotherapist. The assessment enables the physiotherapist to direct treatment to the level of your spine that is responsible for your symptoms. During this examination you will be asked about your age and

medical history and your height and weight will be recorded. You will also be asked about where you feel your pain, what causes the pain to become worse and how and when it started. The physiotherapist will then look at and feel the movement of your back and your sensation, muscle strength and reflexes may also be tested. During these procedures there is likely to be some reproduction of your pain. It is necessary to reproduce some of your pain in order to understand the nature of your complaint and tailor treatment to your specific presentation. You will be asked to stop any movement that become too uncomfortable. This procedure is standard practice in physiotherapy assessment of patients with low back pain. You will also be asked to complete some questionnaires about your pain and your beliefs about pain, your cigarette and alcohol consumption and general health as it is thought that these may be factors that affect your response to treatment (the questionnaires will take approximately 20 minutes to complete).

On the second occasion, you will be asked to bend forwards, backwards and bend and twist from side to side and asked to rate on a scale of 0-10 how much pain is produced on each movement. You will not be asked to move further into your pain than you are comfortable to.

A machine with a contact area the size of a 5 pence piece will be applied to 5 points in your lower limb, a point in your upper arm and two points on your back. This machine is used to measure pressure pain threshold, which is the point at which sensation turns from pressure to pain. The machine will be used to gradually apply increasing pressure, you will be asked to press a button as soon as the sensation you are experiencing changes form pressure to discomfort or pain, at which point the pressure will be removed.

You will then be required to lie on your front whilst a physiotherapist presses on your low back and you will be asked to rate on a scale of 0-10 how much pain is produced on each movement.

The measurements of pain on movement, and pressure detailed above will be repeated on two further occasions after periods of rest and application of mobilisation to your back. You will also be asked to rate whether there has been any change in your pain following the mobilisations.

You will receive mobilisation treatment that consists of repeated pressure applied through your back; this will be interspersed with rest periods. The mobilisation treatment will be tailored to your back pain, based on the findings from the physiotherapy assessment you received on your first assessment'

On your third attendance you will be asked to rate the pain you experience on movement and pressure and you will be asked to rate any change in your pain (the same as on your second attendance) for the final time. You will then be asked to complete a questionnaire on your expectations and experience of receiving a mobilisation technique (completion of the questionnaire will take approximately 15 minutes). The physiotherapist will advise you on the cause of, and best course of management for your back pain.

7 **What do I have to do?**

You will be asked to avoid undertaking strenuous exercise for at least 2 hours prior to each session. You will be asked to avoid taking pain-killing medication after 8pm the evening before each attendance.

8 **What are the possible disadvantages and risks of taking part?**

The intervention you will receive is safe and is of the type commonly used by physiotherapists in the assessment and treatment of the lumbar spine. It is normal for some of your back pain to be reproduced during mobilisations, the physiotherapist will monitor this throughout the procedure and if this should become unduly painful you should inform the physiotherapist and the procedure will be terminated.

There is a chance that you will experience soreness in your low back for 24-48 hours after each session. If this should occur you could take the painkillers, which you would normally, take for your back pain.

9 **What are the possible benefits of taking part?**

The examining physiotherapist will conduct an examination, and will be able to advise you of the possible cause of your symptoms and whether further treatment for your symptoms may be beneficial. However the physiotherapist will not be able to provide you with on-going treatment.

The information from this study will help establish the pain relieving effect of using lumbar mobilisations.

10 **What if something goes wrong?**

If you experience undue discomfort during the intervention please tell the physiotherapist at the time and the procedure will be terminated. There is a chance that you will experience soreness in your low back for 24-48 hours after the treatment. If this should persist for longer period then you could take the painkillers that you would normally take for your back pain.
We do not envisage any longer term complications as none have been reported to result from lumbar mobilisations, however if you should experience increased soreness for longer than 72 hours after each session you should contact the principle researcher (Clair Hebron) on (01273) 643878 or email C.L.Hebron@brighton.ac.uk. If you do require further treatment after the completion of this study you should contact your General Practitioner.

If you have any issues or concerns about the procedures or how they are carried out, you may contact Dr Jane Morris who is Deputy Head of the School of Health Professions. Should you have any concerns regarding the conduct of the study, please contact Dr Morris on (01273) 643651 or email JM309@bton.ac.uk.

11 **Will my taking part in this study be kept confidential?**

On entering the study you will be allocated with a subject number by which you will be referred for the remainder of the study. The code to your name will be kept on a password-protected computer; this will ensure your anonymity throughout.

12 **What will happen to the results of the research study?**

It is intended that the results from this study will be published in professional journals and presented at scientific conferences. You will not be identified in any publication. A summary of the results will be made available to you on your request once the study has been completed (by January 2014).

13 **Who has reviewed the study?**

This study has been reviewed and approved by the University of Brighton, Faculty of Health Research Ethics and Governance Committee

14 **Contact for Further Information**

If you require any further information you can contact Clair Hebron (the researcher) on 01273 643878 or e-mail C.L.Hebron@brighton.ac.uk

You will be given a copy of the information sheet and a signed consent form to keep for reference.

Thank you for taking part in this study

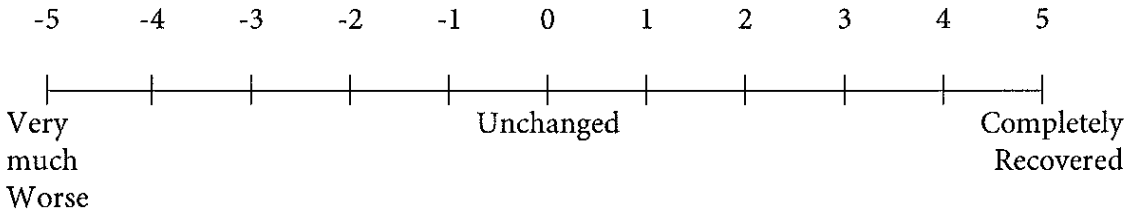
Appendix 16

Global rating of perceived effect

Session two

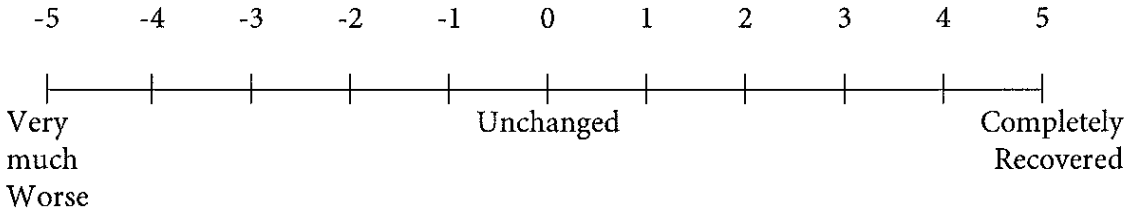
Global rating of perceived change scale

With respect to your low back pain, how would you describe yourself now compared to immediately before the mobilisation treatment you have just received ?



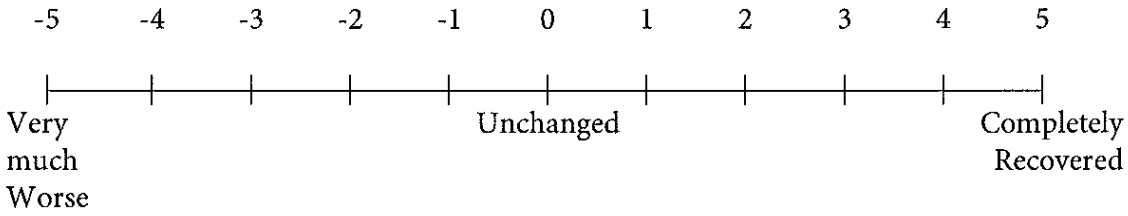
Global rating of perceived change scale

With respect to your low back pain, how would you describe yourself now compared to immediately before the mobilisation treatment you have just received ?



Session 3

With respect to your low back pain, how would you describe yourself now compared to immediately before the mobilisation treatment you received yesterday?



Appendix 17

Participant expectations and experience of mobilisations questionnaire

The technique you received was a **"mobilisation technique"** involving pressure being applied to your lower back. This technique is often applied as part of treatment for low back pain. We would like to know more about what you expected from this technique and, what your experience was when the technique was applied. Please could you answer the following questions?

Have you had previous experience of receiving this mobilisation technique? **Yes/ No** (please circle).

Please describe any previous experience of mobilisations that you have had.

What were you expecting from having this 'mobilisation technique' applied on this occasion?

Was there anything that you didn't expect about the mobilisation technique? If so, what happened that you didn't expect?

What were you thinking and feeling when the mobilisation technique was applied?

How comfortable was the mobilisation technique?

What effect do you think the mobilisation technique had on your back?

Do you have any other comments?

Appendix 18

Test of normality for the RCT

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
force	.096	67	.200*	.960	67	.032
Age	.077	67	.200*	.958	67	.024
Oswestry	.134	67	.005	.964	67	.048
McGill	.124	67	.012	.948	67	.007
Control	.115	67	.029	.986	67	.632
Disability	.119	67	.019	.948	67	.008
Harm	.108	67	.051	.965	67	.058
Emotion	.192	67	.000	.873	67	.000
medication	.118	67	.021	.952	67	.012
solicitude	.108	67	.052	.933	67	.001
medcure	.114	67	.031	.963	67	.045

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PPB	.292	71	.000	.733	71	.000
PP1	.305	71	.000	.731	71	.000
PP2	.258	71	.000	.718	71	.000
PP24	.278	71	.000	.663	71	.000
PAB	.105	71	.052	.954	71	.012
PA1	.099	71	.083	.971	71	.096
PA2	.126	71	.007	.960	71	.022
PA24	.125	71	.008	.949	71	.006
GRPE1	.141	71	.001	.970	71	.084
GRPE2	.118	71	.015	.972	71	.119
GRPE24	.113	71	.025	.965	71	.045

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
sympB	.121	72	.011	.938	72	.002
sympt1	.104	72	.053	.922	72	.000
sympt2	.124	72	.008	.927	72	.000
sympt24	.098	72	.083	.957	72	.014
T10B	.096	72	.098	.925	72	.000
T101	.129	72	.005	.895	72	.000
T102	.099	72	.077	.917	72	.000
T1024	.142	72	.001	.934	72	.001
DeltoidB	.094	72	.191	.965	72	.043
Deltoid1	.088	72	.200*	.949	72	.006
Deltoid2	.117	72	.017	.926	72	.000
Deltoid24	.130	72	.004	.917	72	.000
S1B	.094	72	.195	.968	72	.060
S11	.079	72	.200*	.956	72	.012
S12	.134	72	.003	.924	72	.000
S124	.112	72	.025	.916	72	.000
L2B	.114	72	.021	.950	72	.006
L21	.095	72	.175	.950	72	.006
L22	.110	72	.030	.953	72	.010
L224	.075	72	.200*	.976	72	.188
L3B	.117	72	.017	.941	72	.002
L31	.101	72	.066	.909	72	.000
L32	.137	72	.002	.910	72	.000
L324	.127	72	.006	.911	72	.000
L4B	.099	72	.075	.961	72	.024
L41	.096	72	.095	.946	72	.004
L42	.102	72	.059	.955	72	.012
L424	.105	72	.047	.935	72	.001
L5B	.147	72	.001	.918	72	.000
L51	.115	72	.019	.927	72	.000
L52	.115	72	.019	.947	72	.004
L524	.087	72	.200*	.918	72	.000

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
symptBtrans	.078	71	.200*	.983	71	.472
sympt1trans	.049	71	.200*	.987	71	.698
sympt2trans	.103	71	.060	.970	71	.090
sympt24trans	.074	71	.200*	.964	71	.041
T10Btrans	.065	71	.200*	.989	71	.769
T101trans	.075	71	.200*	.983	71	.461
T102trans	.071	71	.200*	.987	71	.700
T1024trans	.081	71	.200*	.983	71	.444
DeltoidBtrans	.093	71	.200*	.978	71	.238
Deltoid1trans	.084	71	.200*	.985	71	.575
Deltoid2trans	.054	71	.200*	.986	71	.599
Deltoid24trans	.113	71	.024	.964	71	.042
S1Btrans	.073	71	.200*	.978	71	.258
S11trans	.085	71	.200*	.990	71	.831
S12trans	.071	71	.200*	.987	71	.654
S124trans	.072	71	.200*	.984	71	.530
L2Btrans	.072	71	.200*	.983	71	.441
L21trans	.083	71	.200*	.982	71	.391
L22trans	.117	71	.017	.976	71	.188
L224trans	.097	71	.094	.977	71	.223
L3Btrans	.057	71	.200*	.993	71	.970
L31trans	.057	71	.200*	.985	71	.587
L32trans	.085	71	.200*	.977	71	.229
L324trans	.048	71	.200*	.993	71	.961
L4Btrans	.052	71	.200*	.989	71	.790
L41trans	.093	71	.200*	.983	71	.464
L42trans	.095	71	.184	.985	71	.554
L424trans	.077	71	.200*	.977	71	.206
L5Btrans	.063	71	.200*	.993	71	.971
L51trans	.070	71	.200*	.989	71	.777
L52trans	.054	71	.200*	.984	71	.516
L524trans	.067	71	.200*	.982	71	.424

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Appendix 19

T-test for differences in PPT between groups at baseline.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
symptBtrans	Equal variances assumed	.000	.982	1.257	70	.213	.05936	.04721	-.03479	.15351
	Equal variances not assumed			1.260	68.611	.212	.05936	.04710	-.03461	.15332
T10Btrans	Equal variances assumed	.324	.571	1.702	70	.093	.07608	.04469	-.01306	.16522
	Equal variances not assumed			1.688	65.364	.096	.07608	.04506	-.01391	.16607
DeltoidBtrans	Equal variances assumed	.274	.603	1.374	70	.174	.05592	.04069	-.02523	.13708
	Equal variances not assumed			1.379	68.850	.172	.05592	.04055	-.02498	.13683
S1Btrans	Equal variances assumed	.000	.990	.383	70	.703	.01351	.03531	-.05692	.08394
	Equal variances not assumed			.380	65.582	.705	.01351	.03559	-.05755	.08456
L2Btrans	Equal variances assumed	9.202	.003	-.551	70	.584	-.02222	.04037	-.10274	.05829
	Equal variances not assumed			-.568	67.213	.572	-.02222	.03915	-.10036	.05591
L3Btrans	Equal variances assumed	.686	.410	.512	70	.610	.02347	.04584	-.06795	.11489
	Equal variances not assumed			.519	69.977	.606	.02347	.04526	-.06680	.11374
L4Btrans	Equal variances assumed	3.674	.059	1.320	70	.191	.05145	.03899	-.02631	.12921
	Equal variances not assumed			1.352	68.977	.181	.05145	.03806	-.02447	.12737
L5Btrans	Equal variances assumed	.370	.545	-.423	70	.673	-.01808	.04269	-.10321	.06706
	Equal variances not assumed			-.425	69.016	.672	-.01808	.04250	-.10287	.06672

T-test for differences in VRS between groups at baseline.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
VRS	Equal variances assumed	4.529	.037	1.081	70	.283	2.20513	2.03902	-1.86157	6.27182
	Equal variances not assumed			1.052	56.698	.297	2.20513	2.09571	-1.99195	6.40221
PPB	Equal variances assumed	.588	.446	1.233	70	.222	.46387	.37608	-.28620	1.21394
	Equal variances not assumed			1.227	66.493	.224	.46387	.37801	-.29075	1.21848
PAB	Equal variances assumed	.766	.384	.689	70	.493	.34965	.50714	-.66182	1.36112
	Equal variances not assumed			.709	68.147	.481	.34965	.49334	-.63475	1.33406

T-test for differences in Questionnaires / demographics between groups at baseline. T-test for force of treatment between groups

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
force	Equal variances assumed	.446	.507	.965	68	.338	12.80045	13.26527	-13.66999	39.27089
	Equal variances not assumed			.968	67.763	.336	12.80045	13.22159	-13.58450	39.18540
Age	Equal variances assumed	.308	.581	3.055	69	.003	9.502	3.110	3.298	15.706
	Equal variances not assumed			3.064	66.976	.003	9.502	3.101	3.311	15.692
Oswestry	Equal variances assumed	1.871	.176	1.606	69	.113	2.627	1.636	-.636	5.890
	Equal variances not assumed			1.577	60.238	.120	2.627	1.666	-.705	5.960
Control	Equal variances assumed	1.069	.305	.081	69	.935	.06731	.82616	-1.58083	1.71544
	Equal variances not assumed			.083	68.988	.934	.06731	.81101	-1.55061	1.68523
Harm	Equal variances assumed	3.011	.087	-1.175	69	.244	-.90545	.77090	-2.44335	.63245
	Equal variances not assumed			-1.199	68.991	.235	-.90545	.75496	-2.41156	.60066
medcure	Equal variances assumed	.042	.838	-1.457	69	.150	-1.27163	.87305	-3.01332	.47005
	Equal variances not assumed			-1.455	66.098	.150	-1.27163	.87379	-3.01617	.47290

Mann-Whitney U test for difference between skewed questionnaire data sets between groups at baseline

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of McGill is the same across categories of condition.	Independent-Samples Mann-Whitney U Test	.627	Retain the null hypothesis.
2	The distribution of Disability is the same across categories of condition.	Independent-Samples Mann-Whitney U Test	.052	Retain the null hypothesis.
3	The distribution of Emotion is the same across categories of condition.	Independent-Samples Mann-Whitney U Test	.744	Retain the null hypothesis.
4	The distribution of medication is the same across categories of condition.	Independent-Samples Mann-Whitney U Test	.102	Retain the null hypothesis.
5	The distribution of solicitude is the same across categories of condition.	Independent-Samples Mann-Whitney U Test	.012	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Test for baseline difference between responders and non-responders

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of forcenonresp is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.353	Retain the null hypothesis.
2	The distribution of age is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.047	Reject the null hypothesis.
3	The distribution of durationofsymp is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.481	Retain the null hypothesis.
4	The distribution of GHQ is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.860	Retain the null hypothesis.
5	The distribution of Oswestery is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.528	Retain the null hypothesis.
6	The distribution of McGill is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.986	Retain the null hypothesis.
7	The distribution of Control is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.506	Retain the null hypothesis.
8	The distribution of disab is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.170	Retain the null hypothesis.
9	The distribution of harm is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.528	Retain the null hypothesis.
10	The distribution of emotion is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.334	Retain the null hypothesis.
11	The distribution of medication is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.839	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
12	The distribution of solicitude is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.958	Retain the null hypothesis.
13	The distribution of medcure is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.058	Retain the null hypothesis.
14	The distribution of alcohol is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.549	Retain the null hypothesis.
15	The distribution of binge is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.419	Retain the null hypothesis.
16	The distribution of hoursex is the same across categories of respnonresp.	Independent-Samples Mann-Whitney U Test	.177	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Appendix 20

ANOVA/ ANCOVA for PPT - RCT

ANOVA PPT Baseline to after treatment period 1.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
te	Sphericity Assumed	6.988	7	.998	54.610	.000
	Greenhouse-Geisser	6.988	5.383	1.298	54.610	.000
	Huynh-Feldt	6.988	5.967	1.171	54.610	.000
	Lower-bound	6.988	1.000	6.988	54.610	.000
site * condition	Sphericity Assumed	.167	7	.024	1.308	.244
	Greenhouse-Geisser	.167	5.383	.031	1.308	.257
	Huynh-Feldt	.167	5.967	.028	1.308	.253
	Lower-bound	.167	1.000	.167	1.308	.257
Error(site)	Sphericity Assumed	8.957	490	.018		
	Greenhouse-Geisser	8.957	376.816	.024		
	Huynh-Feldt	8.957	417.704	.021		
	Lower-bound	8.957	70.000	.128		
time	Sphericity Assumed	.001	1	.001	.057	.812
	Greenhouse-Geisser	.001	1.000	.001	.057	.812
	Huynh-Feldt	.001	1.000	.001	.057	.812
	Lower-bound	.001	1.000	.001	.057	.812
time * condition	Sphericity Assumed	.032	1	.032	3.330	.072
	Greenhouse-Geisser	.032	1.000	.032	3.330	.072
	Huynh-Feldt	.032	1.000	.032	3.330	.072
	Lower-bound	.032	1.000	.032	3.330	.072
Error(time)	Sphericity Assumed	.666	70	.010		
	Greenhouse-Geisser	.666	70.000	.010		
	Huynh-Feldt	.666	70.000	.010		
	Lower-bound	.666	70.000	.010		
site * time	Sphericity Assumed	.023	7	.003	.964	.457
	Greenhouse-Geisser	.023	5.774	.004	.964	.447
	Huynh-Feldt	.023	6.442	.004	.964	.453
	Lower-bound	.023	1.000	.023	.964	.329
site * time * condition	Sphericity Assumed	.050	7	.007	2.100	.042
	Greenhouse-Geisser	.050	5.774	.009	2.100	.055
	Huynh-Feldt	.050	6.442	.008	2.100	.047
	Lower-bound	.050	1.000	.050	2.100	.152
Error(site*time)	Sphericity Assumed	1.672	490	.003		
	Greenhouse-Geisser	1.672	404.176	.004		
	Huynh-Feldt	1.672	450.918	.004		
	Lower-bound	1.672	70.000	.024		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	518.595	1	518.595	1358.134	.000
condition	.108	1	.108	.282	.597
Error	26.729	70	.382		

ANOVA PPT Baseline to after treatment period 2.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	6.698	7	.957	52.410	.000
	Greenhouse-Geisser	6.698	5.552	1.206	52.410	.000
	Huynh-Feldt	6.698	6.172	1.085	52.410	.000
	Lower-bound	6.698	1.000	6.698	52.410	.000
site * condition	Sphericity Assumed	.131	7	.019	1.028	.410
	Greenhouse-Geisser	.131	5.552	.024	1.028	.404
	Huynh-Feldt	.131	6.172	.021	1.028	.407
	Lower-bound	.131	1.000	.131	1.028	.314
rror(site)	Sphericity Assumed	8.946	490	.018		
	Greenhouse-Geisser	8.946	388.667	.023		
	Huynh-Feldt	8.946	432.041	.021		
	Lower-bound	8.946	70.000	.128		
time	Sphericity Assumed	.002	1	.002	.093	.761
	Greenhouse-Geisser	.002	1.000	.002	.093	.761
	Huynh-Feldt	.002	1.000	.002	.093	.761
	Lower-bound	.002	1.000	.002	.093	.761
time * condition	Sphericity Assumed	.051	1	.051	2.779	.100
	Greenhouse-Geisser	.051	1.000	.051	2.779	.100
	Huynh-Feldt	.051	1.000	.051	2.779	.100
	Lower-bound	.051	1.000	.051	2.779	.100
Error(time)	Sphericity Assumed	1.277	70	.018		
	Greenhouse-Geisser	1.277	70.000	.018		
	Huynh-Feldt	1.277	70.000	.018		
	Lower-bound	1.277	70.000	.018		
site * time	Sphericity Assumed	.029	7	.004	.924	.488
	Greenhouse-Geisser	.029	5.110	.006	.924	.467
	Huynh-Feldt	.029	5.639	.005	.924	.474
	Lower-bound	.029	1.000	.029	.924	.340
site * time * condition	Sphericity Assumed	.086	7	.012	2.705	.009
	Greenhouse-Geisser	.086	5.110	.017	**2.705**	**.020**
	Huynh-Feldt	.086	5.639	.015	2.705	.016
	Lower-bound	.086	1.000	.086	2.705	.105
Error(site*time)	Sphericity Assumed	2.213	490	.005		
	Greenhouse-Geisser	2.213	357.681	.006		
	Huynh-Feldt	2.213	394.713	.006		
	Lower-bound	2.213	70.000	.032		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	519.412	1	519.412	1365.215	.000
condition	.079	1	.079	.208	.650
Error	26.632	70	.380		

Pairwise Comparisons

Measure: MEASURE_1

site	time	(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
							Lower Bound	Upper Bound
1	1	Short	Long	.059	.047	.213	-.035	.154
		Long	Short	-.059	.047	.213	-.154	.035
	2	Short	Long	-.003	.057	.959	-.117	.111
		Long	Short	.003	.057	.959	-.111	.117
2	1	Short	Long	.076	.045	.093	-.013	.165
		Long	Short	-.076	.045	.093	-.165	.013
	2	Short	Long	.023	.047	.626	-.071	.117
		Long	Short	-.023	.047	.626	-.117	.071
3	1	Short	Long	.056	.041	.174	-.025	.137
		Long	Short	-.056	.041	.174	-.137	.025
	2	Short	Long	.031	.050	.537	-.069	.132
		Long	Short	-.031	.050	.537	-.132	.069
4	1	Short	Long	.014	.035	.703	-.057	.084
		Long	Short	-.014	.035	.703	-.084	.057
	2	Short	Long	.011	.034	.742	-.056	.078
		Long	Short	-.011	.034	.742	-.078	.056
5	1	Short	Long	-.022	.040	.584	-.103	.058
		Long	Short	.022	.040	.584	-.058	.103
	2	Short	Long	-.014	.045	.748	-.104	.075
		Long	Short	.014	.045	.748	-.075	.104
6	1	Short	Long	.023	.046	.610	-.068	.115
		Long	Short	-.023	.046	.610	-.115	.068
	2	Short	Long	-.004	.045	.922	-.094	.085
		Long	Short	.004	.045	.922	-.085	.094
7	1	Short	Long	.051	.039	.191	-.026	.129
		Long	Short	-.051	.039	.191	-.129	.026
	2	Short	Long	-.028	.046	.545	-.119	.063
		Long	Short	.028	.046	.545	-.063	.119
8	1	Short	Long	-.018	.043	.673	-.103	.067
		Long	Short	.018	.043	.673	-.067	.103
	2	Short	Long	.011	.042	.802	-.073	.094
		Long	Short	-.011	.042	.802	-.094	.073

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

ANOVA PPT Baseline to after treatment at 24 hour follow-up

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
site	Sphericity Assumed	7.040	7	1.006	52.202	.000
	Greenhouse-Geisser	7.040	5.560	1.266	52.202	.000
	Huynh-Feldt	7.040	6.191	1.137	52.202	.000
	Lower-bound	7.040	1.000	7.040	52.202	.000
site * condition	Sphericity Assumed	.189	7	.027	1.403	.202
	Greenhouse-Geisser	.189	5.560	.034	1.403	.217
	Huynh-Feldt	.189	6.191	.031	1.403	.210
	Lower-bound	.189	1.000	.189	1.403	.240
Error(site)	Sphericity Assumed	9.305	483	.019		
	Greenhouse-Geisser	9.305	383.663	.024		
	Huynh-Feldt	9.305	427.210	.022		
	Lower-bound	9.305	69.000	.135		
time	Sphericity Assumed	.383	1	.383	16.687	.000
	Greenhouse-Geisser	.383	1.000	.383	16.687	.000
	Huynh-Feldt	.383	1.000	.383	16.687	.000
	Lower-bound	.383	1.000	.383	16.687	.000
time * condition	Sphericity Assumed	.174	1	.174	7.585	.008
	Greenhouse-Geisser	.174	1.000	.174	7.585	.008
	Huynh-Feldt	.174	1.000	.174	7.585	.008
	Lower-bound	.174	1.000	.174	7.585	.008
Error(time)	Sphericity Assumed	1.583	69	.023		
	Greenhouse-Geisser	1.583	69.000	.023		
	Huynh-Feldt	1.583	69.000	.023		
	Lower-bound	1.583	69.000	.023		
site * time	Sphericity Assumed	.049	7	.007	1.219	.291
	Greenhouse-Geisser	.049	4.852	.010	1.219	.300
	Huynh-Feldt	.049	5.339	.009	1.219	.298
	Lower-bound	.049	1.000	.049	1.219	.273
site * time * condition	Sphericity Assumed	.043	7	.006	1.062	.387
	Greenhouse-Geisser	.043	4.852	.009	1.062	.381
	Huynh-Feldt	.043	5.339	.008	1.062	.383
	Lower-bound	.043	1.000	.043	1.062	.306
Error(site*time)	Sphericity Assumed	2.764	483	.006		
	Greenhouse-Geisser	2.764	334.785	.008		
	Huynh-Feldt	2.764	368.393	.008		
	Lower-bound	2.764	69.000	.040		

Tests of Between-Subjects Effects

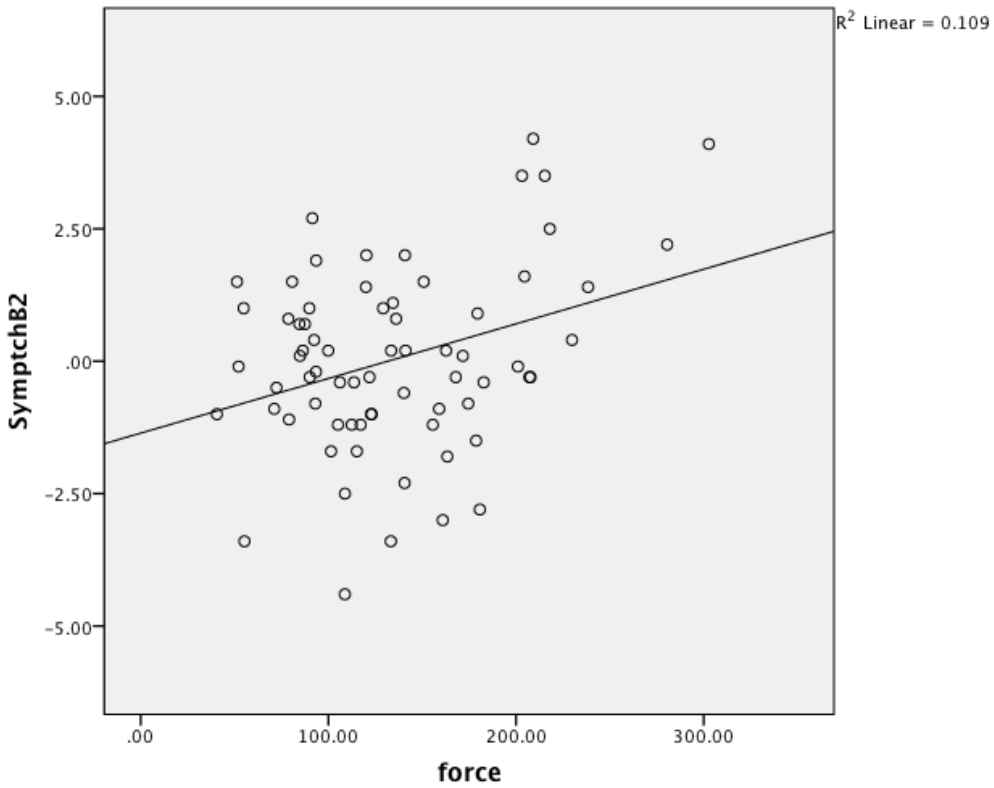
Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	482.814	1	482.814	1177.762	.000
condition	.012	1	.012	.028	.867
Error	28.286	69	.410		

Appendix 21

Stratified analysis for mediating effect of force on PPT at the symptomatic paravertebral level after treatment period 2



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.330[a]	.109	.096	1.64493	.109	8.318	1	68	.005

a. Predictors: (Constant), force

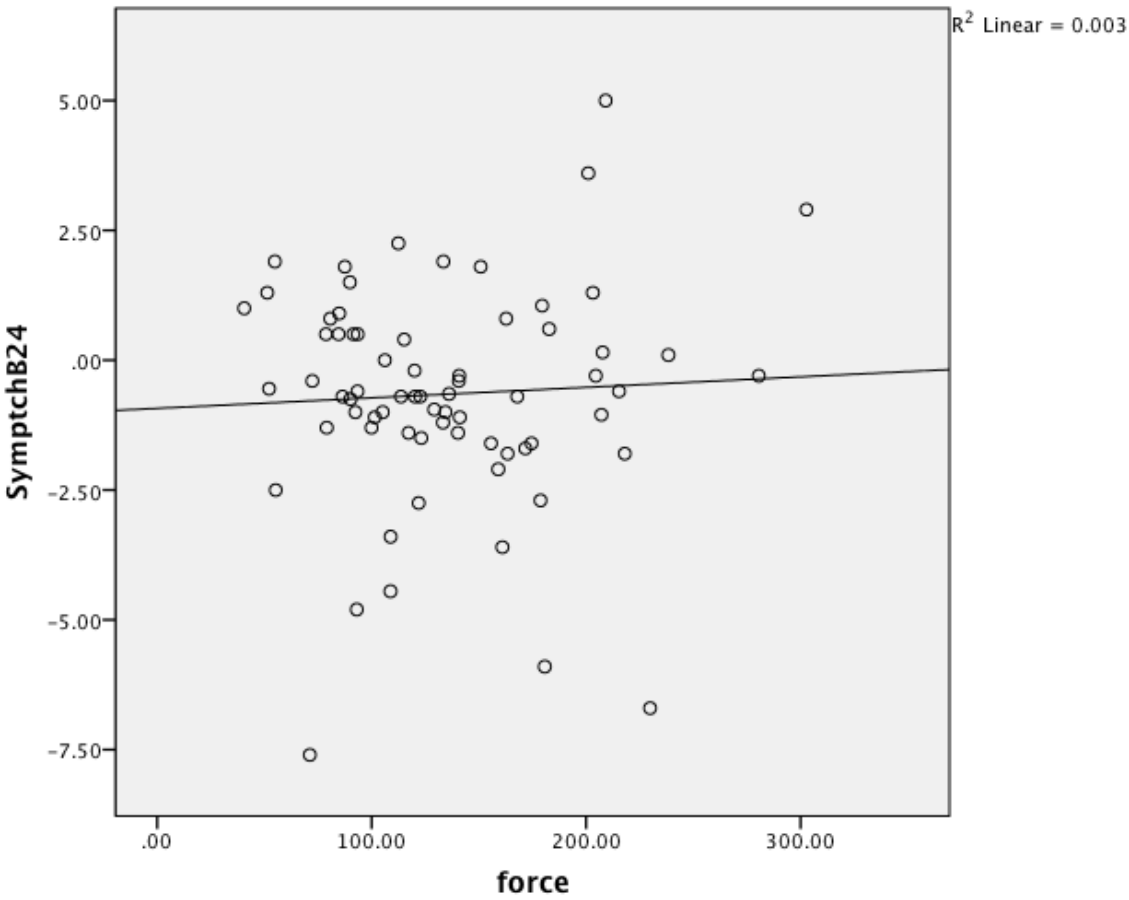
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.507	1	22.507	8.318	.005[b]
	Residual	183.993	68	2.706		
	Total	206.501	69			

a. Dependent Variable: SymptchB2

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on PPT at the symptomatic paravertebral level at 24 hour follow-up



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.302[a]	.091	.078	1.29292	.091	6.807	1	68	.011

a. Predictors: (Constant), force

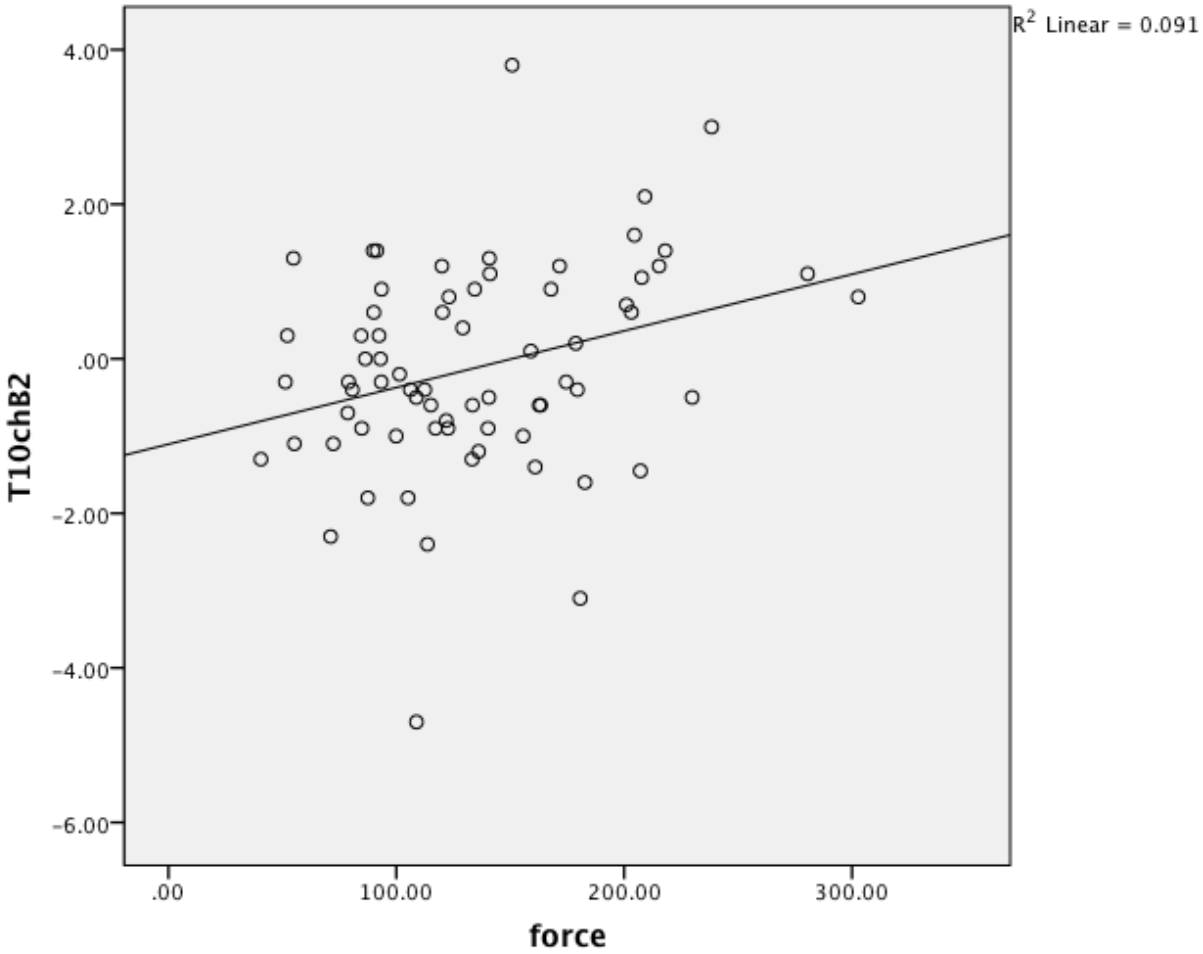
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.379	1	11.379	6.807	.011[b]
	Residual	113.671	68	1.672		
	Total	125.051	69			

a. Dependent Variable: T10chB2

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on PPT at the T10 paravertebral level after treatment period 2



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.052[a]	.003	-.012	2.14888	.003	.188	1	68	.666

a. Predictors: (Constant), force

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.867	1	.867	.188	.666[b]
	Residual	314.002	68	4.618		
	Total	314.869	69			

a. Dependent Variable: SymptchB24

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on PPT at the Deltoid muscle site after treatment period 2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.124[a]	.015	-.002	1.41325	.015	.881	1	56	.352

a. Predictors: (Constant), force

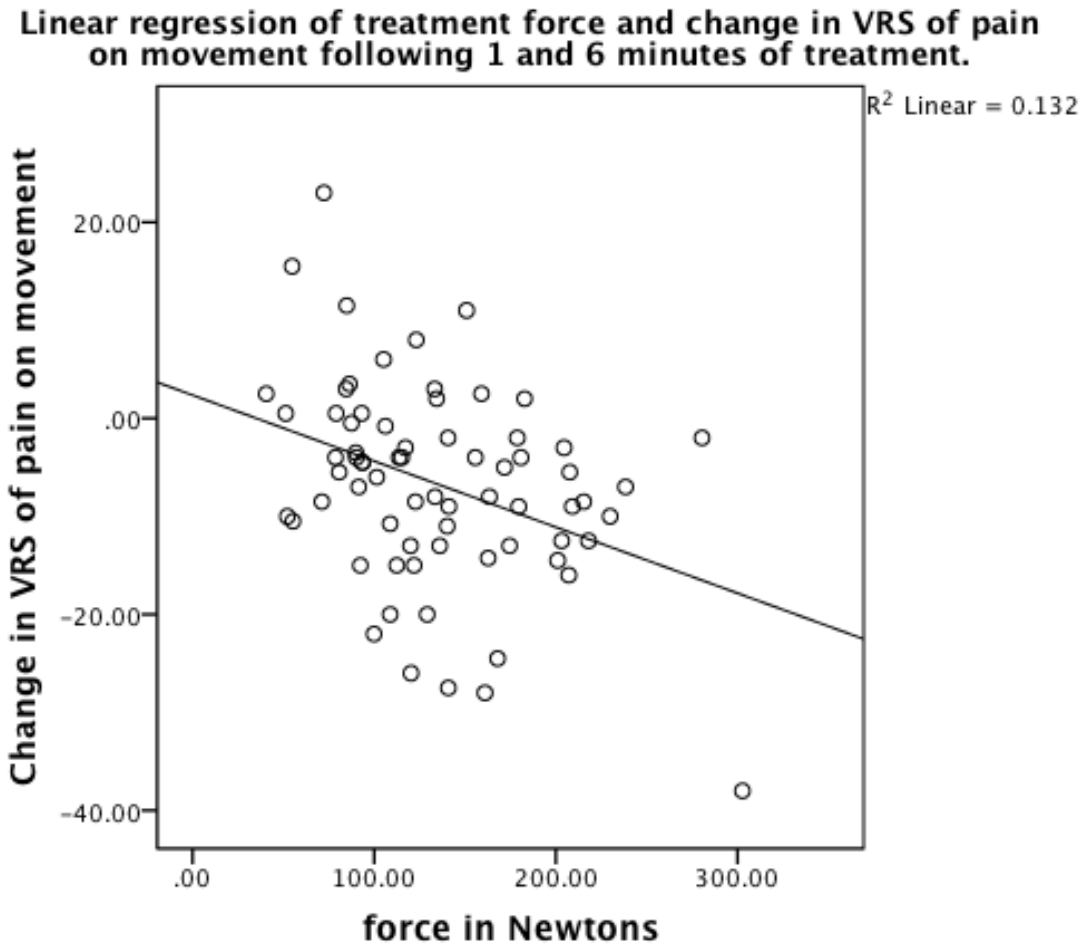
ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.760	1	1.760	.881	.352[b]
	Residual	111.847	56	1.997		
	Total	113.606	57			

a. Dependent Variable: DeltchB2

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on Verbal rating of pain on movement after treatment period 2



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.364[a]	.132	.120	9.61258

a. Predictors: (Constant), force

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	959.499	1	959.499	10.384	.002[b]
	Residual	6283.320	68	92.402		
	Total	7242.819	69			

a. Dependent Variable: ChangeVRSmvt

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on Verbal rating of pain on movement at 24 hour follow-up

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.245[a]	.060	.046	9.72957	.060	4.337	1	68	.041

a. Predictors: (Constant), force

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	410.528	1	410.528	4.337	.041[b]
	Residual	6437.187	68	94.665		
	Total	6847.714	69			

a. Dependent Variable: ChangeVRSmvt24

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on Verbal rating of pain on PA force application

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.109[a]	.012	-.003	1.58164	.012	.815	1	68	.370

a. Predictors: (Constant), force

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.039	1	2.039	.815	.370[b]
	Residual	170.107	68	2.502		
	Total	172.146	69			

a. Dependent Variable: ChangePA

b. Predictors: (Constant), force

Stratified analysis for mediating effect of force on Verbal rating of pain of resting pain

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.183[a]	.033	.019	1.47303

a. Predictors: (Constant), force

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.114	1	5.114	2.357	.129[b]
	Residual	147.548	68	2.170		
	Total	152.662	69			

a. Dependent Variable: ChangeRP

b. Predictors: (Constant), force

Appendix 22

ANOVA - VRS of pain on movement between baseline and after treatment period 1

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.767	1	.767	31.448	.000
	Greenhouse-Geisser	.767	1.000	.767	31.448	.000
	Huynh-Feldt	.767	1.000	.767	31.448	.000
	Lower-bound	.767	1.000	.767	31.448	.000
time * Condition	Sphericity Assumed	.002	1	.002	.073	.788
	Greenhouse-Geisser	.002	1.000	.002	.073	.788
	Huynh-Feldt	.002	1.000	.002	.073	.788
	Lower-bound	.002	1.000	.002	.073	.788
Error(time)	Sphericity Assumed	1.609	66	.024		
	Greenhouse-Geisser	1.609	66.000	.024		
	Huynh-Feldt	1.609	66.000	.024		
	Lower-bound	1.609	66.000	.024		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	.767	1	.767	31.448	.000
time * Condition	Linear	.002	1	.002	.073	.788
Error(time)	Linear	1.609	66	.024		

VRS of pain on movement between baseline and after treatment period 2

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	1.632	1	1.632	38.802	.000
	Greenhouse-Geisser	1.632	1.000	1.632	38.802	.000
	Huynh-Feldt	1.632	1.000	1.632	38.802	.000
	Lower-bound	1.632	1.000	1.632	38.802	.000
time * Condition	Sphericity Assumed	.056	1	.056	1.325	.254
	Greenhouse-Geisser	.056	1.000	.056	1.325	.254
	Huynh-Feldt	.056	1.000	.056	1.325	.254
	Lower-bound	.056	1.000	.056	1.325	.254
Error(time)	Sphericity Assumed	2.777	66	.042		
	Greenhouse-Geisser	2.777	66.000	.042		
	Huynh-Feldt	2.777	66.000	.042		
	Lower-bound	2.777	66.000	.042		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	1.632	1	1.632	38.802	.000
time * Condition	Linear	.056	1	.056	1.325	.254
Error(time)	Linear	2.777	66	.042		

VRS of pain on movement between baseline and 24-hour follow-up

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	1.517	1	1.517	48.266	.000
	Greenhouse-Geisser	1.517	1.000	1.517	48.266	.000
	Huynh-Feldt	1.517	1.000	1.517	48.266	.000
	Lower-bound	1.517	1.000	1.517	48.266	.000
time * Condition	Sphericity Assumed	.003	1	.003	.098	.755
	Greenhouse-Geisser	.003	1.000	.003	.098	.755
	Huynh-Feldt	.003	1.000	.003	.098	.755
	Lower-bound	.003	1.000	.003	.098	.755
Error(time)	Sphericity Assumed	1.949	62	.031		
	Greenhouse-Geisser	1.949	62.000	.031		
	Huynh-Feldt	1.949	62.000	.031		
	Lower-bound	1.949	62.000	.031		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	1.517	1	1.517	48.266	.000
time * Condition	Linear	.003	1	.003	.098	.755
Error(time)	Linear	1.949	62	.031		

Resting Pain 2-way mixed ANOVA between baseline and after treatment period 1

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.255	1	.255	.296	.588
	Greenhouse-Geisser	.255	1.000	.255	.296	.588
	Huynh-Feldt	.255	1.000	.255	.296	.588
	Lower-bound	.255	1.000	.255	.296	.588
time * condition	Sphericity Assumed	.339	1	.339	.393	.533
	Greenhouse-Geisser	.339	1.000	.339	.393	.533
	Huynh-Feldt	.339	1.000	.339	.393	.533
	Lower-bound	.339	1.000	.339	.393	.533
Error(time)	Sphericity Assumed	60.326	70	.862		
	Greenhouse-Geisser	60.326	70.000	.862		
	Huynh-Feldt	60.326	70.000	.862		
	Lower-bound	60.326	70.000	.862		

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	615.289	1	615.289	157.726	.000
condition	4.803	1	4.803	1.231	.271
Error	273.070	70	3.901		

Resting Pain 2-way mixed ANOVA between baseline and after treatment period 2

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.083	1	.083	.076	.784
	Greenhouse-Geisser	.083	1.000	.083	.076	.784
	Huynh-Feldt	.083	1.000	.083	.076	.784
	Lower-bound	.083	1.000	.083	.076	.784
time * condition	Sphericity Assumed	.044	1	.044	.041	.841
	Greenhouse-Geisser	.044	1.000	.044	.041	.841
	Huynh-Feldt	.044	1.000	.044	.041	.841
	Lower-bound	.044	1.000	.044	.041	.841
Error(time)	Sphericity Assumed	76.288	70	1.090		
	Greenhouse-Geisser	76.288	70.000	1.090		
	Huynh-Feldt	76.288	70.000	1.090		
	Lower-bound	76.288	70.000	1.090		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	.083	1	.083	.076	.784
time * condition	Linear	.044	1	.044	.041	.841
Error(time)	Linear	76.288	70	1.090		

Resting Pain 2-way mixed ANOVA between baseline and 24-hour follow-up

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	1.395	1	1.395	1.168	.284
	Greenhouse-Geisser	1.395	1.000	1.395	1.168	.284
	Huynh-Feldt	1.395	1.000	1.395	1.168	.284
	Lower-bound	1.395	1.000	1.395	1.168	.284
time * condition	Sphericity Assumed	.598	1	.598	.501	.482
	Greenhouse-Geisser	.598	1.000	.598	.501	.482
	Huynh-Feldt	.598	1.000	.598	.501	.482
	Lower-bound	.598	1.000	.598	.501	.482
Error(time)	Sphericity Assumed	83.652	70	1.195		
	Greenhouse-Geisser	83.652	70.000	1.195		
	Huynh-Feldt	83.652	70.000	1.195		
	Lower-bound	83.652	70.000	1.195		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	1.395	1	1.395	1.168	.284
time * condition	Linear	.598	1	.598	.501	.482
Error(time)	Linear	83.652	70	1.195		

Pain on PA force. 2-way mixed ANOVA between baseline to after treatment period 1.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.004	1	.004	.127	.723
	Greenhouse-Geisser	.004	1.000	.004	.127	.723
	Huynh-Feldt	.004	1.000	.004	.127	.723
	Lower-bound	.004	1.000	.004	.127	.723
time * condition	Sphericity Assumed	.008	1	.008	.241	.625
	Greenhouse-Geisser	.008	1.000	.008	.241	.625
	Huynh-Feldt	.008	1.000	.008	.241	.625
	Lower-bound	.008	1.000	.008	.241	.625
Error(time)	Sphericity Assumed	2.373	70	.034		
	Greenhouse-Geisser	2.373	70.000	.034		
	Huynh-Feldt	2.373	70.000	.034		
	Lower-bound	2.373	70.000	.034		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	.004	1	.004	.127	.723
time * condition	Linear	.008	1	.008	.241	.625
Error(time)	Linear	2.373	70	.034		

Pain on PA force. 2-way mixed ANOVA between baseline to after treatment period 2.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.001	1	.001	.014	.905
	Greenhouse-Geisser	.001	1.000	.001	.014	.905
	Huynh-Feldt	.001	1.000	.001	.014	.905
	Lower-bound	.001	1.000	.001	.014	.905
time * condition	Sphericity Assumed	.004	1	.004	.110	.741
	Greenhouse-Geisser	.004	1.000	.004	.110	.741
	Huynh-Feldt	.004	1.000	.004	.110	.741
	Lower-bound	.004	1.000	.004	.110	.741
Error(time)	Sphericity Assumed	2.490	70	.036		
	Greenhouse-Geisser	2.490	70.000	.036		
	Huynh-Feldt	2.490	70.000	.036		
	Lower-bound	2.490	70.000	.036		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	.001	1	.001	.014	.905
time * condition	Linear	.004	1	.004	.110	.741
Error(time)	Linear	2.490	70	.036		

Pain on PA force. 2-way mixed ANOVA between baseline to 24 hour follow-up.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	.042	1	.042	1.145	.288
	Greenhouse-Geisser	.042	1.000	.042	1.145	.288
	Huynh-Feldt	.042	1.000	.042	1.145	.288
	Lower-bound	.042	1.000	.042	1.145	.288
time * condition	Sphericity Assumed	.001	1	.001	.025	.874
	Greenhouse-Geisser	.001	1.000	.001	.025	.874
	Huynh-Feldt	.001	1.000	.001	.025	.874
	Lower-bound	.001	1.000	.001	.025	.874
Error(time)	Sphericity Assumed	2.596	70	.037		
	Greenhouse-Geisser	2.596	70.000	.037		
	Huynh-Feldt	2.596	70.000	.037		
	Lower-bound	2.596	70.000	.037		

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	time	Type III Sum of Squares	df	Mean Square	F	Sig.
time	Linear	.042	1	.042	1.145	.288
time * condition	Linear	.001	1	.001	.025	.874
Error(time)	Linear	2.596	70	.037		

Appendix 23

Global rating of perceived effect

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect after treatment period 1.

Correlations

			PPTchnage baserx1	GRPE
Spearman's rho	PPTchnage baserx1	Correlation Coefficient	1.000	.086
		Sig. (2-tailed)	.	.469
		N	73	73
	GRPE	Correlation Coefficient	.086	1.000
		Sig. (2-tailed)	.469	.
		N	73	73

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect after treatment period 2.

Correlations

			PPTChange baseRx2	GPRPE2
Spearman's rho	PPTChange baseRx2	Correlation Coefficient	1.000	.349**
		Sig. (2-tailed)	.	.002
		N	73	73
	GPRPE2	Correlation Coefficient	.349**	1.000
		Sig. (2-tailed)	.002	.
		N	73	73

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect at 24 hour follow-up.

Correlations

			PPTChange base24	GRPE24
Spearman's rho	PPTChange base24	Correlation Coefficient	1.000	.256*
		Sig. (2-tailed)	.	.030
		N	73	72
	GRPE24	Correlation Coefficient	.256*	1.000
		Sig. (2-tailed)	.030	.
		N	72	72

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect after treatment period 1.

Correlations

			VRSDiffBrx1	GRPE
Spearman's rho	VRSDiffBrx1	Correlation Coefficient	1.000	.083
		Sig. (2-tailed)	.	.489
		N	72	72
	GRPE	Correlation Coefficient	.083	1.000
		Sig. (2-tailed)	.489	.
		N	72	73

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect after treatment period 2.

Correlations

			VRmvtDiffbaseRx2	GPRPE2
Spearman's rho	VRmvtDiffbaseRx2	Correlation Coefficient	1.000	-.414**
		Sig. (2-tailed)	.	.000
		N	73	73
	GPRPE2	Correlation Coefficient	-.414**	1.000
		Sig. (2-tailed)	.000	.
		N	73	73

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect at 24 hour follow-up.

Correlations

			VRmvtDiffbase24	GRPE24
Spearman's rho	VRmvtDiffbase24	Correlation Coefficient	1.000	-.534**
		Sig. (2-tailed)	.	.000
		N	73	72
	GRPE24	Correlation Coefficient	-.534**	1.000
		Sig. (2-tailed)	.000	.
		N	72	72

Correlation between change in verbal rating of pain on application of PA force and Global Rating of Perceived Effect after treatment period 1.

Correlations

			GRPE	ChangePAB1
Spearman's rho	GRPE	Correlation Coefficient	1.000	-.269*
		Sig. (2-tailed)	.	.022
		N	73	73
	ChangePAB1	Correlation Coefficient	-.269*	1.000
		Sig. (2-tailed)	.022	.
		N	73	73

*. Correlation is significant at the 0.05 level (2-tailed).

Correlation between change in verbal rating of pain on application of PA force and Global Rating of Perceived Effect after treatment period 2

Correlations

			VRPAchnagebaserx2	GPRPE2
Spearman's rho	VRPAchnagebaserx2	Correlation Coefficient	1.000	-.219
		Sig. (2-tailed)	.	.063
		N	73	73
	GPRPE2	Correlation Coefficient	-.219	1.000
		Sig. (2-tailed)	.063	.
		N	73	73

Correlation between change in verbal rating of pain on application of PA force and Global Rating of Perceived Effect at 24 hour follow-up

Correlations

			ChangePAbase24	GRPE24
Spearman's rho	ChangePAbase24	Correlation Coefficient	1.000	-.480**
		Sig. (2-tailed)	.	.000
		N	73	72
	GRPE24	Correlation Coefficient	-.480**	1.000
		Sig. (2-tailed)	.000	.
		N	72	72

Correlation between change in verbal rating of resting pain and Global Rating of Perceived Effect after treatment period 1

Correlations

			Change RPB1	GRPE
Spearman's rho	Change RPB1	Correlation Coefficient	1.000	-.321**
		Sig. (2-tailed)	.	.006
		N	73	73
	GRPE	Correlation Coefficient	-.321**	1.000
		Sig. (2-tailed)	.006	.
		N	73	73

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between change in verbal rating of resting pain and Global Rating of Perceived Effect after treatment period 2

Correlations

			RestingPcahngebaseRx2	GPRPE2
Spearman's rho	RestingPcahngebaseRx2	Correlation Coefficient	1.000	-.341**
		Sig. (2-tailed)	.	.003
		N	73	73
	GPRPE2	Correlation Coefficient	-.341**	1.000
		Sig. (2-tailed)	.003	.
		N	73	73

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between change in verbal rating of resting pain and Global Rating of Perceived Effect at 24 hour follow-up

Correlations

			ChnageRPB24	GRPE24
Spearman's rho	ChnageRPB24	Correlation Coefficient	1.000	-.235*
		Sig. (2-tailed)	.	.047
		N	73	72
	GRPE24	Correlation Coefficient	-.235*	1.000
		Sig. (2-tailed)	.047	.
		N	72	72

*. Correlation is significant at the 0.05 level (2-tailed).

Analysis for Global Rating of Perceived Change

Group Statistics

	condition	N	Mean	Std. Deviation	Std. Error Mean
GRPE1	1.00	34	.6765	1.74026	.29845
	2.00	38	.5132	1.72614	.28002
GRPE2	1.00	34	.6103	2.22179	.38103
	2.00	38	.8289	1.69768	.27540
GRPE24	1.00	34	1.2647	1.93546	.33193
	2.00	37	1.1757	1.80745	.29714

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
GRPE1	Equal variances assumed	.622	.433	.399	70	.691	.16331	.40906	-.65253	.97916
	Equal variances not assumed			.399	68.990	.691	.16331	.40925	-.65312	.97974
GRPE2	Equal variances assumed	3.864	.053	-.472	70	.638	-.21865	.46323	-1.14253	.70523
	Equal variances not assumed			-.465	61.512	.644	-.21865	.47014	-1.15860	.72129
GRPE24	Equal variances assumed	.608	.438	.200	69	.842	.08903	.44420	-.79712	.97518
	Equal variances not assumed			.200	67.404	.842	.08903	.44550	-.80009	.97815

Correlations between GRPC and pain measures

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect after treatment period 1.

Correlations

			PPTchnage baserx1	GRPE
Spearman's rho	PPTchnage baserx1	Correlation Coefficient	1.000	.271
		Sig. (2-tailed)	.	.121
		N	34	34
	GRPE	Correlation Coefficient	.271	1.000
		Sig. (2-tailed)	.121	.
		N	34	34

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect after treatment period 1.

Correlations

			GRPE	VRSDiffBrx1
Spearman's rho	GRPE	Correlation Coefficient	1.000	.057
		Sig. (2-tailed)	.	.748
		N	34	34
	VRSDiffBrx1	Correlation Coefficient	.057	1.000
		Sig. (2-tailed)	.748	.
		N	34	34

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect after treatment period 2.

Correlations

			PPTchnage baserx1	GRPE
Spearman's rho	PPTchnage baserx1	Correlation Coefficient	1.000	-.065
		Sig. (2-tailed)	.	.692
		N	39	39
	GRPE	Correlation Coefficient	-.065	1.000
		Sig. (2-tailed)	.692	.
		N	39	39

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect after treatment period 2.

Correlations

			GRPE	VRSDiffBrx1
Spearman's rho	GRPE	Correlation Coefficient	1.000	.143
		Sig. (2-tailed)	.	.391
		N	39	38
	VRSDiffBrx1	Correlation Coefficient	.143	1.000
		Sig. (2-tailed)	.391	.
		N	38	38

Correlation between change in PPT at the symptomatic level and Global Rating of Perceived Effect at 24 hour follow-up.

Correlations

			PPTChange base24	GRPE24
Spearman's rho	PPTChange base24	Correlation Coefficient	1.000	.256*
		Sig. (2-tailed)	.	.030
		N	73	72
	GRPE24	Correlation Coefficient	.256*	1.000
		Sig. (2-tailed)	.030	.
		N	72	72

*. Correlation is significant at the 0.05 level (2-tailed).

Correlation between change in verbal rating of pain on movement and Global Rating of Perceived Effect at 24 hour follow-up.

Correlations

			VRmvtDiff base24	GRPE24
Spearman's rho	VRmvtDiff base24	Correlation Coefficient	1.000	-.534**
		Sig. (2-tailed)	.	.000
		N	73	72
	GRPE24	Correlation Coefficient	-.534**	1.000
		Sig. (2-tailed)	.000	.
		N	72	72

Appendix 24
Correlation between pain measures at baseline

Correlations

					sympB	VRSuntransB	PPB	PAB
Spearman's rho	sympB	Correlation Coefficient			1.000	.091	-.013	-.194
		Sig. (2-tailed)			.	.448	.917	.102
		N			72	72	72	72
		Bootstrap[c]	Bias		.000	.001	-.014	-.005
			Std. Error		.000	.118	.123	.123
			95% Confidence Interval	Lower	1.000	-.153	-.269	-.425
				Upper	1.000	.315	.216	.038
	VRSuntransB	Correlation Coefficient			.091	1.000	.258*	.149
		Sig. (2-tailed)			.448	.	.029	.212
		N			72	72	72	72
		Bootstrap[c]	Bias		.001	.000	-.008	-.009
			Std. Error		.118	.000	.119	.127
			95% Confidence Interval	Lower	-.153	1.000	-.002	-.115
				Upper	.315	1.000	.489	.387
	PPB	Correlation Coefficient			-.013	.258*	1.000	.268*
		Sig. (2-tailed)			.917	.029	.	.023
		N			72	72	72	72
		Bootstrap[c]	Bias		-.014	-.008	.000	.002
			Std. Error		.123	.119	.000	.122
			95% Confidence Interval	Lower	-.269	-.002	1.000	.015
				Upper	.216	.489	1.000	.491
	PAB	Correlation Coefficient			-.194	.149	.268*	1.000
		Sig. (2-tailed)			.102	.212	.023	.
		N			72	72	72	72
		Bootstrap[c]	Bias		-.005	-.009	.002	.000
			Std. Error		.123	.127	.122	.000
			95% Confidence Interval	Lower	-.425	-.115	.015	1.000
				Upper	.038	.387	.491	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlation between pain measures after treatment period 1

Correlations

					sympt1	VRSuntrans1	PP1	PA1
Spearman's rho	sympt1	Correlation Coefficient			1.000	.010	.026	-.245*
		Sig. (2-tailed)			.	.932	.825	.038
		N			72	72	72	72
		Bootstrap[c]	Bias		.000	.006	.004	.006
			Std. Error		.000	.119	.116	.117
			95% Confidence Interval	Lower	1.000	-.210	-.205	-.455
				Upper	1.000	.250	.261	.001
	VRSuntrans1	Correlation Coefficient			.010	1.000	.329**	.314**
		Sig. (2-tailed)			.932	.	.005	.007
		N			72	72	72	72
		Bootstrap[c]	Bias		.006	.000	-.004	-.006
			Std. Error		.119	.000	.128	.115
			95% Confidence Interval	Lower	-.210	1.000	.056	.085
				Upper	.250	1.000	.561	.523
	PP1	Correlation Coefficient			.026	.329**	1.000	.551**
		Sig. (2-tailed)			.825	.005	.	.000
		N			72	72	72	72
		Bootstrap[c]	Bias		.004	-.004	.000	-.006
			Std. Error		.116	.128	.000	.091
			95% Confidence Interval	Lower	-.205	.056	1.000	.354
				Upper	.261	.561	1.000	.707
	PA1	Correlation Coefficient			-.245*	.314**	.551**	1.000
		Sig. (2-tailed)			.038	.007	.000	.
		N			72	72	72	72
		Bootstrap[c]	Bias		.006	-.006	-.006	.000
			Std. Error		.117	.115	.091	.000
			95% Confidence Interval	Lower	-.455	.085	.354	1.000
				Upper	.001	.523	.707	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlation between pain measures after treatment period 2

Correlations

					sympt2	VRSuntrans2	PP2	PA2
Spearman's rho	sympt2	Correlation Coefficient			1.000	.002	-.208	-.280*
		Sig. (2-tailed)			.	.987	.080	.017
		N			72	72	72	72
		Bootstrap[c]	Bias		.000	.007	.007	.007
			Std. Error		.000	.123	.121	.126
			95% Confidence Interval	Lower	1.000	-.230	-.432	-.509
				Upper	1.000	.251	.049	-.034
	VRSuntrans2	Correlation Coefficient			.002	1.000	.331**	.331**
		Sig. (2-tailed)			.987	.	.005	.005
		N			72	72	72	72
		Bootstrap[c]	Bias		.007	.000	-.002	-.003
			Std. Error		.123	.000	.125	.115
			95% Confidence Interval	Lower	-.230	1.000	.083	.097
				Upper	.251	1.000	.562	.548
	PP2	Correlation Coefficient			-.208	.331**	1.000	.395**
		Sig. (2-tailed)			.080	.005	.	.001
		N			72	72	72	72
		Bootstrap[c]	Bias		.007	-.002	.000	-.001
			Std. Error		.121	.125	.000	.108
			95% Confidence Interval	Lower	-.432	.083	1.000	.168
				Upper	.049	.562	1.000	.592
	PA2	Correlation Coefficient			-.280*	.331**	.395**	1.000
		Sig. (2-tailed)			.017	.005	.001	.
		N			72	72	72	72
		Bootstrap[c]	Bias		.007	-.003	-.001	.000
			Std. Error		.126	.115	.108	.000
			95% Confidence Interval	Lower	-.509	.097	.168	1.000
				Upper	-.034	.548	.592	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between pain measures at 24-hour follow-up

Correlations

					sympt24	VRSutrans24	PP24	PA24
Spearman's rho	sympt24	Correlation Coefficient			1.000	-.002	-.022	-.248*
		Sig. (2-tailed)			.	.985	.853	.037
		N			71	71	71	71
		Bootstrap[c]	Bias		.000	-.005	.001	.002
			Std. Error		.000	.123	.131	.117
			95% Confidence Interval	Lower	1.000	-.254	-.285	-.466
				Upper	1.000	.231	.228	-.004
	VRSutrans24	Correlation Coefficient			-.002	1.000	.166	.319**
		Sig. (2-tailed)			.985	.	.166	.007
		N			71	71	71	71
		Bootstrap[c]	Bias		-.005	.000	-.002	-.004
			Std. Error		.123	.000	.126	.118
			95% Confidence Interval	Lower	-.254	1.000	-.091	.075
				Upper	.231	1.000	.398	.555
	PP24	Correlation Coefficient			-.022	.166	1.000	.105
		Sig. (2-tailed)			.853	.166	.	.385
		N			71	71	71	71
		Bootstrap[c]	Bias		.001	-.002	.000	.000
			Std. Error		.131	.126	.000	.127
			95% Confidence Interval	Lower	-.285	-.091	1.000	-.149
				Upper	.228	.398	1.000	.347
	PA24	Correlation Coefficient			-.248*	.319**	.105	1.000
		Sig. (2-tailed)			.037	.007	.385	.
		N			71	71	71	71
		Bootstrap[c]	Bias		.002	-.004	.000	.000
			Std. Error		.117	.118	.127	.000
			95% Confidence Interval	Lower	-.466	.075	-.149	1.000
				Upper	-.004	.555	.347	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlations between PPT and VRS in Treatment Responders

Correlations

			PPTChangebaseRx2	VRmvtDiffbaseRx2
Spearman's rho	PPTChangebaseRx2	Correlation Coefficient	1.000	-.314
		Sig. (2-tailed)	.	.063
		N	36	36
	VRmvtDiffbaseRx2	Correlation Coefficient	-.314	1.000
		Sig. (2-tailed)	.063	.
		N	36	36

Correlations

			PPTChangebaseRx2	RestingPcahngebaseRx2
Spearman's rho	PPTChangebaseRx2	Correlation Coefficient	1.000	-.084
		Sig. (2-tailed)	.	.627
		N	36	36
	RestingPcahngebaseRx2	Correlation Coefficient	-.084	1.000
		Sig. (2-tailed)	.627	.
		N	36	36

Correlations

			PPTChangebaseRx2	VRPAchnagebaserx2
Spearman's rho	PPTChangebaseRx2	Correlation Coefficient	1.000	-.222
		Sig. (2-tailed)	.	.194
		N	36	36
	VRPAchnagebaserx2	Correlation Coefficient	-.222	1.000
		Sig. (2-tailed)	.194	.
		N	36	36

Appendix 25

Chi –square analysis for PPT responders based on SEM/ MDC

placebo v 2 minutes of treatment * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
placebo v 2 minutes of treatment	Placebo	Count	7	26	33
		Expected Count	8.3	24.8	33.0
		Std. Residual	-.4	.3	
	2 minutes of treatment	Count	11	28	39
		Expected Count	9.8	29.2	39.0
		Std. Residual	.4	-.2	
Total		Count	18	54	72
		Expected Count	18.0	54.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.466[a]	1	.495		
Continuity Correction[b]	.168	1	.682		
Likelihood Ratio	.470	1	.493		
Fisher's Exact Test				.590	.343
Linear-by-Linear Association	.460	1	.498		
N of Valid Cases	72				

1 minute v 6 minutes of treatment * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
1 minute v 6 minutes of treatment	short duration	Count	5	28	33
		Expected Count	11.9	21.1	33.0
		Std. Residual	-2.0	1.5	
	long duration	Count	21	18	39
		Expected Count	14.1	24.9	39.0
		Std. Residual	1.8	-1.4	
Total		Count	26	46	72
		Expected Count	26.0	46.0	72.0

hi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	11.601[a]	1	.001		
Continuity Correction[b]	9.984	1	.002		
Likelihood Ratio	12.278	1	.000		
Fisher's Exact Test				.001	.001
Linear-by-Linear Association	11.440	1	.001		
N of Valid Cases	72				

Duration of treatment at 24 hours * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
Duration of treatment at 24 hours	short durationof treatment	Count	5	28	33
		Expected Count	7.8	25.2	33.0
		Std. Residual	-1.0	.6	
	long duration of treatment	Count	12	27	39
		Expected Count	9.2	29.8	39.0
		Std. Residual	.9	-.5	
Total		Count	17	55	72
		Expected Count	17.0	55.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.417[a]	1	.120		
Continuity Correction[b]	1.629	1	.202		
Likelihood Ratio	2.487	1	.115		
Fisher's Exact Test				.166	.100
Linear-by-Linear Association	2.384	1	.123		
N of Valid Cases	72				

Chi –square analysis for responders based on percentage change in PPT

placebo v 2 minutes of treatment * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
placebo v 2 minutes of treatment	Placebo	Count	4	29	33
		Expected Count	6.4	26.6	33.0
		Std. Residual	-1.0	.5	
	2 minutes of treatment	Count	10	29	39
		Expected Count	7.6	31.4	39.0
		Std. Residual	.9	-.4	
Total		Count	14	58	72
		Expected Count	14.0	58.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.086[a]	1	.149		
Continuity Correction[b]	1.312	1	.252		
Likelihood Ratio	2.156	1	.142		
Fisher's Exact Test				.232	.126
Linear-by-Linear Association	2.057	1	.152		
N of Valid Cases	72				

1 minute v 6 minutes of treatment * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
1 minute v 6 minutes of treatment	short duration	Count	4	29	33
		Expected Count	10.5	22.5	33.0
		Std. Residual	-2.0	1.4	
	long duration	Count	19	20	39
		Expected Count	12.5	26.5	39.0
		Std. Residual	1.9	-1.3	
Total		Count	23	49	72
		Expected Count	23.0	49.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	11.012[a]	1	.001		
Continuity Correction[b]	9.393	1	.002		
Likelihood Ratio	11.793	1	.001		
Fisher's Exact Test				.001	.001
Linear-by-Linear Association	10.859	1	.001		
N of Valid Cases	72				

Duration of treatment at 24 hours * Response to treatment Crosstabulation

			Response to treatment		Total
			responder	non-responder	
Duration of treatment at 24 hours	short duration of treatment	Count	5	28	33
		Expected Count	8.3	24.8	33.0
		Std. Residual	-1.1	.7	
	long duration of treatment	Count	13	26	39
		Expected Count	9.8	29.2	39.0
		Std. Residual	1.0	-.6	
Total		Count	18	54	72
		Expected Count	18.0	54.0	72.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.152[a]	1	.076		
Continuity Correction[b]	2.256	1	.133		
Likelihood Ratio	3.256	1	.071		
Fisher's Exact Test				.103	.065
Linear-by-Linear Association	3.108	1	.078		
N of Valid Cases	72				

Chi –square analysis for responders based on change in Verbal rating of pain on movement

RespondVRS * Longshort Crosstabulation

Count

		Longshort		Total
		1.00	2.00	
RespondVRS	1.00	25	28	53
	2.00	8	9	17
Total		33	37	70

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.000[a]	1	.994		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.000	1	.994		
Fisher's Exact Test				1.000	.608
Linear-by-Linear Association	.000	1	.994		
N of Valid Cases	70				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.01.

b. Computed only for a 2x2 table

Chi Square analysis of expectations of responders

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
respnonresp * expectations	72	100.0%	0	0.0%	72	100.0%

respnonresp * expectations Crosstabulation

Count

		expectations			Total
		.00	1.00	2.00	
respnonresp	1.00	16	16	3	35
	2.00	20	14	3	37
Total		36	30	6	72

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.523[a]	2	.770
Likelihood Ratio	.523	2	.770
Linear-by-Linear Association	.335	1	.562
N of Valid Cases	72		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.92.

Appendix 26. Questionnaire analysis

Expectations of mobilisation treatment		
Positive	neutral	Low
4, 9, 10, 17, 18, 19, 21, 23, 24, 25, 27, 28, 29, 30, 32, 35, 36, 38, 39, 44, 47, 49, 53, 57, 61, 65, 66, 68, 72, 16	2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14,15, 20, 22, 26, 31, 33, 34, 37, 40, 42, 43, 45, 46, 48, 50, 51, 54, 55, 59, 60, 63, 64, 70, 71	1, 16, 37, 41, 52, 58, 67, 69
=30	=34	=8

Expectations of treatment				
Reduce pain	Increased ROM	Reduced pressure/stiffness tension/ stretching	Identify source of symptoms	Short term effect
10, 17, 18, 19, 21, 24, 25, 27, 29, 30, 32, 35, 38, 44, 47, 58, 61, 66, 68, 73	9, 10, 17, 24, 27, 32, 36, 49	4, 8, 20, 23, 29	3, 7, 21, 22, 33, 35, 48, 54, 55	1, 27, 44
=20	=8	=5	=9	=3

Expectations of Pain during treatment		
Low expect of outcome	Expect to then improve	Kill or cure
37, 41, 69	49, 61	51, 54
=3	=2	=2

Expected more complex treatment – 5, 8, 50, 67,11,17, 25, 27, 41.

Experience of mobilisation treatment					
Painful treatment	Reducing pain during treatment	Painful during better after	Increased pain / tightness after	Reduced pain	Sore immediately after then better
4, 5, 7, 14, 19, 23, 24, 28, 32, 38, 39, 46 48, 52, 54, 65, 68, 70, 71, 16	14, 29, 36, 44, 58, 61, 64, 73	4, 8, 14, 27, 29, 36, 88, 61, 65	17, 23, 29, 31, 33, 35, 42, 43, 60, 64	1, 3, 7, 8, 10, 11, 19, 20, 21, 27, 38, 44, 46, 52, 58, 61, 69, 71, 72	27, 28
=20	=8	=9	=10	=19	=2

Perceived beneficial effects of mobilisation treatment			
Reduced stiffness	Reduced pressure/ tightness	Increased movement	“improvement” effective
7, 12, 19	3, 6, 8	1, 8, 10, 14, 16, 20, 27, 28, 49, 55, 16	1, 12, 13, 18, 25, 26, 34, 36, 37, 39, 43, 44, 46, 63, 67
=3	=3	=11	=15

Perceived effects of mobilisation treatment			
Minimal effect	Short term relief	Not sure	None
2, 5, 48, 50, 66, 68	22, 23, 24, 32, 44, 45, 47, 57	29, 33, 46, 50, 33, 58, 65, 68, 70, 72	15, 18, 40, 41, 52, 59
=6	=8	=10	=6

Comfortable 33, uncomfortable 13

Relaxing: 4, 18, 25, 27, 28, 34, 36, 43, 50, 64, 65, 69

Commented on PPT: 7, 9, 33, 40, 60,

Have you had previous experience of receiving this mobilisation technique. Please describe any previous mobilisations that you have had.		
No. But, I have had physio on my back using different techniques: ITB release, stretching programme and IR lamp. P1		Previous Rx not mobilisations Stretching Electrotherapy
No P2		
No P3		
No P4		
No P5		
No. General massage at Physiotherapists P6		Massage
No P7		
No P8		
Yes – Previous physiotherapy when my back has gone into spasm P9		Mobilisations
Yes: Osteopathy, chiropractor and Physiotherapy P10		Mobilisations Chiro/osteo
No – being pulled about by a chiropractor P11		'Pulled about' chiro
No P12		
No P13		
No P14		
No P15		
No P17		
No P18		
I had approximately 3 years of osteopathy P19		Osetopath
No P20		
No P21		
No P22		
Yes, 2 years ago I went to a chiropractor for the first time for 3 sessions P23		Chiro did
No P24		
No, Mobility drills pre exercise P25		Home exercises
Yes, Kneading, needling of lower back from previous physio treatments, specific stretching to prevent pain P26		Massage Acupuncture Stretching
No P26		
No P27		
No P28		
No. I have had some mobilisation on my upper back by an osteopath, but mostly manipulation of thoracic spine. As a physio student I have had other students practicing on me P29		Mobilisation and manip Osteopath PT student experience
No Sacroiliac manipulation P30		Manip
No, only with the osteopath, but not the same P31		Osteopath
Similar mobilisations in lecture as Physio student P32		PT student – not as patient
No P33		
No – introduction to alexander technique P34		Alexander technique
No P35		
Yes, I had mobilisation technique on both lumbar and cervical spine, from prone, same as this one P36		Mobilisations
No P37		
No P38		
No P39		

Back manipulation through osteopath, massage and physio exercise stretching P40		Manip osteo Massage and stretching physio
No. chiropractor intervention, osteopathic treatment P41		Chiro/oseto
No manipulation by osteopath P42		
No P43		Osteo
No P44		
Yes P45		
No P46		
No P47		
No P48		
Yes, have had previous treatment to neck and upper back P49		Mobilisations
No P50		
No P51		
No 52 when I had my car accident, manipulation on my back and top of my spine. In the early days of my back injury I was placed in certain positions and my body was pressed down on and my back creaked sometimes.		Mobilisations and manipulation
P53 No		
No P54		
No P55		Massage
Sports massage P57		
No P58		
No P59		
No P60		
Yes. I am a physiotherapist so I have had experience of mobilisation technique being applied to me. I never had any previous experience of receiving mobilisation technique as a treatment. P61		Is a Physio. Had mobs but not as a patient
No P63		
No P4		
Yes, massage to the sides of my back P65		Massage
No P66		
No P67		
No P68		
NoP69		
NoP70		
No P71		
Yes. A physio applied pressure /massage to several specific points on my back (until it felt numbed) if not the mobilisation technique it was similar. P72		Physio mobilisations
NoP73		
Yes, I have had experience as a physiotherapist of applying mobilisations. I have also received treatment using mobilisations by another therapist. P74		Is a Physio has received mob as a patient
What were you expecting from having this 'mobilisation technique' applied on this occasion?		
Low expectation due to previous treatment being either ineffective or only of short term benefit. P1	-ve	Low expectation Previous Rx ineffective Short term
I wasn't sure what to expect, other than just measuring and assessing the level of pain rather than any treatment P2	neut	Unformed expectations. Monitoring of pain expected
I expected that the pain/problem would be identified first. When this was done, I assumed the 'mobilisation technique' would then be applied to the specific targeted where the pain originates from. P3	Neut	ID location of pain. Rx targeted at problem area
That it would release pressure and tension in my lower	+ve	

back P4		Reduce pressure/tension
I did not expect it to cure my back pain, but understood that it was part of a scientific study. P5	neut	Not expected to help
I expected maybe a little more twisting of my back P5	neut	Expected more vigorous Rx
No expectations, completely open-minded P6	neut	Unformed expec
Expected to locate the location of the pain and to see what movements caused the pain to happen P7	neut	Expected to ID location of pain
Was expecting a release of pressure and pain from my lower back. I was also expecting the mobilisation technique to be more complex (more involvement from the physio) as it seems quite a simple exercise (i.e. applying pressure to the sore point). P8	Neut	Reduced pressure experienced Expected more complex rx
To give me increased movement P9	+ve	Increased movement
Reduction in discomfort and better movement and better strength P10	+ve	Increased movement Reduced pain
No idea what to expect P11	neut	Unformed
Not sure what I was expecting P12	neut	Unformed
I really didn't know as I wasn't aware of which technique would be applied P13	neut	Unformed
No expectations P14	neut	Unformed
Was not expecting anything P15	neut	Unformed
Relief from the pain and increase in movement in my lower back P17	+ve	Increased movement reduced pain
Hopefully relief from the discomfort P18	+ve	Reduced pain
Hopefully that it may help alleviate some of the discomfort I experience. Also to gain advice about strategies that may help in the future P19	+ve	Reduced pain Advice for the future
I was unsure exactly what to expect. I suppose a degree of stretching was expected, however, the technique used was different to anything I have had in previous treatments P20	Neut	Unformed Stretching
Find out where problem is and hopefully establish method for maintaining decreased pain P21	+ve	Identify problem Reduced pain long term
Didn't know what to expect really, thought it might be more like making my spine do a range of movements, rather than pushing on spine P22	Neut	Expected more complex technique
I wanted to see if this technique would give some release to the tightness of my lower back P23	+ve	Reduced tightness
Ease in pain, enable movement to become more comfortable. Loosen my back which feels tight P24	+ve	Loosen back Reduce pain
Pain relief P25	+ve	Reduced pain
Different techniques from what I experienced previously to treatment of lower back pain P26	neut	
Perhaps relief of symptoms of LBP, with an increased range of movement. I did not expect full recovery given just one treatment and the fact the pain is intermittent at times P27.	+ve	Reduced pain Increase movement Short term effect
Ideally some level of pain relief or increased movement.		Reduced pain

To possibly learn more about how to manage my back pain/what therapy to pursue. P28	+ve	Increased movement Long term strategy
That it would reduce the feelings of stiffness and discomfort in my lower back P29	+ve	Reduce pain Reduced stiffness
To reduce the symptoms of long term back pain P30	+ve	Reduced pain
Unsure P31	Neut	
Slight reduction in pain, slight increase in mobility P32	+ve	Reduced pain Increased movement
I expected concentration on upper legs and gluts opposed to knee/foot. I expected to understand the source of my pain more and have it surface more prominently P33	neut	Low expect Understand s of s
No expectations P34	neut	
The reason for my pain to be identified. Treatment of my pain P35	+ve	Understand reason for pain Reduced pain
I'd like to start to move better and I think with mobilisations and my trying, I can achieve that P36	+ve	Increased movement
Expecting to feel a lot of pain when pressure applied. Didn't expect that it would have much effect P37	-ve	Expecting to feel pain Low expectations
I was expecting this technique to have some sort of heavy pressure been applied to my back. Overall I expected this technique to relieve some of the pain P38	+ve	Reduced pain
That it would help relieve some of my back pain P39	+ve	Reduced pain
Some analysis between previous results P40	Neut	
To experience pain. To help find causation of back troubles P41	-ve	Find s of s Expected treatment to be painful
I didn't have any expectations P42	Neut	
I wasn't sure at all what it would be like P43	Neut	
Brief and mild alleviation of back pain. Not lasting, short term fix P44	+ve	Reduced pain Short term
No expectations P45	Neu	
Don't know P46	Neut	
Help with pain P47	+ve	Reduced pain
To find the area of the body that would help in identifying the problem of pain P48	Neut	Find s of s
To expect some discomfort as pressure is applied but to hopefully achieve freer movement after P49	+ve	Painful Rx Increased movement
I thought there might be more pressure involved P50	Neut	More pressure
No real expectations but I assumed it might either hurt a lot, make a boney noise or solve the situation, either kill or cure P51	Neut	Kill or cure Pain and clicking
I was surprised at the technique. I have never had this done before. I did not quite know what to expect. I did expect pain to come at some threshold. P52	-ve	Expected painful Rx
Pain relief P53	+ve	pain relief
To find exactly where the point of the pain is and increase it or decrease it P54	Neut	find s of s increase or decrease pain

To find the cause of my discomfort P55	Neut	find s of s decreased pain
Less pain P57	+ve	painful rx
A degree of pain/tenderness in my lower back P58	-ve	
Wasn't sure what to expect P59	neut	
Not sure what to expect P60	Neut	
I was expecting to have reduction of my back pain. I was also expecting to experience some pain during the application of the technique P61	+ve	Reduced pain but pain during technique
I had no expectations regarding either the technique or the outcomes P63	neut	
Didn't really give it a thought, just thought it was part of the test P64	neut	
In the beginning I expected to relax me or stop any pain, but when the technique was applied it felt uncomfortable like it was the cause of the pain P65	+ve	+ve expect / -ve experience. Didn't expect painful rx
Pain relief P66	+ve	Pain relief
I couldn't possibly imagine a simple movement could prevent the pains I have been sustaining P67	-ve	More complex technique
I am hoping that the findings from this will help me with the pain in my back eventually going P68	+ve	Reduced pain
That I would not relax during the technique, therefore feel anxious about having pressure applied in the area. I was expecting the technique to increase the pain slightly P69	-ve	To feel anxious Painful rx
I didn't know what to expectP70	neut	
The second time when asked to bend backwards I did not feel the pain in my low back P71	neut	
For the muscle area to feel malleable (and warm) after a while P72	+ve	to feel warm
Relief from pain P73	+ve	Pain relief
I was expecting a force to be applied to a segment of my spine in a specified direction and for my pain to be replicated. I was then expecting this symptomatic segment to be repeatedly mobilised for a set duration P74	neut	Physio known expectation
Was there anything that you didn't expect about the mobilisation technique? If so, what happened that you didn't expect?		
I had no real preconceptions and an open mind, so nothing that I didn't expect really. My only observations are that the treatments were shorter than I would expect. 30 seconds of pressure. My only other slight surprise was that it worked (seemingly) so effectively! P1		Unformed expectations Expected more treatment Surprisingly effective
The amount of pressure applied was much stronger than I'd expected P2		Stronger pressure than expected Massage
I felt the technique had an almost immediate "calming" effect on the specific painful area. I wasn't expecting the procedure to ease the pain that quickly. P3		'calming effect' "I wasn't expecting it to ease the pain that quickly'

That it got more painful, opposite to what I thought as it was taking place P4		More painful than expected
No P5		
The use of the instrument to apply the pressure P6		PPT measures
Didn't expect to feel the lower back pain in my hip area when the source of the pain feels like it's in a different place (towards lower spine). P7		Referral of pain to another area
Didn't expect the muscle around my lower spine to be so tight initially, but also to relax so much as they did after the mobilisation technique. P8		Didn't expect muscle to relax as much
Discomfort in the front pelvic area when maximum pressure (of the 3) was applied yesterday…a type of muscular pain/discomfort. P9		Referral of pain to another area
Felt better, out of pain, and a lot more comfortable, healing hands P10		Less pain "healing hands'
Thought it might be more active and not so gentle P11		Expected more vigorous technique
Pressure testing was a new experience for me P12		PPT
No as I was prepared for any technique to be applied, but I am pleasantly surprised about how effective they have been how quickly P13		Surprised how effective how quickly.
-P14		
No P15		
Thought there would be more involved in this technique P17		Expected more complex technique
No, I just went along with it P18		
It was short in time. I anticipated a technique may need longer time in application or duration over time P19		Expected longer treatment
No, again as I was unsure what would be involved. I certainly didn't expect the technique to be centered on a few very precise areas across such a wide area P20		
No P21		
Didn't expect pushing on spine P22		Didn't expect pushing on spine
I didn't expect for the next day to be tight and tense. This however could be due to other factors (carrying heavy bags). P23		Didn't expect tightness the next day
I didn't expect the pressure point on my legs, shoulder and feet. These points were just pressured until I felt anything other than pressure such as pain or discomfort P24		PPT
How straight forwards it was P25		Expected more complex technique
Measurements of exact pressure being applied, esp to parts other than the back P26		PPT
I had no expectations or previous experience in the technique. Perhaps thought it wouldn't be so isolated. However this would be due to inexperience and the nature of the pain in the first place P27		Didn't expect such an isolated technique
-P28		
I didn't expect the ache and discomfort in my back to be as		Didn't expect ache immediately

strong in the immediate period afterwards P29		after
No P30		
You wonder if/when the pain will kick in P31		Anticipating pain
No P32		
I didn't expect an immediate painless recovery – this didn't happen. I didn't expect to be stiffer today (D2) P33		Didn't expect immediate recovery Didn't expect stiffness the next day.
Repetitive Pressure point test a surprise P34		PPT
No P35		
No P36		
No, I didn't expect anything during the technique P38		Unformed
Didn't really know what to expect but it was fine P39		Unformed
No P40		
Expected more manipulation P41		Expected more complex technique
I had no expectations P42		
After each session my back did feel a little easier P43		It did feel easier
Reduced discomfort for longer than was expecting P44		It reduced pain more than expected
No P45		
Changes to where and how much I felt the pain afterwards, including during and after exercises P46		Helped more than expected
No P47		
Drawing the nerve points and applying pressure P48		PPT
No P49		
Less invasive P50		
It was longer than anticipated and repetitive rather than one movement P51		Longer than expected
The sharp pain quite central when it did come. P52		Pain
Pain increase P53		Pain increase
I had no expectations P54		Unformed
Nothing I didn't expect from this technique P55		
-P57		
Pain seemed to decrease with time spent applying this technique P58		Reducing pain
As above P59		
Not really as I didn't know what to expect in the first place P60		Unformed
I didn't expect to become painfree after the application of the technique for 2-3 minutes. I didn't expect that the result would last until the next day. P61		Didn't expect relief of pain lasting until the next day
No P63		
-P64		
The technique made quite a change in the sense of pain P65		Changed pain more than expected

-P66 To have so much improvement P67 -P68		Didn't expect so much improvement
I did relax, and did not worry about having the pressure applied. It did not expect the technique to be so concentrated and I enjoyed the release of the pressure in the area P69		Enjoyed release of pressure
No P70		
The second time when asked to bend backwards I did not feel the pain in my low back. I did not expect this. P71		Didn't expect relief of pain on movement
I didn't expect the lack of pressure, ie under the threshold of 1 on a pain scale P72		Expected more pain
Heat P73		
The duration of mobilisation P74		Duration
What were you thinking and feeling when the mobilisation technique was applied?		
Thinking- nothing specific. Feeling – from an emotional perspective nothing of note. P1		
It felt like I was being squashed and was fairly uncomfortable P2		Felt squashed and uncomfortable
I was trying to relax my muscles as much as possible when the technique was being applied. During the technique I felt a degree of pressure being applied to the area. P3		Pressure
Trying to understand how it works on the back P4 It was quite relaxing but slightly painful P4		Relaxing but painful Trying to understand how it works
I was feeling a bit of pain/discomfort, I wasn't really thinking anything about it. P5		Feeling pain
Confidence in the operator P6		Confidence in Physio
I was mainly concentrating on when I felt the pressure changed to pain. I don't remember having any particular feelings at the time P7		PPT
I felt a release of pressure from the lower back region P8		Reduced pressure
Wondering if it would increase the leg discomfort/ awareness in my right calf and toes P9		PPT
Is this going to hurt? What clicks are going to happen? Am I going to get better or worse? P10		Is it going to hurt, am I going to get better or worse
That it seemed like a good way to ease the problem P11		
Was wondering what was going to be done. I was pleased it did not involve lots of manipulation P12		Pleased it did not involve manipulation
I was just trying to stay relaxed and let the applications take place as I have a lot of trust and belief in physiotherapy P13		Confidence and trust in physio
When the pressure was applied at first I felt the pain I had been experiencing but after the second time I felt it release P14		Released pain
Nothing in particular P15		
The movement and pressure was quite light, thought it		Not complex

would be more involved P17		
I was feeling at ease and thinking about relieving he discomfort P18		Relaxed thinking about pain relief
Feeling some slight increase in discomfort with one of the techniques. Have been interested in technique and how it may help P19		Increased pain How the technique will work
I was feeling uncertain as to how the technique worked and what effects it would have. I was thinking that there would be more pain involved! P20		How the technique will work Expecting more pain
Pleasant and decreasing pain and warm P21		Decreasing pain
Wondering how this could help P22		How the technique will work
The pressure felt like it was pinning the point of pain and I thought that this technique would provide relief from present back issues P23		Pain relief
The pressure and pain it was causing P24		Caused pain
I was thinking I hope this works and feeling relaxed P25		Hope it works Relaxed
Where and when exactly the pain I experience occurs, and how to explain/feedback most accurately P26		Concentrating on pain
I tried to feel relaxed and clear my thoughts. I felt mild discomfort during application however with a satisfying 'massage' sensation through the origin of the pain P27		Relaxed Discomfort 'Satisfying massage'
Relaxing sensation despite the pain that was generated P28		relaxing despite pain
I found that the pain decreased as the technique was applied and it was quite comfortable, pleasant experience by the end. Initially the pressure was uncomfortable P29		painful initially, then quite comfortable
I didn't realize it was happening P30		
Comfortable P31		Comfortable
Concentrating on type and level of pain and discomfort P32		Concentrating on pain
Sometimes drifting off the fact I was feeling any pressure. A change of mindset creates a gap in the sensation. Suddenly it reintroduces itself P33		
Trying to relax P34		Trying to relax
Was slightly painful, but was as expected thinking whether there is anything that can be done for the pain P35		Painful Will this help
I was focused on the pain in the beginning. As the mobilisation was continued I felt somehow better and I was just relaxed. I didn't have any thoughts P36		Pain, decreasing pain as it continued Relaxed
Whilst pressure was being applied and increased I was thinking the pain would get worse, and when it didn't, thought to myself the worst pain must be related to certain movements P37		Pain
My back felt more relieved than normal and just felt as my back was in a relaxation mode P38		Relaxed
It hurt slightly but felt good P39		Painful
Pressure and discomfort threshold P40		PPT
Focusing on back and levels of discomfort P41		Concentrating on Pain

What will these tests show P42		
It was quite soothing and relaxing P43		Relaxing
Was unsure how to react, but thought it was working even if only a little bit. Felt a bit more comfortable on last application of the technique than on the first P44		More comfortable as the technique continued
Temporary relief P45		Relief
Increase in pain sensation in affected area P46		Pain
Concentrating on the process and feeling in my back P47		Concentrating
Interested in the treatment and trying to concentrate on the exact point of pain P48		Interested in RX Concentrate on pain
That it was uncomfortable but that it would hopefully reduce pain and tension in lower back P49		Uncomfortable Reduced pain and tension
Quite relaxed P50		Relaxed
I was hoping it would enable my back to heal P51		
I was concentrating on waiting for it to cause me pain. Quite focused. P52		Pain
Nothing in particular P53		
How interesting it was to be able to find the exact point where my pain is P54		
I was thinking in a positive way that this technique would do some good. And feeling pretty upbeat about it P55		Thinking it would help
Very gentle P57		
I thought that it wasn't hurting particularly, that it wasn't unpleasant P58		
This doesn't hurt P59		
Was wondering how it could improve my back pain and also wondering how pressure to the lower leg/ foot area could help P60		How it would work PPT
That is localized on the area where my most pain is. I was feeling the pain to be reduced during the application of the mobilisation technique P61		Reducing pain
It felt good and seemed to ease the pain a bit P63		Reducing pain
Playing golf. Just relaxing P64		Relaxing
Sometimes relaxing but sometimes it was uncomfortable P65		Relaxing
Fine P66		
How could this possibly work P67		How it could work
Just hoping all this is going to help me and did feel pain when pressure was applied P68		Pain
I relaxed, actually felt calmer. I can't recall many thoughts at the time of the technique, probably because I did relax. I concentrated on the pressure that was being applied and how this was making me feel, which was good, ie I felt my mood lift P69		Relaxed
Whether the pain was increasing or decreasing P70		Pain

Thinking that I didn't know the particular point in my lower back was sore as the pain is referred around my lower back P71		Referral of pain
I was thinking I could feel the pressure but it was very light, like I should be reacting, but there was nothing to react to P72		
Be careful !! P73		e careful!!
That is was tolerable and to feedback to the therapist as accurately as possible P74		
How comfortable was the technique?		
It was painful but in a sort of nice way that makes you feel it is working. A good pain. Felt nice. P1		Nice pain Feels it's working
Fairly uncomfortable but tolerable if it achieves a result. P2		Tolerable if it works
The technique I felt was comfortable enough and I never once felt as if the pain/tension became too much too take. P3		Comfortable
Quite comfortable until the pressure was increased P4		Comfortable
Fairly comfortable, it hurt though when the pressure increased P5		Comfortable
Fine P6		
Fine. Positioning on the bed was comfortable. Didn't feel anything until the pressure increased to the point when I pressed the button. My ankle point could hardly take any pressure. P7		PPT
The mobilisation technique itself was fine, there was no discomfort during the application P8		Comfortable
Gave a relieving feeling in my lower back whilst being applied. Laying prone was not comfortable as a starting position and neither was the face hole which distracts from relaxing P9		Relieving in low back. But position on plinth uncomfortable.
Very comfortable and relaxing P10		Comfortable/relaxing
Very comfortable really P11		Comfortable
It was not at all painful, was just a little uncomfortable P12		A little uncomfortable
Quite comfortable. I could feel the amount of pressure being applied but it didn't cause me any concern at all and no discomfort P13		Comfortable
Relieving P14		Relieving
Not uncomfortable P15		Comfortable
Fine, felt comfortable P17		Comfortable
Apart from the pressure reading, it was reasonably comfortable P18		PPT Comfortable
Only very minor discomfort, but not an issue P19		Minor discomfort
Very comfortable in most cases, except the lower leg and toe, which I found to be quite painful. The effects wore off very quickly though P20		Comfortable PPT's
Very P21		

Little bit of increased pain, but final one was almost relaxing, felt a bit sleepy P22		Bit of pain Sleepy
It was pressured but not uncomfortable during the session P23		Comfortable
It was not comfortable when the pressure was applied because the area is sore and sensitive. However it felt somewhat relieving P24		Comfortable relieving
Very comfortable P25		Comfortable
Comfortable mostly, except when large amounts of pressure is applied to local point where I experience pain P26		Mostly comfortable
Generally ok, slight/mild discomfort, particularly during the start P27		Slight discomfort
As the treatment continued it became more comfortable and less painful (started off tender to the touch). Did however give pain down the thigh also P28		Comfortable
Yes although initially it was uncomfortable P29		Initially uncomfortable
Very P30		Very comfortable
Same, as was sore in the afternoon /evening after P31		Sore in afternoon /evening
Very comfortable P32		Very comfortable
A little uncomfortable on some muscles P33		PPT
Not particularly, but not painful P34		
Was comfortable to start with, but after a while it became relaxing. P35		Comfortable/ relaxing
It was uncomfortable the first seconds but then it was ok P36		Uncomfortable to start with
Fairly comfortable. Pain never felt like it would be too much to handle P37		Comfortable
From a scale 1-10 I would say 8 P38		Slight pain
Slightly painful but nothing extreme P39		Slight pain
Minimal discomfort P40		Minimal discomfort
Very comfortable P41		Comfortable
Fine P42		
See above P43		
More comfortable towards the end. Some spikes of increase pain which subsided when pressure was reduced P44		Pain>comfort
Comfortable P45		Comfort
Reasonable – although an increase in pain at the time, not excessively painful P46		
Very P47		
Not too bad bearable P48		Bearable
It was uncomfortable but not painful P49		Uncomfortable but not painful

It was quite comfortable P50		
It was a bit uncomfortable at the beginning but this wore off the more it was applied P51		Decreasing discomfort
Not very comfortable at all. P52		Uncomfortable
OK P53		
It was not uncomfortable per say, but as it was a way to find my pain spot I would not catagorise it as comfortable either, therefore all I can say is that it did it's purpose P54		Uncomfortable
The mobilisation technique was fairly comfortable P55		Comfortable
Painless P57		Painless
Quite comfortable and fairly pleasant P58		Comfortable
Fine P59		Comfortable
Reasonably comfortable P60		
Very (although it was partially reproducing my pain) P61		Comfortable though some pain
Very comfortable P63		Comfortable
The first session was a bit uncomfortable but as the pressure reduced it was relaxing P64		Uncomfortable but relaxing
On a scale of 1-10 I would say 6.5 although it was confortable sometimes it felt slightly painful P65		
Fine P66		
Reasonable. Getting both arms behind your back in not the easiest technique P67		Positioning uncomfortable
Completely bearable P68		
The technique felt comfortable P69		Comfortable
Not uncomfortable P70		Comfortable
It was fairly comfortable P71		Comfortable
Yes P72		Comfortable
At the beginning not very comfortable then the pain eased off P73		Initially uncomfortable
Touching on pain but otherwise comfortable P74		comfortable
What effect do you think the mobilisation technique had on your back?		
Immediate benefit as illustrated by increased mobilisation during stretching and a major reduction in soreness. P1		Immediate benefit Decreased pain Increased movement
I don't know what was intended by I assume it was loosening the muscles and the spine. P2		
Felt as if the tightness I experienced had been reduced and that movements which may have caused pain before became more bearable. P3		Reduced tightness Reduced pain on mvt
It made it more painful to start with but it felt much better afterwards (later on). P4		Increased pain initially then better
Minimal- would probably help as part of physio treatment P5		Minimal

Possible release of muscle tension P6.		Reduced tension
The stiffness has eased since yesterday and the recovery from feeling pain (ie bending forwards) eases more quickly rather than feeling pain with every movement. P7		Reduced pain on movement Reduced stiffness
Mobilisation technique improved my range of motion after application and also reduced my pain levels yesterday. Certainly improved my lower back pain and flexibility, however I wouldn't say it has cured the issue but rather assisted in pain relief. Would need to be able to do something like this myself everyday as can't go to the physio everytime I experience pain. P8		Increased movement Decreased pain Not cured Need to be able to do it myself
Initially when I had just left the session it felt a bit 'vulnerable' . This wore off quickly, no issues overnight/in the morning. P9		Initially felt vulnerable
Great improvement, better mobility, back felt stronger and no pain P10		Increased movement Felt stronger
It seemed to ease it somewhat P11		Felt eased
I feel a lot more comfortable and less stiff in my lower back P12		More comfortable Less stiff
It was a noticeable improvement over a short period of time P13		Improved
I feel more free P14		Free
None P15		None
Made it stiffer and sore today P17		Stiffer and sore
So far, improvement P18		None
Difficult to know at this early stage? Some slight improvement in stiffness and level of discomfort today P19		Slight decrease pain Increased movement
I seem to have more movement and less pain. I was able to stretch further with not as much discomfort on the second day P20.		Increased movement decreased pain
Reduced the pain P21		Reduced pain
Back felt a little sore (that afternoon/evening) BUT did seem to sleep better (I often wake at night with back ache). Today my back seems its usual self- just small amounts of background pain there P22.		Sore
Up to eight hours after the technique my back felt very relaxed> However I woke up and it was once again tense/tight P23		Short term relaxation
It was relieving shortly after receiving it and although it was uncomfortable at first, I felt it was doing my back some good. The relief was only short term P24		Short term relief
Seems to be effective P25		Effective
Improved symptoms, improved knowledge on how to prevent/ treat myself when/if pain occurs P26		Improved symptoms
Some relief, particularly on the pain symptoms. Ranges of motion appear better 24 hours later despite feelings of slight stiffness on some actions, immediately after P27		Reduced pain Stiff immediately then greater movement
After a nights rest the back feels much more flexible and not so tight – greater range of movement without an		Reduced tightness Increased movement

increase in the pain. Pain was still present but markedly reduced and less bothersome P28		Decreased pain
I feel at this stage I can't honestly say. I would have a better idea when the pain settles – at the moment it feels like I've done a hard session of exercise (DOM's like feel, especially on movement).		Not sure
Difficult to say as I wasn't in extreme pain before hand P30		
Slight relief of pain, but only temporary P32		Short term relief
Not sure P33		Not sure
Slight improvement P34		
Made it feel better at the time, however, I ached slightly the following day. BUT this may have been due to ROM exercises P35		Ached the following day
I think that the next day after the mobilisation I woke up unusually better P36		Improved next day
Getting up in the morning the pain wasn't as bad as the previous morning (when it's normally at its worst). Based on today I feel slight improvement and reduction in pain from yesterday P37		Improved next day
I believed it had a positive effect on my back in the sense that the pain/uncomfortableness in my back was less severe and some occasions couldn't feel any pain P38		Decreased pain
Its helped just when completing day to day activities P39		
No apparent change in back discomfort P40		None
No discernable effect P41		None
Increased the overall pain after an initial reduction P42		Increased pain
After the mobilisation my back did feel easier and when I left it felt looser. However later on in the day my back did seem to ache more P43		Initially decreased pain then increased
Hard to tell, relief from some of the pain for a few hours after. Not long lasting P44.		Short term pain relief
Temporary (short term) relief P45		Short term relief
Not sure. Was more aware of the pain sensation and more frequently afterwards, but at different times and different situations than previously i.e. usually during and after exercise the pain eases, but not this time, but other times eg when sitting in certain chairs when I would feel the pain, or in bed, there was more instances of no pain. P46		unsure
Seemed to relieve the pain, at least in the short term P47		Short term relief
I think it helped P48		unsure
To relieve tension in the muscles and increase movement in the vertebrae P49		
It may have loosened it P50		unsure
I think it is re injuring the joints to promote a healing response P51		
None to be honest P52		None
Don't know P53		unsure

Find the pressure point where my pain originates, and increase it or decrease it according to need. Beneficial to be able to know where it is now P54		
The effect of the M/T was to loosen up my lower back in a similar way to excersie for example yoga P55		Looser
Short term relief P57		Short term relief
My back seemed a little lea painful and stiff today but I'm not sure of this is an effect of my swim this morning. P58		Not sure
Not sure no noticeable difference P59		None
Felt a wee bit stiffer this morning but whether it was as a result of the technique or not I'm not sure P60		Stiffer
Pain relief (placebo effect) P61.		Decreased pain
Gentle movement helps with my back and this had a similar effect P63		
Trying to bend forward after the massage was pretty uncomfortable P64		More pain on movement
I cannot justify if the technique had any positive effect or negative effect because sometimes I felt pain and sometimes I felt quite relaxed P65		Not sure
Slight relief P66		Slight relief
Very good relief P67		Good relief
Hard to say presently, maybe I feel less stiff with it today P68		Not sure
I felt that the area where I experienced the technique began to feel less painful, almost like the numbness that I experienced had eased away P69		Decreased pain
Not too sore. I think the points became a little less painful. Definitely not more painful P70.		Unsure
It made it feel more relaxed P71		More relaxed
Limbers area/? More flexible. Hard to tell P72		Unsure
Ease of pain. More movement around hip area P73.		Reduced pain
I felt as though pain replicated upon active movement was slightly better, but sensation of pressure pain thresholds I couldn't determine a difference P74 **Any other comments:**		PPT
I quite enjoyed being a guinae pig and feel much better. The morning after session 2 was unusual for me in that I had less pain than has been typical for the last 2 months. P1		Less pain than last 2 months
No, other than it was interesting to be part of. P2		
I had heard a lot about the technique and it was interesting to experience it. P3		
No P4		
No P5		
No P6		
Slept on a different mattress last night to previous weeks		

P8. Has increased the awareness of my left leg issues and I'm left with a dull awareness in my lower (RH) back. P9 I am aware I need to keep exercising and help long term support of my back. Thank you for helping P10 Would be interested to see the effect of continuous treatment over a period of time P11 This technique appears to have worked and improved my back P12 I will recommend this technique and pursue this type of treatment if and when I need it P13 No P14 The whole experience was quite pleasant P18 Its been an interesting experience and I am always welcome to new ideas to pain relief without painkillers P23 No P24 No P25 Unfortunately, immediately before the mobilisation technique my back pain was low so any effects were difficult to determine. Pain and discomfort in my back has a history of being erratic with not always a reason for pain P32 I liked the mobilisation but I find the pressure measures a bit weird P36 Was the technique expected to have an impact? P40 No P44 No P45 - P46 No P47 - P48 - -P49 - P50 - -P51 - P53 Having the pressure placed on the point today I probably felt some bruising from yesterday so may have reacted earlier to stimuli than yesterday. The pillow under my legs works wonders P54 It remains to be seen if this has helped when I come to stress my lower back when for example I have been standing or gardening for any length of time. It would also be helpful to know the cause of my discomfort (whether I could do anything different in my day to day life) P55 Can you make it more long term? P57 -P58 -P59 Not at this stage P60 I am extremely happy that such a small movement has given me the relief I require and a confidence in exercise P67 -P68 -P69 -P70 No P71		Would be interested to see effect of multiple rx helped would recommend mobs and seek more treatment Can you make it more long term? Extremely happy with relief

Purely preference. Would have preferred stronger massage/pressure P72 -P73 -P74		