Swansea University
Prifysgol Abertawe

Cronfa
Setting Research Free

Cronfa - Swansea University Open Access Repository

This is an author produced version of a paper published in:
Journal of Bodywork and Movement Therapies

Cronfa URL for this paper:
http://cronfa.swan.ac.uk/Record/cronfa43592

Paper:
Cathcart, E., McSweeney, T., Johnston, R., Young, H. & Edwards, D. (2018). Immediate biomechanical, systemic, and interoceptive effects of myofascial release on the thoracic spine: A randomised controlled trial. *Journal of Bodywork and Movement Therapies*
http://dx.doi.org/10.1016/j.jbmt.2018.10.006

Released under the terms of a Creative Commons Attribution Non-Commercial No Derivatives License (CC-BY-NC-ND).

This item is brought to you by Swansea University. Any person downloading material is agreeing to abide by the terms of the repository licence. Copies of full text items may be used or reproduced in any format or medium, without prior permission for personal research or study, educational or non-commercial purposes only. The copyright for any work remains with the original author unless otherwise specified. The full-text must not be sold in any format or medium without the formal permission of the copyright holder.

Permission for multiple reproductions should be obtained from the original author.

Authors are personally responsible for adhering to copyright and publisher restrictions when uploading content to the repository.

http://www.swansea.ac.uk/library/researchsupport/ris-support/

Title page

Immediate biomechanical, systemic, and interoceptive effects of myofascial release on the thoracic spine: a randomised controlled trial

Ellie Cathcart M.Ost[1]

Terence McSweeney M.Sc. M.Ost DO ND[2]

Ross Johnston, M.Sc. B.Sc. (Hons) Ost Med, DO[3]

Hayley Young B.Sc. Ph.D[4]

Darren J. Edwards B.Sc. M.Sc. Ph.D[5*]

[1] *Osteopath, College of Human & Health Sciences, Swansea University, Singleton Park, Swansea, Wales, SA2 8PP*

[2] *Lecturer, College of Human & Health Sciences, Swansea University, Singleton Park, Swansea, Wales, SA2 8PP*

[3] *Senior Lecturer, College of Human & Health Sciences, Swansea University, Singleton Park, Swansea, Wales, SA2 8PP*

[4] *Senior Lecturer, College of Human & Health Sciences, Swansea University, Singleton Park, Swansea, Wales, SA2 8PP*

[5] *Senior Lecturer, College of Human & Health Sciences, Swansea University, Singleton Park, Swansea, Wales, SA2 8PP*

[*] *Corresponding author. Tel: +44 (0) 1792 604185*

E-mail address: d.j.edwards@swansea.ac.uk

Abstract

Background. Myofascial release (MFR) is used to restore tissue extensibility of the fascia tissue and is considered to be useful in a number of clinical settings such as low back pain, ankle injuries, fibromyalgia and headaches. There is, however, despite the popularity of MFR in manual therapy, little consensus on whether it leads to biomechanical, systemic or interoceptive outcomes. **Aims.** This study aimed to explore the immediate biomechanical (increased elasticity for increased range of motion), systemic (local vs. distal areas of pain threshold) and bodily awareness effects (interoception) of a myofascial release technique on the thoracic spine. **Method.** 12 healthy participants took part in this triple-bind, repeated measures, cross over design study, and were randomised into counterbalanced sequences of three conditions; a control, a sham and the MFR condition. The outcome measures used were; range of motion (ROM), pain pressure thresholds (PPT), and interoceptive sensitivity (IS) to assess biomechanical, systemic and interoceptive effects of MFR. **Results.** There were significant increases in ROM and PPT (both local and distal) post MFR intervention. There was also a positive correlation between baseline interoceptive sensitivity and post-MFR ROM and a negative correlation for baseline interoceptive sensitivity and post-MRF PPT. Interoceptive sensitivity did increase post-MFR but this was non-significant. **Conclusions.** The increase in ROM suggests that the MFR may have caused a biomechanical change in tissue elasticity creating an increase in tissue flexibility. The increase in both local and distal sites of the PPT suggest an overall systemic response to the therapy. The correlation between baseline IS and post-MFR ROM and PPT suggest that IS may be usefully applied as a predictor for ROM and PPT post-MFR.

Keywords: Myofascial Release; thoracic spine; ROM; PPT; Interoception

Introduction

Fascial tissue includes the loose areolar tissue of the superficial fascia and deeper layers such as the epimysium layer of the muscles and those which envelopes the nerves, blood and lymphatic vessels (Drake, Vogel, & Mitchell, 2009). In a more all-encompassing definition, it is described as the soft tissue component of the connective tissue system that permeates the human body (Huijing et al., 2009).

Facia is considered to be a source of nociceptive pain (myofascial pain) in several musculoskeletal disorders including plantar fasciitis, Dupuytren's contracture and non-specific low back pain (Mense et al., 2016). When chronic, it has also been associated with the deteriorating health of a patient and is implicated in the aetiology of more systemic symptoms such as chronic fatigue (Mastaglia 2012).

In terms of epidemiology, some studies reveal that myofascial pain occurs in 37% and 65% of middle-aged men and women respectively (Drewes & Jennum, 1995) and up to 85% in the older population (Podichetty, Mazanec & Biscup, 2003). It has also been estimated to occur in an astounding 85% of chronic pain patients and is the foremost diagnosis in musculoskeletal pain patients reported in general practices (Skootsky, Jaeger & Oye, 1989). From these demographics, it is evident that this myofascial pain creates a significant burden for the medical system.

Numerous therapies have been employed in the treatment of myofascial pain such as varying forms of myofascial release (MFR) which have been based upon Rolf's structural integration model and developed by Stecco over the last 30 years (Stecco, 2004). In this model and similarity with most forms of MFR techniques, the duration of the stroke or technique on a particular area is usually based upon the palpable changes felt underneath the practitioner's hands, but generally, this lasts between 120-300 seconds (Adigozali et al.,

2016). MFR involves a manual application of low amplitude, long duration stretches to the fascia and muscles which will rarely involve the manipulation of one area for more than two minutes (Schleip, 2003).

The purpose of MFR is to restore tissue extensibility to connective tissue which has undergone changes to its mechanical properties such as loss of normal pliability and viscosity (Barnes, 1997). In addition to this, the same authors suggest that MFR in used to affect putative changes in local inflammatory mediator proliferation (via drainage) and mechanical pressure on nerves and circulatory vessels. The efficacy of MFR has been demonstrated in a multitude of conditions including low back pain, ankle injuries, carpal tunnel syndrome, chronic asthma, headaches and fibromyalgia (Tozzi, 2012). However, despite the clinical usefulness of MFR there is little consensus on what is does at the biomechanical (e.g., cellular elasticity, neuronal), systemic (local vs. distal effects) and the bodily awareness level (e.g., interoceptive sensitivity). There have been some developments towards a comprehensive model of how different biomechanical, cognitive and autonomic nervous system (ANS) pathways interact within a manual therapy context (see Bialosky et al., 2009), however, as identified by the authors, this is by no means complete, and it is not specific to any one type of manual therapy.

As there is a clear gap in the literature regarding this, this present study therefore aims to explore the immediate biomechanical (increased elasticity), systemic (local vs. distal) and bodily awareness effects (interoception) of a myofascial release technique on the thoracic spine, to help develop the empirical knowledge in this area further.

So, to start, form the literature, the biomechanical component refers to the plasticity, elasticity and viscosity of the tissue itself. It has been suggested that MFR may cause a change in fascia as it causes an alteration in the density, tonus, viscosity and arrangement of fascia via mechanical pressure (Rolf, 1977; Schleip, 2003). Rolf claimed that as the ground

substance of fascia is a colloidal substance, this allows it to convert from its dense 'gel' state to a more fluid 'sol' state (Rolf, 1977). So, from this, the first hypothesis of the present study is that MFR may increase a more fluid state in the facia and therefore increase range of motion (ROM), more so than a sham or control.

From the systemic perspective, MFR not only has a local neurological response but other systemic responses may be triggered via autonomic reflexes. When stimulated, Ruffini corpuscles (mechanosensitive nerves) have been associated with a decrease in activity of the sympathetic nervous system of the autonomic nervous system (ANS), as fascia has high density of free nerve endings that belong to the sympathetic nervous system (Schleip, 2003). Likewise, stimulation of the sensory mechanoreceptors has been identified as a cause for the activating the anterior lobe of the hypothalamus, which induces a global overall decrease of sympathetic muscle tonus and emotional arousal, as well as a change in local tissue viscosity (Gellhorn, 1967). As there is a reported global as well as local impact in terms of mechanosensitivity, pain pressure thresholds (PPT) may increase in other areas outside of the area the MFR is conducted. This, therefore, is the second hypothesis of this study where it is predicted that MFR will lead to a local and systemic increase in PPT and more so than control and sham conditions.

The bodily awareness component explored in this present study is that of interoceptive pathways (Craig, 2004). Interoception refers to a set of neuro-anatomical pathways which allow bodily signals to travel through, to form bodily awareness (Craig, 2004; Garfinkel & Critchley, 2013; Garfinkel, et al., 2015). Interoception has a strong impact on cognition and has been shown to alter cognition in a sensation categorization task (Peterson et al., 2014). In terms of pain, specifically, Pollatos, Füstös and Critchley (2012) observed that individuals with higher interoceptive sensitivity (IS) had lower pain thresholds and tolerance, higher pain perceptual experience and higher levels of anxiety. As such,

several models of cognition suggest that pain is modulated based on emotion, attention, and memory of previous experience leading to anticipation (Stoeter et al., 2007; Melzack, 1999).

Interoception has been used in general pain threshold studies, but not specifically in a case where a MFR technique is used. So, the third hypothesis is that baseline-IS will be negatively correlated with PPT as it has been shown to reduce PPT in the study by Pollatos, Füstös and Critchley (2012). It is also hypothesised that there will be a correlation between baseline-IS and ROM, but the direction is unspecified given the lack of specific evidence supporting one direction or the other, so this would be two-tailed.

In summary, this study aimed to explore the biomechanical, systemic and interoceptive effects of the MFR technique, and in doing this presents a comprehensive battery of outcome measures which measure components of the biomechanical (ROM for an elastic effect and PPT for a hypoalgestic effect), systemic (local vs. distal) and bodily awareness (interoception), before and after the MFR. It is anticipated that there will be an increase in ROM and PPT (across local and distal areas) after MFR, as well as baseline-IS correlating with ROM and PPT post-MFR outcomes.

Methods

Participants

The recruitment involved a purposive sample of 12 asymptomatic first year Swansea University osteopathic students who were invited to participate. The purposive sample of first year students were recruited as they were naiver to the active interventions than the more experienced students of later years (see CONSORT flow diagram, figure 1). The inclusion criteria for this study involved being of the ages between 18-55, and female or male. The exclusion criteria consisted of any systemic disease and long-term medications that could

alter perceptions of pain, a recent or long-term spinal musculoskeletal injury/pathology and any vigorous exercise or manual therapy two days prior to the study.

----------Insert Figure 1 here----------

Research Design

The experimental design conducted was a triple-blind, randomised, sham-controlled, within subjects, crossover study design.

Ethical approval

Ethical approval was obtained through Swansea University College of Human and Health Science.

Examiner Repeatability

Interclass correlation coefficients (ICC) were conducted to ensure that there was a high level of examiner reliability. Multiple measures were taken at the same time and location to ensure this as described by Fless (1987). The classification system used was as suggested by Shrout and Fleiss (1979), where: >0.75 was determined as excellent; 0.6-0.75 as good; 0.4-0.59 as fair; and <0.04 as poor. Fixed raters and random participants were utilised in an analysis of variance using a two-way mixed model for the ROM and PPT measures.

Internal validity

Blinding

The tentative use of the term 'triple-blinding' was used, as (1) the participants were blind to the condition, (2) the researcher taking measurements (ROM, PPT, and interoception) was blind to the condition, and (3) the osteopath delivering the MFR technique was blind to all measurements.

Randomisation

Before the experiment began, participants were assigned to their intervention group sequence which was selected on the basis of six possible sequence combinations in order to balance any order effects; [1, 2, 3]; [1, 3, 2]; [2, 1, 3]; [2, 3, 1]; [3, 1, 2]; [3, 2, 1]. To do this, the second researcher randomly allocated each of the participants into one of the six sequences via a computer randomised number generator (e.g., sequence [1, 2, 3] equalled 1) (Urbaniack & Plous, 2013).

Materials and dependent measures

Pain Pressure Threshold via an Algometer

PPT measurements were assessed using a digital algometer (Wagner Force Ten FDX). The algometer was calibrated by the manufacturer and a $1cm^2$ rubber tip was used for the pressure application. The gauge displays values in kg/cm^2 ranging from 0 to $5.5kg/cm^2$.

Pressure algometry is designed to record the smallest measurement of mechanical stimuli that can be perceived as pain (Fischer, 1987). Pressure algometry is frequently utilised to quantify whether there are any alterations in the participants' pain perception following a treatment intervention (McCoss et al., 2017). There is much literature supporting the algometer as a reliable, valid and easy method of measuring the hypoalgestic effects of manual therapy (ICC = 0.78-0.93) (Ylinen, Nykanen, Kautiainen & Hakkinen, 2007). Other

papers have also reported good inter-examiner reliability (ICC = 0.75) and excellent intra-examiner reliability (ICC = 0.84) (Antonaci, Sand & Lucas, 1998).

Range of Motion via an Inclinometer

The Acumar dual digital inclinometer was used to measure ROM. In studies, digital inclinometers are regularly used and have been acknowledged as reliable and easy to use. Examples of this include high inter-rater reliability when measuring movement in the scapula (ICC>0.892) (Tucker & Ingram, 2012) and thoracic spine (ICC>0.89-0.99) (Lin & Wang, 2015). These are highly reliable, with even smart phone inclinometer apps having an excellent reliability (ICC>0.75) (Charlton, Mentiplay, Pua, Clark, 2015).

Inclinometers are instruments used to measure the ROM of a joint with respect to a particular level or angle and has been previously used in several trials assessing cervical, thoracic, lumbar spine and median nerve ROM where all authors concluded moderate to good reliability (ICC = 0.6-0.9) (MacDermid, Arumugan, Vincent, Payne & So, 2015; MacDermid, Arumugam, Vincent & Carroll, 2014; Prushansky, Deryi & Jabarreen, 2010; Whelan et al., 2017).

Interoceptive sensitivity (IS) via Biopac

IS were measured through an electrocardiogram (ECG) analysis BioPac which has been used in other studies (e.g., Buttagat, et al, 2008). The current study used the BioPac MP160 version.

Interoceptive sensitivity is commonly quantified by measuring a person's ability to perceive and accurately report one's heartbeats at rest. Differences in IS are related to differences in pain perception (Pollatos, et al. 2012). There are a few heartbeat mental-tracking tasks that have been used to index the IS of a participant. One way to gain the

perceptual accuracy score, and what was used in the present study, is to get participants to verbally estimate their heart beats without an exteroceptive aid using intervals of 30, 35, 40, and 45, 50, 55 and 60 seconds. These time intervals are separated by 30 second resting periods, and the participant's verbal estimate is then compared to the actual recorded score via a heart rate monitor (Schandry, 1981; Ehlers and Breuer, 1996). This method is a widely used measure for IS, has a good test-retest reliability (Pollatos, Traut-Mattausch & Schandry, 2009) and it has also emerged as the dominant method for testing IS (Schandry,1981; Critchley, et al., 2004). The participants are not informed about the length of the counting phases nor the quality of their performance. Then following transformation is then used to calculate IS, as used in other studies: $1 - \frac{|n\ beats_{actual} - n\ beats_{perceived}|}{(n\ beats_{actual} + n\ beats_{percived})/2}$ (Mallorquí-Bagué et al., 2014).

Experimental intervention

MFR was applied to the thoracic erector spinae muscles between the levels of T6-T12 for 120 seconds. MFR involves a manual application of low amplitude, long duration stretches to the fascia and muscles, usually between 120-300 seconds (Ajimsha, et al, 2015).

Sham Intervention

This was a purposefully disengaged balanced ligamentous tension technique unilaterally on the ribcage. This involved the practitioner placing his hands directly on the ribs and resting them there for two minutes (see Figure 2).

Control

For this condition, the participants lay supine on the plinth with their head on a pillow for two minutes (see Figure 2).

----------Insert Figure 2 here----------

Procedure

The study began with a brief clinical evaluation performed on the participants by the first researcher (the final year student osteopath) to confirm no evident pathology in the spine. An area along the thoracic erector spinae between T6-T12 was identified for the intervention and PPT check points were marked with a felt-tip marker. These check points were bilateral and marked on the tibialis anterior muscle belly half-way up the shin, the thoracic erector spinae of the back at the level T10 and the cervical erector spinae of the neck at the level C7. The inclinometer check points were marked on the spinous process of T6 and S2. The data measurements were then taken, starting with ECG (interoception) then the inclinometer (ROM) and finally the algometer (PPT).

Once all the pre-intervention data had been recorded, the first researcher left the room and the second researcher (a qualified osteopath with over ten years of clinical experience) entered the room and performed one of the three randomly allocated interventions (control, sham or experimental). The second researcher then exited the room and the first researcher returned to the room, not knowing which intervention was conducted, to re-measure the same measures and in the same order (interoception, ROM and PPT). The participants were subjected to all three condition in this repeated measure crossover design with a one-week period washout period in-between conditions.

Data Analysis

A Shapiro-Wilk test was used to confirm that the data was normally distributed ($p > 0.05$), thus justifying the use of parametric tests. A general linear model, consisting of a repeated measures univariate Analysis of Variance (ANOVA) was used comparing the control, sham,

and experimental conditions for PPT, ROM and IS. The dependent measure (DV) used the change score, i.e., pre-subtracted by post PPT, ROM and IS scores. In addition to this, comparisons were made between pre and post PPT, ROM and IS measures for all three conditions, using paired samples *t*-tests. Finally, a series of bivariate correlations were conducted correlating baseline IS with post condition ROM and PPT scores.

Results

Demographic results

Table 1 shows the demographical data for age, height, weight and body mass index. As these were the same individuals tested over the three condition (repeated measures, crossover design) homogeneity tests were not needed.

----------Insert Table 1 here----------

ICC results

The intra-class reliability for the PPT scores were excellent and therefore reliable (see Table 2).

----------Insert Table 2 here----------

Change-scores for ROM, PPT and IS

The difference (or change) scores for ROM, PPT and IS were calculated as post subtracted by pre-scores (see Tables 3, 4 and 5). From this, it is interesting to see that for ROM and PPT scores, in most situations post-MFR Change-scores were positive whilst the control and sham scores were negative. This indicates that the MFR intervention had a positive effect on PPT and ROM. For IS, all three conditions seemed to increase and more so for MFR which suggests that the intervention makes individuals more interoceptively sensitive.

----------Insert Table 3 here----------

----------Insert Table 4 here----------

----------Insert Table 5 here----------

Inferential statistics

PPT left leg

For the differences scores of PTT, Change-PPT for the left leg revealed; $F(2) = 12.398$, p <0.001, $\eta_p^2 = 0.530$ (large effect size). Pairwise comparisons revealed that the MFR was significant when compared against the control and sham conditions; MFR vs control, $p <$ 0.01 (CI = 0.293, 0.852); MFR vs sham $p < 0.01$ (CI = 0.142, 0.582); control vs. sham, $p =$ 0.107 (CI = -0.475, 0.054). Pairwise *t*-tests were conducted for base and post conditions with the following results; $t(11) = 2.669$, $p < 0.05$, Cohen's $d = 0.23$ (medium effect size) for pre-post control; $t(11) = 1.351$, $p = 2.04$, Cohen's $d = 0.117$ (small effect size) for pre-post sham; $t(11) = -6.791$, $p < 0.01$, Cohen's $d = 0.24$ (medium effect size) for pre-post MFR.

PPT right leg

Change-PPT right leg revealed; $F(2) = 7.655$, $p < 0.01$, $\eta_p^2 = 0.410$ (large effect size).

Pairwise comparisons again revealed that the MFR was significant when compared against the control and sham conditions; MFR vs control $p < 0.05$ (CI = 0.171, 0.626); MFR vs sham $p < 0.01$ (CI = 0.122, 0.524); control vs. sham, $p = 0.567$ (CI = -0.355, 0.204). Pairwise *t*-tests were conducted for base and post conditions with the following results; $t(11) = 2.390$, $p < 0.05$, Cohen's $d = 0.16$ (small effect size) for pre-post control; $t(11) = 1.324$, $p = 0.213$, Cohen's $d = 0.139$ (small effect size) for pre-post sham; $t(11) = -1.802$, $p = 0.09$, Cohen's $d = 0.17$ (small effect size) for pre-post MFR.

PPT left back

Change-PPT left back revealed; $F(2) = 0.534$, $p < 0.001$, $\eta_p^2 = 0.534$ (large effect size).

Pairwise comparisons again revealed that the MFR was significant when compared against the control and sham conditions, MFR vs control $p < 0.01$ (CI = 0.399, 0.808); MFR vs sham $p < 0.01$ (CI = 0.281, 0.931); control vs. sham, $p = 0.831$ (CI = -0.295, 0.360). Pairwise *t*-tests were conducted for base and post conditions with the following results; $t(11) = 0.747$, $p = 0.471$, Cohen's $d = 0.04$ (small effect size) for pre-post control; $t(11) = 0.771$, $p = 0.457$, Cohen's $d = 0.059$ (small effect size) for pre-post sham; $t(11) = -6.084$, $p < 0.01$, Cohen's $d = 0.388$ (medium effect size) for pre-post MFR.

PPT right back

Change-PPT right back revealed; $F(2) = 25.487$, $p < 0.001$, $\eta_p^2 = 0.699$ (large effect).

Pairwise comparisons again revealed that the MFR was significant when compared against the control and sham conditions; MFR vs control $p < 0.01$ (CI = 0.465, 0.929); MFR vs sham $p < 0.01$ (CI = 0.357, 0.853); control vs. sham, $p = 0.378$ (CI = -0.311, 0.128). Pairwise *t*-

tests were conducted for base and post conditions with the following results; $t(11) = 2.842$, $p < 0.01$, Cohen's $d = 0.127$ (small effect size) for pre-post control; $t(11) = 0.921$, $p = 0.377$, Cohen's $d = 0.056$ (small effect size) for pre-post sham; $t(11) = -5.063$, $p < 0.01$, Cohen's $d = 0.380$ (medium effect size) for pre-post MFR.

PPT left neck

Change-PPT left neck revealed; $F(2) = 5.204$, $p < 0.01$, $\eta_p^2 = 0.321$ (large effect). Pairwise comparisons again revealed that the MFR was significant when compared against the control and sham conditions; MFR vs control, $p < 0.05$ (CI = -0.075, 0.630); MFR vs sham, $p < 0.05$ (CI = -0.02, 0.516); control vs. sham, $p = 0.325$ (CI = -0.299, 0.109). Pairwise *t*-tests were conducted for base and post conditions with the following results; $t(11) = -0.237$, $p = 0.817$, Cohen's $d = 0.013$ (small effect size) for pre-post control; $t(11) = -1.413$, $p = 0.185$, Cohen's $d = 0.095$ (small effect size) for pre-post sham; $t(11) = -0.367$, $p < 0.01$, Cohen's $d = 0.271$ (medium effect size) for pre-post MFR.

PPT right neck

Change-PPT right neck revealed; $F(2) = 10.857$, $p < 0.01$, $\eta_p^2 = 0.497$ (large effect). Pairwise comparisons again revealed that the MFR was significant when compared against the control and sham conditions; MFR vs control $p < 0.01$ (CI = 0.160, 0.477); MFR vs sham $p < 0.01$ (CI = 0.149, 0.554); control vs. sham, $p = 0.705$ (CI = -0.153, 0.219). Pairwise *t*-tests were conducted for base and post conditions with the following results; $t(11) = -1.059$, $p = 0.312$, Cohen's $d = 0.042$ (small effect size) for pre-post control; $t(11) = -0.286$, $p = 0.780$, Cohen's $d = 0.016$ (small effect size) for pre-post sham; $t(11) = -5.218$, $p < 0.001$, Cohen's $d = 0.288$ (medium effect size) for pre-post MFR.

ROM

For ROM, a repeated measures univariate ANOVA with difference scores (post minus pre) and with the three conditions (control, sham and MFR) demonstrated; ($F(2) = 18.969$, $p < 0.01, \eta_p^2 = 0.633$) a significant difference in Change-ROM between the three conditions (large effect). Pairwise comparisons demonstrated that MFR was significant when compared against sham and control; MFR vs control $p < 0.01$ (CI = 3.98, 9.02), MFR vs sham $p < 0.01$ (CI = 3.55, 9.45); control vs. sham, $p = 1.00$ (CI = -0.256, 2.556). Pairwise *t*-tests were conducted between base and post conditions with the following results; $t(11) = 1.11$, $p = 0.29$, Cohen's $d = 0.09$ (small effect size), for pre-post control; $t(11) = 0.94$, $p = 0.37$, Cohen's $d = 0.06$ (small effect size), for pre-post sham; $t(11) = 6.35$, $p < 0.01$, Cohen's $d = 0.55$ (large effect size) for pre-post MFR.

Interoceptive Sensitivity (IS)

A repeated measures univariate ANOVA with difference scores (post minus pre) and with the three conditions (control, sham and MFR), was use to compare the differences in change of IS, demonstrating; ($F(2) = 0.413$, $p = 0.66, \eta_p^2 = 0.036$) a small but non-significant increase in IS for the MFR condition compared to the other conditions (small effect). Pairwise comparisons demonstrated; MFR vs control, $p = 0.5212$ (CI = -0.064, 0.119), MFR vs sham, $p = 0.495$ (CI = -0.061, 0.118); control vs. sham, $p = 0.957$ (CI = -0.049, 0.046). Pairwise *t*-tests were conducted for base and post conditions with the following results, indicating that these were non-significant changes for all three conditions; $t(11) = -0.049$, $p = 0.962$, for pre-post control; $t(11) = -0.160$, $p = 0.876$, for pre-post sham; $t(11) = 0.707$, $p = 0.494$, for pre-post MFR.

A series of bivariate correlations were also conducted where, baseline (pre-condition) IS were associated with post ROM measures. The relationship between pre-interoception and

post MFR was significant; $r = 0.596$, $p < 0.05$. The relationship between pre-interoception and post-sham was non-significant; $r = -0.369$, $p = 0.238$. The relationship between pre-interoception and post-control was also non-significant; $r = 0.079$, $p = 0.806$.

In addition to this, another series of bivariate correlations were conducted, where baseline (pre-condition) IS were associated with post PPT measures. The association between baseline (pre-condition) IS and post-MFR-cervical spine right was non-significant, but close to a border-line significance and negatively correlated; $r = -0.464$, $p = 0.065$. The relationship between baseline (pre-condition) interoception and post-MFR-cervical spine left was broadline negatively correlated; $r = -0.492$, $p = 0.052$. The relationship between baseline (pre-condition) interoception and post-sham-tibialis anterior, was also of borderline significance and negatively correlated; $r = -0.491$, $p = 0.053$.

Discussion

This study explored the immediate effects of MFR on the thoracic spine with three areas of interest, that being; (1) Biomechanical; (2) Systemic; and (3) Interoceptive effects. ROM was recorded for Biomechanical, where it was hypothesised that if MFR led to greater elasticity of the facia at the biomechanical level, then this would increase ROM. PPT was recorded for the systemic component where it was hypothesised that if it was shown that there were increases in PPT in other areas outside of the MFR application (thoracic spine area) then this was evidence of MFR having a systemic effect across the body. In this case, PPT were recorded at the cervical, thoracic and tibialis anterior sites. Finally, it was

hypothesised that baseline IS would correlate with post-MFR ROM (no predicted direction) as well as post-MFR PPT (negatively).

Of these, the results showed that there were biomechanical effects where ROM increased (significantly) for the MFR condition but not for sham or control conditions. It also showed that there were systemic effects where PPT increased for other areas outside of the locally applied MFR. Finally, baseline IS positively correlated with post-ROM and negatively with PPT.

For the biomechanical effects, the greater elasticity in the facia, demonstrated through an increase in ROM, suggests that perhaps the MFR stimulated the facia in way as described by Schleip (2003), leading to change in viscosity and density, and as Rolf (1977) suggests, this allows it to transform into a more fluid state.

PPT after the MFR also increased both locally and distally, but not for the sham and control conditions, indicating that MFR caused a systemic effect. This non-local neurological systemic responses may be triggered via autonomic reflexes. For example, when stimulated, Ruffini corpuscles (mechanoreceptors) have been associated with a decrease in activity of the sympathetic nervous system of the ANS, as fascia has a high density of free nerve endings that belong to the sympathetic nervous system (Schleip, 2003). Likewise, stimulation of the sensory mechanoreceptors has been identified to activate the anterior lobe of the hypothalamus, which induces a global overall decrease of sympathetic muscle tonus and emotional arousal, as well as a change in local tissue viscosity (Gellhorn, 1967). So, there may be a connection between this complex ANS system, reduction in the sympathetic arousal, and an increase in systemic PPT. However, a combination of further brain imaging and ECG studies need to be conducted to provide further evidence for this interaction specifically.

There was also an IS effect where, IS correlated positively with ROM and negatively with PPT. This may be due to the stimulation of the sensory interstitial mechanoreceptors which may have activated the anterior lobe of the hypothalamus, thus inducing a global overall decrease of sympathetic muscle tonus and emotional arousal (Gellhorn, 1967). Therefore, a higher IS may have amplified the hypothalamus reaction and further decreased the sympathetic response leading to a more relaxed parasympathetic response, thus allowing for greater ROM.

The connection between mechanosensitive nerves and the ANS system seem to be extremely complex. For example, within the interoceptive pathways, the mid insula has ongoing communication with the amygdala regarding emotional memories and the stimulus salience, as well as with the hypothalamus in terms of the current state of the ANS (Craig, 2008). The higher IS scores leading to lower PPT and tolerance, higher pain perceptual experience demonstrated by Pollatos, Füstös & Critchley (2012), may explain why there was a negative correlation between IS and PPT, whilst expectation bias of the intervention may have accounted for the positive correlation between IS and ROM. For example, pain modulation and effectiveness of intervention have been suggested to relate to emotion, memory, attention, experience and expectations (e.g., Stoeter et al., 2007; Melzack, 1999). So, the higher emotional, and attentional sensitivity could have led to an increased expectation bias that the intervention would cause a positive effect in increasing ROM.

However, again, many more studies are needed to be conducted utilising psychology to understand the relationship between psychological bias, osteopathy and the complex interoceptive pathway. These psychological biases have been noted in other studies (e.g., Whelan et al., 2017) and were noted again here with global increases in some places between baseline and post-condition scores for control, sham and MFR. Therefore, it seems important to understand any placebo effects that might be caused. One way of doing this is through the

Neuromatrix model (Melzack, 1999). This model suggests that sensory experience, perceptions and expectations can all influence subjective experience, so these may lead to the placebo effect.

Placebo effect can also be explained by cognitive psychology where, for example, Peterson et al. (2014) demonstrated how cognition can alter pain perception through categorization studies. In addition to this many other cognition studies have explored perceptual biases and contextual bias effects (e.g., Edwards, 2017; Edwards & Wood, 2016; Edwards et al., 2012a, 2012b), including contextual behavioral psychology (Edwards et al., 2017). Future studies could utilise some of these theories to better understand any expectation bias.

In terms of clinical practice, as these findings demonstrate that MFR can be effective in increasing both local and distal ROM and PPT, this can potentially help practitioners to better understand the efficacy of MFR treatment in restoring tissue extensibility to connective tissue and returning it to normal pliability and viscosity both locally and distally as well as reducing pain. In addition to this, as baseline IS correlated with both ROM and PPT, this suggests that clinicians may be able to use this as a predictor of treatment outcomes in the diagnosis stage. However, these suggestions are made with caution as clinical trials would need to follow in order to make concrete implications of these findings to clinical practice.

There were some limitations to this study, firstly, asymptomatic participants were used and not clinical patients, so the degree to which these results will generalise to a clinical population is uncertain until a clinical trial is conducted. Secondly, this was a convenience sample of only 12 participants, so a larger study with a full sample size calculated through a power analysis should follow this study to ensure the consistency of these results. Thirdly, it is also recognised that having several hypotheses does increase the chance of finding a false positive (a type one error). Fourth, in the control and sham conditions the participants were

in the supine position, whilst in the experimental intervention (MFR) the participants were in the prone position. It is acknowledged that position may have influence the results to some degree. The fact that this was a repeated measures study was not deemed a limitation as the order of condition sequences were randomised with a one-week washout period to balance any learning effects, but as with all cross-over designs it is acknowledged that learning effects do occur.

In summary, this work produced some interesting findings in relation to how MFR can affect PPT and ROM outcomes as well as how IS relates to ROM and PPT. Several accounts were given through the biomechanical, systemic and interoceptive systems. This work may help further develop more unified models of osteopathy such as the 'comprehensive pathway' model as described by Bialosky et al. (2009). Further work could now explore additional aspects of the various pathways, with additional cognitive modelling and neuroscience data. One specific aspect for further work could be to explore how other more specific ANS measures such as heart rate variability is influenced by MFR.

Acknowledgments

None.

Conflict of Interest

The authors report no conflict of interest.

References

Adigozali, H., Shadmehr, A., Ebrahimi, E., Rezasoltani, A., Naderi, F. (2016). Reliability of assessment of upper trapezius morphology, its mechanical properties and blood flow in female patients with myofascial pain syndrome using ultrasonography. *Journal of Bodywork and Movement Therapies,* available online.

Ajimsha, M. S., Al-Mudahka, N. R., & Al-Madzhar, J. A. (2015). Effectiveness of myofascial release: Systematic review of randomized controlled trials. *Journal of bodywork and movement therapies*, *19*(1), 102-112.

Antonaci, F., Sand, T., Lucas, G. (1998). Pressure algometry in healthy subjects: inter-examiner variability. *Scandinavian Journal of Rehabilitation Medicine,* 30(1):3–8.

Barnes, M. (1997). The basic science of myofascial release: morphologic change in connective tissue. *Journal of Bodywork and Movement Therapies,* 1(4), 231-238.

Bialosky, J. E., Bishop, M. D., Price, D. D., Robinson, M. E., & George, S. Z. (2009). The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Manual therapy*, *14*(5), 531-538.

Buttagat, V., Eungpinichpong, W., Chatchawan, U., Kharmwan, S. (2011). The immediate effects of traditional Thai massage on heart rate variability and stress-related parameters in patients with back pain associated with myofascial trigger points. *Journal of Bodywork and Movement Therapies,* 15(1), 15-23.

Charlton, P. C., Mentiplay, B. F., Pua, Y. H., & Clark, R. A. (2015). Reliability and concurrent validity of a Smartphone, bubble inclinometer and motion analysis system for measurement of hip joint range of motion. *Journal of Science and Medicine in Sport*, *18*(3), 262-267.

Craig, A. D. (2004). Human feelings: why are some more aware than others?. *Trends in*

cognitive sciences, *8*(6), 239-241.

Craig, A. D. (2008). Interoception and emotion: a neuroanatomical perspective. *Handbook of emotions*, *3*(602), 272-88.

Critchley, H., Wiens, S., Rotshtein, P., Öhman, A., Dolan, R. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience,* 7(2), 189-195.

Drake, R., Vogel, A., Mitchell, A. (2009). *Gray's anatomy for students.* Philadelphia: Churchill Livingstone, Elsevier.

Drewes, A., Jennum, P. (1995). Epidemiology of myofascial pain, low back pain, morning stiffness and sleep-related complaints in the general population. *Journal of Musculoskeletal Pain,* 3(1), 68.

Edwards, D.J., 2017. Unsupervised categorization with a child sample: category cohesion development. Eur. J. Dev. Psychol. 14 (1), 75e86.

Edwards, D.J., Pothos, E.M., Perlman, A., 2012a. Relational Vs. absolute representation in categorization. Am. J. Psychol. 125 (4), 481e497.

Edwards, D.J., Perlman, A., Reed, P., 2012b. Unsupervised Categorization in a sample of children with autism spectrum disorders. Res. Dev. Disabil. 33 (4), 1264e1269.

Edwards, D.J., Wood, R., 2016. Unsupervised categorization with individuals diagnosed as having moderate traumatic brain injury: over-selective responding. Brain Inj. 30 (13e14), 1576e1580.

Edwards, D. J., McEnteggart, C., Barnes-Holmes, Y., Lowe, R., Evans, N., & Vilardaga, R. (2017). The Impact of Mindfulness and Perspective-Taking on Implicit Associations Toward the Elderly: a Relational Frame Theory Account. *Mindfulness*, *8*(6), 1615-1622.

Ehlers, A., Breuer, P. (1996). How good are patients with panic disorder at perceiving their heartbeats? *Biological Psychology*, 42(1), 165-182.

Fischer, A. A. (1987). Pressure algometry over normal muscles. Standard values, validity and reproducibility of pressure threshold. *Pain*, *30*(1), 115-126.

Fleiss, J.L., 1987. The design and analysis of clinical experiments. In: Computers & Mathematics with Applications, vol 14. Wiley Classics Library, New York.

Garfinkel, S. N., & Critchley, H. D. (2013). Interoception, emotion and brain: new insights link internal physiology to social behaviour. Commentary on: "Anterior insular cortex mediates bodily sensibility and social anxiety" by Terasawa et al.(2012). *Social cognitive and affective neuroscience*, *8*(3), 231-234.

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: distinguishing interoceptive accuracy from interoceptive awareness. *Biological psychology*, *104*, 65-74.

Gellhorn, E. (1967) Principles of Autonomic–Somatic Integration: *Physiological Basis and Psychological and Clinical Implications*. University of Minnesota Press, Minneapolis, MN

Huijing, P., Langevin, H. (2009). Communicating about fascia: history, pitfalls and recommendations. *International Journal of Therapeutic Massage and Bodywork*, 2(4), 3-8.

Lin, H. Y., & Wang, T. J. (2015). Reliability of dual digital inclinometer in measuring thoracic kyphosis angle and thoracic mobility in healthy adults. *Physiotherapy*, *101*, e879-e880.

MacDermid, J. C., Arumugam, V., Vincent, J. I., Payne, K. L., & So, A. K. (2015). Reliability of three landmarking methods for dual inclinometry measurements of lumbar flexion and extension. *BMC musculoskeletal disorders*, *16*(1), 121.

MacDermid, J. C., Arumugam, V., Vincent, J. I., & Carroll, K. L. (2014). The reliability and

validity of the computerized double inclinometer in measuring lumbar mobility. *The open orthopaedics journal*, *8*, 355.

Mallorquí-Bagué, N., Garfinkel, S. N., Engels, M., Eccles, J. A., Pailhez, G., Bulbena, A., & Critchley, H. D. (2014). Neuroimaging and psychophysiological investigation of the link between anxiety, enhanced affective reactivity and interoception in people with joint hypermobility. *Frontiers in psychology*, *5*, 1162.

McCoss, C. A., Johnston, R., Edwards, D. J., & Millward, C. (2017). Preliminary evidence of Regional Interdependent Inhibition, using a 'Diaphragm Release'to specifically induce an immediate hypoalgesic effect in the cervical spine. *Journal of bodywork and movement therapies*, *21*(2), 362-374.

Melzack, R. (1999). From the gate to the neuromatrix. *Pain*, *82*, S121-S126.

Mastaglia, F. (2012). The relationship between muscle pain and fatigue. *Neuromuscular Disorders*, 22(3), S178-S180.

Mense, S., Hoheisel, U. (2016). Evidence for the existence of nociceptors in rat thoracolumbar fascia. *Journal of Bodywork and Movement Therapies*, 20(3), 623-628.

Petersen, S., Schroijen, M., Moelders, C., Zenker, S., & Van den Bergh, O. (2014). Categorical interoception: perceptual organization of sensations from inside. *Psychological science*, *25*(5), 1059-1066.

Podichetty, V., Mazanec, D., Biscup, R. (2003). Chronic non-malignant musculoskeletal pain in older adults: clinical issues and opioid intervention. *Postgraduate Medical Journal*, 79(937), 627-633.

Pollatos, O., Traut-Mattausch, E., Schandry, R. (2009). Differential effects of anxiety and depression on interoceptive accuracy. *Depression and Anxiety*, 26(2), 167-173.

Pollatos, O., Füstös, J., Critchley, H. D. (2012). On the generalised embodiment of pain: how

interoceptive sensitivity modulates cutaneous pain perception. *Pain,* 153(8), 1680-1686.

Prushansky, T., Deryi, O., & Jabarreen, B. (2010). Reproducibility and validity of digital inclinometry for measuring cervical range of motion in normal subjects. *Physiotherapy Research International*, *15*(1), 42-48.

Rolf, I. (1977). *Rolfing: The Integration of Human Structures.* Dennis Landman: Santa Monica.

Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, 18(4), 483-488.

Schleip, R. (2003). Fascial plasticity - a new neurobiological explanation: Part 1. *Journal of Bodywork and Movement Therapies*, 7(1), 11-19.

Shrout, P.E., Fleiss, J.L., 1979. Intraclass correlations: uses in assessing rater reliability. *Psychol. Bull*. 86, 420-428

Skootsky, S., Jaeger, B., Oye, R. (1989). Prevalence of myofascial pain in general internal medicine practice. *Western Journal of Medicine,* 151(2), 157.

Stecco, L. (2004). Fascial Manipulation for musculoskeletal pain. Piccin, Padova

Stoeter, P., Bauermann, T., Nickel, R., Corluka, L., Gawehn, J., Vucurevic, G., ... & Egle, U. T. (2007). Cerebral activation in patients with somatoform pain disorder exposed to pain and stress: an fMRI study. *Neuroimage*, *36*(2), 418-430.

Tozzi, P. (2012). Selected fascial aspects of osteopathic practice. *Journal of Bodywork and Movement Therapies,* 16(4), 503-519.

Tucker, W. S., & Ingram, R. L. (2012). Reliability and validity of measuring scapular upward rotation using an electrical inclinometer. *Journal of Electromyography and Kinesiology*, *22*(3), 419-423.

Urbaniak, G.C. & Plous, S. (2013). Research Randomizer (Version 4.0) [Computer software].

Retrieved on September 22, 2017, from http://www. randomizer.org/

Whelan, G., Johnston, R., Millward, C., & Edwards, D. J. (2017). The immediate effect of osteopathic cervical spine mobilization on median nerve mechanosensitivity: A triple-blind, randomized, placebo-controlled trial. To be published in Journal of Bodywork & Movement Therapies/[Preprint] 2018 [cited 8 January 2017]. Available from: http://www.bodyworkmovementtherapies.com/article/S1360-8592(17)30109-2/fulltext https://doi.org/10.1016/j.jbmt.2017.05.009

Ylinen, J., Nykänen, M., Kautiainen, H., & Häkkinen, A. (2007). Evaluation of repeatability of pressure algometry on the neck muscles for clinical use. *Manual therapy*, *12*(2), 192-197.

Figure 1.
Consort Flow Diagram with three groups and with immediate effects recorded.

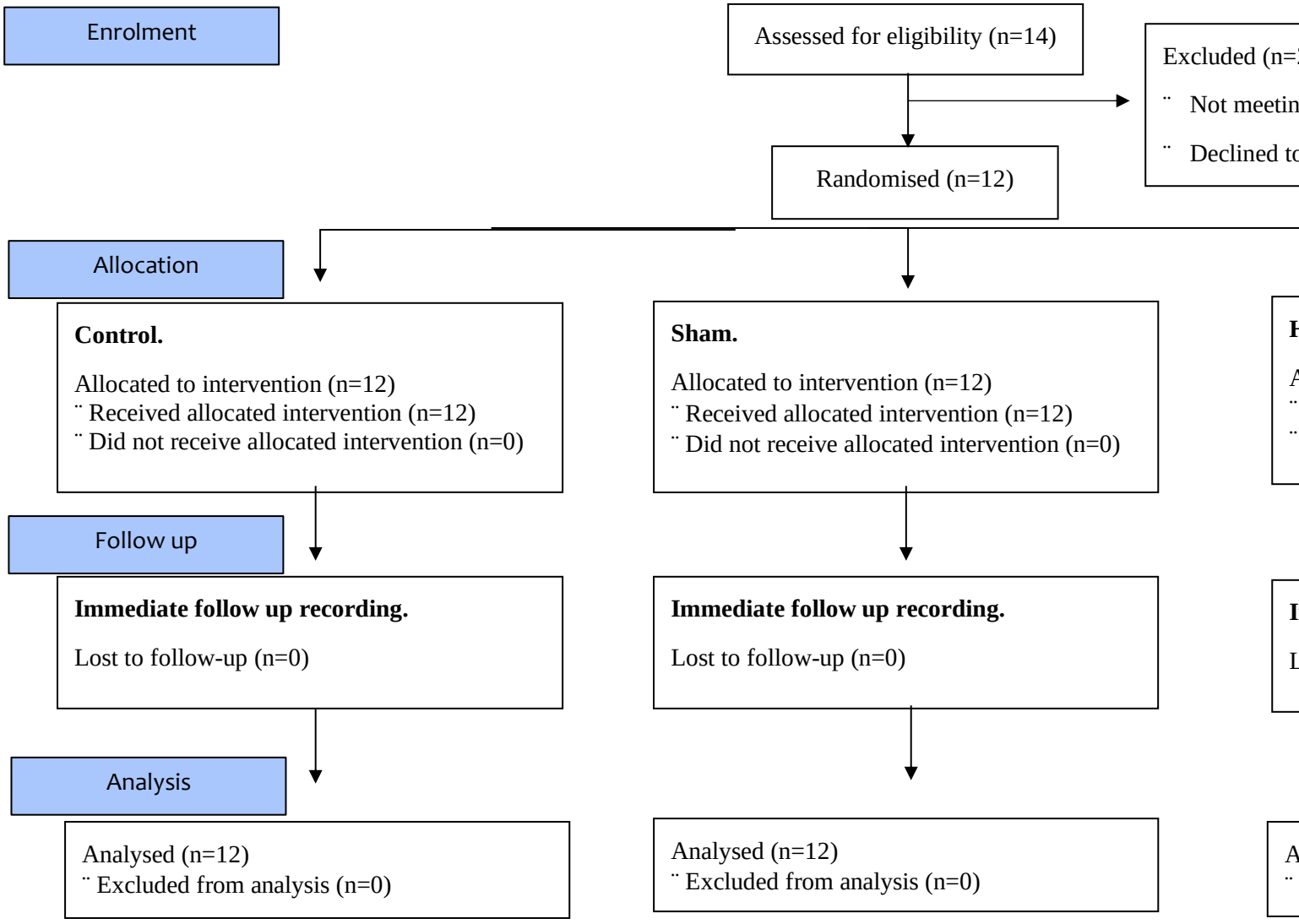
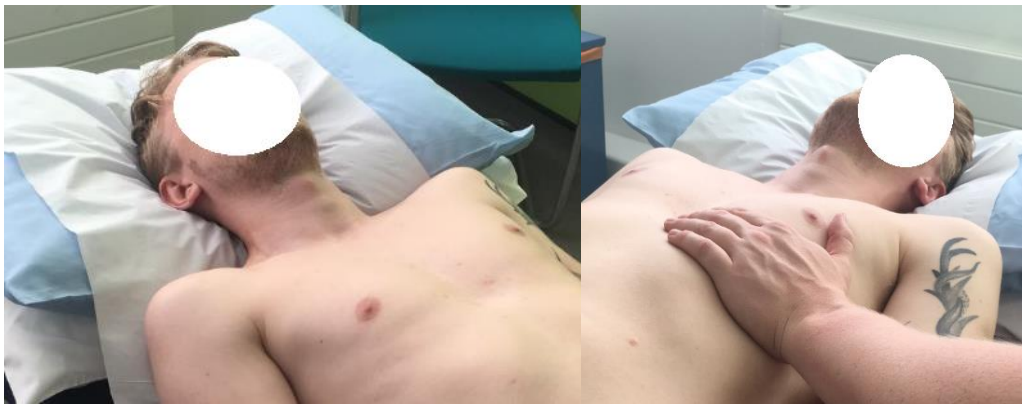


Figure 2:
Top left, lying supine (control); top right, not active touch (sham); bottom, the myofascial release technique



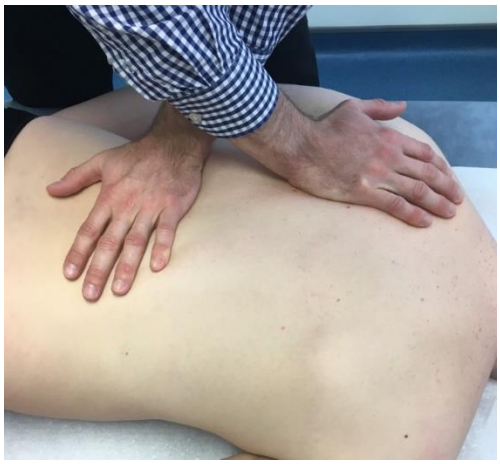


Table 1.
Demographic data.

Measurement Means	Total subjects	Mean	SD	Range	
				Minimum	Maximum
Age (Years)	12	23.08	7.25	18	41
Height (CM)	12	178.17	11.83	158	198
Weight (KG)	12	73.33	14.05	50	105
BMI	12	22.84	2.02	19.5	26.70

SD=Standard Deviation; Age=years; Weight=kilograms; Height=Centimetres; BMI= Body Mass Index. Male (N=7), Female (N=5). Total N = 12

Table 2.
Intra-rater reliability PPT

	Interclass Correlation	95% Confidence interval		Level of reliability	*p*
		Lower Bound	Upper Bound		
Pre-intervention Cervical spine	0.986	0.951	0.996	Excellent	<0.001
Pre-intervention Back	0.986	0.944	0.996	Excellent	<0.001
Pre-intervention Leg	0.986	0.956	0.997	Excellent	<0.001

Note: Shrout and Fleiss (1979) classification reliability>0.75, excellent; 0.6-0.75, good; 0.4-0.59, fair; and <0.4, poor.

Table 3.
Mean, standard deviation (SD) and standard error (SE) of PPT change scores for each condition. Positive numbers indicate an increase in the measure post condition.

Study Condition	N	Mean	SD	SE	Range (min-max)
ConChgePPTLL	12	-0.32	0.42	0.12	-1.25 to 0.11
ShamChgePPTLL	12	-0.11	0.29	0.08	-0.55 to 0.28
MFRChgePPTLL	12	0.24	0.12	0.04	0.04 to 0.42
ConChgePPTRL	12	-0.21	0.31	0.89	-0.86 to 0.20
ShamChgePPTRL	12	-0.14	0.36	0.10	-0.89 to 0.24
MFRChgePPTRL	12	0.18	0.35	0.10	-0.58 to 0.90
ConChgePPTLB	12	-0.06	0.27	0.08	-0.59 to 0.34
ShamChgePPTLB	12	-0.09	0.41	0.12	-0.77 to 0.63
MFRChgePPTLB	12	0.52	0.29	0.08	0.165 to 1.12
ConChgePPTRB	12	-0.18	0.22	0.06	-0.620 to 0.09
ShamChgePPTRB	12	-0.09	0.33	0.09	-0.75 to 0.33
MFRChgePPTRB	12	0.52	0.32	0.09	0.07 to 1.25
ConChgePPTLN	12	0.02	0.22	0.06	-0.34 to 0.45
ShamChgePPTLN	12	0.11	0.27	0.08	-0.27 to 0.75
MFRChgePPTLN	12	0.37	0.38	0.11	-0.08 to 1.25
ConChgePPTRN	12	0.05	0.17	0.05	-0.24 to 0.33
ShamChgePPTRN	12	0.02	0.23	0.07	-0.31 to 0.54
MFRChgePPTRN	12	0.37	0.25	0.07	0.06 to 0.50

Note: ConChge = control change; ShamChge = sham change; MFRchge = MFR change; PPT= pain pressure threshold; LL = left leg; RL = right leg; LN = left neck; RN = right neck; LB = left back; RB = right back

Table 4.
Mean, standard deviation (SD) and standard error (SE) of ROM change scores for each condition. Positive numbers indicate an increase in the measure post condition.

Study Condition	N	Mean	SD	SE	Range (min-max)
ConChgeROM	12	-0.75	2.34	0.66	-5 to 2
ShamChgeROM	12	-0.75	2.77	0.79	-4 to 2
MFRChgeROM	12	5.72	3.13	0.90	-1 to 12

Note: ConChge = control change; ShamChge = sham change; MFRchge = MFR change; ROM = range of motion

Table 5.
Mean, standard deviation (SD) and standard error (SE) of IS change scores for each condition. Positive numbers indicate an increase in the measure post condition.

Study Condition	N	Mean	SD	SE	Range (min-max)
ConChgeIS	12	68.00	42.91	12.39	15 to 161
ShamChageIS	12	70.08	56.39	16.28	6 to 177
MFRChgeIS	12	118.33	90.77	26.20	11 to 275

Note: ConChge = control change; ShamChge = sham change; MFRchge = MFR change; ROM = range of motion; IS = interoceptive sensitivity