Immediate effect of a spinal mobilisation intervention on muscle stiffness, tone and elasticity in subjects with lower back pain – A randomized cross-over trial.

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Background: Despite the lack of objective evidence, spinal manual therapies have been common practice for many years, particularly for treatment of lower back pain (LBP). This exploratory study measured and analysed the effect of a spinal mobilisation intervention on muscle tissue quality in LBP sufferers.

Methods: 40 people with LBP participated in a within-subject repeated measures cross-over study with intervention and control conditions. A myometer was used to assess the change in para-spinal muscle tissue quality before and after the intervention. Analysis considered the magnitude of muscle response together with individual covariates as potential contributors.

Results: A significant post intervention reduction was observed in muscle stiffness ($p = 0.012$, $\eta^2_{partial} = 0.15$), tone ($p = 0.001$, $\eta^2_{partial} = 0.25$) and elasticity ($p = 0.001$, $\eta^2_{partial} = 0.24$). Significant increases were seen in 2 variables post control: stiffness ($p = 0.004$, $\eta^2_{partial} = 0.19$), tone ($p = 0.006$, $\eta^2_{partial} = 0.18$) and a significant decrease in elasticity ($p < 0.000$, $\eta^2_{partial} = 0.3$). Significant contributing covariates include baseline stiffness, BMI, waist circumference and sex. Baseline stiffness and tone were significantly correlated to their response levels.

Conclusions: The significant reduction in all muscle tissue qualities following the intervention provide preliminary data for an evidence-based LBP therapeutic. Baseline stiffness, BMI, waist circumference and sex could act as significant contributors to magnitude of response. The results warrant further investigation into spinal mobilisation therapies to further build the objective evidence base.

CTR: NCT04012970
Word count: 248

Keywords:
Lower back pain
Spinal mobilisations
Myometry
Muscle stiffness

Introduction

Lower back pain (LBP) is one of the most common and economically debilitating pain conditions globally. It is associated with decreased levels of spinal mobility, limited lumbar muscle flexibility and altered spinal kinematics (Ferreira et al., 2009; Goertz et al., 2016; Powers et al., 2008). The likely result of this, is reduced function of the lumbar spine and increased stiffness. This can have an impact on body movement capability and lead to the development of chronic problems with posture, coordination and range of motion (RoM) (Shum et al., 2013, 2007). Manual therapy (MT) is a physical-based therapeutic reportedly used for LBP treatment which targets musculoskeletal structures through several different techniques (Bishop et al., 2015). Commonly reported benefits from MT-based techniques are improvements in RoM, pain relief and muscle stiffness. However, these are often subjectively assessed (Ferreira et al., 2009; George et al., 2006; Lopez-Lopez et al., 2015) with both positive (Chiradejnant et al., 2003; George et al., 2006; Haas et al., 2014; Sterling et al., 2001) and conflicting results (Assendelft et al., 2003; Childs et al., 2004; Goodsell et al., 2000; Stamos-Papastamos et al., 2011; Thomson et al., 2009). These inconsistencies may be explained by methodological differences as well as variability in individual responses to treatment (Childs et al., 2004; Shum et al., 2013). Further, although commonly used in clinical practice to treat musculoskeletal pain, there is limited understanding of the mechanisms responsible for the reported benefits of MT (Goertz et al., 2016; Voogt et al., 2015). The rationale to establish the efficacy of such treatments is supported by the National Institute of Clinical Excellence, given their low risk of minor side effects and potential millions in economic savings (Carnes et al., 2010; National Institute for Health and Care Excellence, 2016; Powers et al., 2008; Stamos-Papastamos et al., 2011; Wong et al., 2016).

Spinal mobilisations is a MT technique used to treat such chronic pain (Chiradejnant et al., 2003; Goodsell et al., 2000; Sterling et al., 2001; Thomson et al., 2009), typically applied in a precise manner, using low velocity oscillatory movements to mobilise joints and passively stretch soft tissues (Maitland et al., 2013; Piekarz and Perry, 2015). While objective research on the efficacy of spinal mobilisations as an LBP treatment has been conducted in recent years, more efficacy based evidence is needed (Piekarz and Perry, 2016), and a better understanding of the response to such treatment is required.

Nonetheless, lower back muscle stiffness appears to be a meaningful contributor to reduced mobility and has seen a growth in investigative literature (Edgecombe et al., 2013; Ferreira et al., 2009). However, information about other aspects of muscle quality that collectively contribute to mobility are lacking but are required to aid improved muscle condition understanding (Kelly et al., 2018; Marusiak et al., 2012; Nair et al., 2016). The capacity of a muscle to resist deformation, either by contraction or external force can be objectively measured using a myometer to show stiffness or compliance. A muscle with higher stiffness has a higher resistance to contraction (Viir et al., 2006). Muscle stiffness can be assessed by palpation as well as characterised biomechanically. Muscle tone characterises the background tension of the muscle in a resting state. Background tension is required to retain stability, structure, and involuntary contractions. However, hypertonicity can cause high intramuscular pressure and have a harmful effect on muscle recovery. Elasticity of a muscle describes its ability to return to original shape after deformation and can be a used as a measure for mechanical stability and tissue changes (Kelly et al., 2018; Schneider et al., 2014). In this study we seek to measure these tissue property changes to contribute to the knowledge of the effectiveness of spinal mobilisation in people with LBP (Kelly et al., 2018; Nair et al., 2016).

This study was an exploratory investigation of MT response and potential contributing factors. We measured the change in stiffness, tone and elasticity in response to a spinal mobilisation intervention within an LBP population to provide objective data for this. This is the first scientific investigation of a 30-minute sustained spinal mobilisation intervention and objective measures of muscular change. This is to provide a contribution to knowledge on MT effectiveness and their beneficial mechanisms within LBP and provide recommendations for further data collection to improve understanding.

We hypothesised that a reduction in paraspinal muscular stiffness and tone and increase in elasticity after receiving a spinal mobilisation intervention could be objectively identified with a validated protocol when compared to a sedentary scenario.

Methods

Participants

40 participants were recruited for this study (male: n = 18, female: n = 22) in a repeated-measures cross-over study design, similar to previous investigations (Goodsell et al., 2000; Jowsey and Perry, 2010; Pecos-Martín et al., 2017; Pentelka et al., 2012). Participants were recruited through posters and word of mouth advertised at Edinburgh Napier University and shared on social media.

Inclusion criteria for participation were: age range 18 to 80 and suffering from any form of self-reported LBP (acute, chronic, diagnosed, undiagnosed, if pain was experienced in the region between the 12th rib and the gluteal folds within the time of recruitment). Participants were excluded if they responded positively to any absolute contraindications for spinal therapy (Liebenson, 2007; Olson, 2009). These include: segment instability, infectious disease, osteomyelitis, bone tumours, neurological deficit, upper motor neuron lesion, spinal cord damage, or cervical arterial dysfunction. Participants responding positively to relative contra-indications were asked to contact their GP and excluded based on severity. These include: osteoporosis, spinal instability, rheumatoid arthritis, inflammatory disease, active history of cancer, hypermobile syndrome, segment hypermobility, cardiovascular disease, cervical anomalies, nerve root disorder, spinal surgery, respiratory problems, thrombosis, open wounds, local infection and fractures or dislocations (Maitland et al., 2013). Ethical approval was obtained from the Edinburgh Napier University Research Integrity Committee, following the ethical guidelines stated by the Declaration of Helsinki.

Procedure

Participants attended a control and a spinal mobilisation intervention session one week apart, at the same time of day for each session. All participants were informed about study details and provided written consent. Participants were randomly allocated into one of two groups via a random group generator, alternating the order of session type they received. All data collection took place in the same treatment room and on the same standard physiotherapy plinth. Ambient room temperature was controlled (20°-23° Celsius) for all sessions.

All participants completed the Oswestry Disability Index (ODI) (Fairbank and Pynsent, 2000) prior to their first session to categorise their level of LBP (Chou and Huffman, 2007; Fritz et al., 2011; Kamali and Shokri, 2012; Savigny P Watson P, Underwood M, Ritchie G , Cotterell M, Hill D, Browne N, Buchanan E, Coffey P, Dixon P, Drummond C, Flanagan M, Greenough,C, Griffiths M, Halliday-Bell J, Hettinga D, Vogel S, Walsh D., 2009). Anthropometric measures of height, mass, waist circumference and sex were also recorded. These were taken as pre-measures to investigate correlations as potential influencers on response and focus on muscle tissue response as the main investigation.

The chartered physiotherapist performing the treatment had extensive experience in spinal mobilisation therapy and as a working physiotherapist in practice at the time of the study. They performed a 30-minute spinal mobilisation intervention, working at a specific rate (0.37Hz) maintained by a metronome (on silent but within view of the therapist) set to the equivalent 22 beats per minute. The physiotherapist worked at a grade lower than grade 1 and specific location (L1-L5), using posteroanterior (PA) mobilisations, oscillating the lumbar vertebra, with both hands working on one side of the lumbar spine. Contact remained consistent over the 30-minute period. These intervention parameters were based on previous physiotherapy practice with anecdotal evidence of success within LBP. The intervention was focussed on the lumbar spine to facilitate data collection.

Outcome measures for muscle stiffness, tone and elasticity were taken immediately before and after both sessions, with participants lying prone. The intervention was performed on one side of the lumbar spine (determined by pre-intervention stiffness values). The control session involved no physical touch. The participant lay on the plinth and was encouraged to relax for 30 minutes. The outcome measures were taken by the lead researcher who was not involved in performing the intervention but was there to oversee the session.

Outcome measures

Measurements for para-spinal muscle stiffness, tone and elasticity were taken using a myometer palpation device (MyotonPRO, Myoton Ltd., London UK). This previously validated handheld device has been documented to give reliable results for muscle stiffness, tone and elasticity (Bizzini and Mannion, 2003; Marusiak et al., 2012; Pruyn et al., 2015; Schneider et al., 2014; Sohirad et al., 2017; Zinder and Padua, 2011). The myometer uses a series of low force mechanical impulses (0.4N) registered as an oscillation in the form of an acceleration signal. The muscle quality parameters are reported as a mean of these impulses along with the coefficient of variation (CV), with recommended CV acceptance values of <3% (Kelly et al., 2018; Schneider et al., 2014; Viir et al., 2006).

Measures were repeated 3 times on each side of the spine, to determine which side had higher levels of stiffness and therefore the side to receive treatment. This was due to literature suggesting that greater initial stiffness levels were more likely to respond with a greater stiffness reduction (Childs et al., 2004; Shum et al., 2013). The location for measurements were identified on both sides of the spine on a central point of the erector spinae by asking the participant to lift their head and feet at the same time contracting their back muscles. This spot was then marked to ensure pre- and post-measures were taken at the same location. The distance and width from the base of the spine was measured to locate the same spot for their 2nd session. The myometer was held perpendicular to the identified spot and oscillations were sent through to the corresponding muscle.

Analysis

Analysis was exploratory and therefore carried out on each dependent variable (stiffness, tone and elasticity) in separate 2-way repeated measure within participant ANOVAs to determine any significant differences that occurred due to the independent variables; condition (control and intervention) and time (pre- and post-). Covariates were assessed in separate ANCOVAs to determine significant factors contributing to muscle changes. Due to previously reported differences in male and female muscle characteristics (Granata et al., 2002; Owens et al., 2007), the sex variable was investigated further with independent t-tests and Pearson correlations, as well as within the ANCOVA analysis. All statistical analysis was carried out using SPSS (version 23) with the alpha level set at 0.05.

Results

Pre- intervention anthropometric measures and ODI scores presented in table 1 for 40 LBP participants and demonstrate a wide LBP population recruitment. Shapiro Wilk tests revealed no normality violations in the dependent variable results. A post-hoc power calculation using G-power (version 3.1) revealed an accepted power level of 0.91 (alpha = 0.05, sample size = 40, groups = 2, measurements = 3).

Muscle stiffness

A 2-way repeated measures ANOVA revealed a pre- to post- intervention significant main effect interaction (between condition and time). Pairwise comparisons were used to determine where specific differences lie in a pre- to post- comparison, revealing a significant stiffness increase within the control and a significant decrease within the intervention (table 2, fig. 1).

ANCOVA was performed using all covariates to explore their interaction with the change in stiffness post intervention. Change in stiffness was used as the dependent variable. Pre intervention stiffness, BMI, ODI, waist circumference, height and sex were added as covariates. A backward elimination was conducted based on highest p-value. The only covariate remaining with significant influence was pre-intervention stiffness ($p = 0.002$) with resultant model $R^2 = 0.22$ (adjusted = 0.2). There was a significant bivariate correlation between pre intervention stiffness and change in stiffness (table 3). This results in a negative correlation due to the reduction in stiffness seen in figure 1.

An independent t-test revealed a significant difference between male and female intervention stiffness change ($p = 0.032$). Bivariate correlations for pre-intervention stiffness and stiffness change carried out separately with male and female data displayed similar trends (table 3).

Muscle tone

A 2-way repeated measures ANOVA revealed a pre- to post- intervention significant main effect on muscle tone (condition) and the interaction (between condition and time). Pairwise comparisons revealed a significant tone increase within the control group and a significant tone decrease within the intervention group (table 2, fig. 2).

ANCOVA was performed using muscle tone as the dependent variable run in the same way as above. BMI ($p = 0.048$), waist circumference ($p = 0.01$) and sex ($p = 0.005$) were found to be significant contributors to tone change with resultant model $R^2 = 0.253$ (adjusted = 0.19). There was a significant bivariate correlation between pre intervention tone and change of tone (table 3), resulting in a negative correlation due to the reduction in tone (fig. 2).

An independent t-test revealed no significant difference between male and female tone change ($p = 0.052$). Bivariate correlations for pre intervention tone and tone change conducted separately with male and female data show different patterns (table 3).

Muscle elasticity

A 2-way repeated measures ANOVA revealed a pre- to post- intervention significant main effect on muscle elasticity (time). Pairwise comparisons revealed a significant increase in muscle logarithmic decrement within the control from pre- to post-intervention and a significant increase within the intervention condition (table 2, fig. 3). This equates to a decrease in muscle elasticity due to its inversely proportional relationship to muscle decrement.

ANCOVA was performed using changes in elasticity as the dependent variable, in the same way as above. There were no covariates with a significant influence on decrement change. A bivariate correlation between pre-intervention decrement in elasticity and decrement change was not significant (table 3).

An independent t-test revealed no significant difference between male and female elasticity change ($p = 0.162$) and bivariate correlations for pre intervention decrement in elasticity and decrement change conducted for male and female data displayed no pattern (table 3).

Discussion

The previously reported benefits of MT range from reduced pain, stiffness, fatigue and improved RoM (Ferreira et al., 2009; Lopez-Lopez et al., 2015; Voogt et al., 2015). Greater knowledge of the mechanistic changes occurring due to MT will benefit LBP management and inform treatment recommendations. The findings from this study suggest that a reduction in lower back para-spinal stiffness can be measured after a 30-minute treatment session and could be determined by initial stiffness levels. These results are an indication of an immediate effect on muscle tissue quality after this specific 30-minute spinal mobilisation treatment. However, differences in specific clinical practices should be taken into consideration for the application of results.

We show for the first time an immediate, objective and significant reduction in para-spinal stiffness with a large effect size (table 2) after a 30-minute spinal mobilisation treatment (fig. 1), supported by previous literature (Ferreira et al., 2009; Fritz et al., 2011; Shum et al., 2013; Wong et al., 2015). However, large SEM values could have resulted from the exploratory nature of the study and the wide recruitment. This reduces the confidence of the findings; therefore, we recommend this stiffness reduction is investigated further with distinct LBP population groups to achieve more meaningful results. Since stiffness characterises the muscle's ability to resist deformation, and is associated with pain and reduced mobility (Fritz et al., 2011; Haas et al., 2014; Lopez-Lopez et al., 2015; Vicenzino et al., 2001), a reduction in stiffness of these muscles may allow greater compliance to muscle contraction and therefore improve movement fluidity (Ferreira et al., 2009). This study demonstrates the impact of lying stationary for 30 minutes can have on stiffness, reinforcing the recommendation to reduce sedentary behaviour, a known risk factor for developing LBP and chronic stiffness (Hartvigsen et al., 2018; Naraoka et al., 2017).

Improved knowledge of muscular stiffness has been identified as crucial to understand underlying mechanistic changes in therapeutic interventions and apply them effectively to the populations at most need (Bailey et al., 2013; Kelly et al., 2018). Potential mechanisms responsible have been suggested to involve the activation of somatosensory signals. Mechanical induction of sensory nerves may cause adaptive signalling in the muscle spindles (stretch receptors) affecting muscle fibre ability to respond to changes in shape (Pickar and Bolton, 2012; Reed et al., 2014). Differences between the mechanical induction of muscle stretch response verses an active muscle stretch response could be further investigated in an MT and stretching study to help decipher the benefits of each. Information on significant influencers on stiffness change, such as initial stiffness levels and anthropometric measures, may help to inform these mechanistic theories through predictive modelling in large scale MT studies.

While this exploratory study demonstrates the benefit of a single MT session, there is a lack of statistical power describing the influencing factors and warrants further investigation. The key influence of initial stiffness levels could be further investigated by taking into consideration prior environmental influences on stiffness. As no significant differences were found between the control and intervention condition pre-stiffness levels (fig. 1), it was concluded that the protocol design had been successful in controlling for this. Further studies investigating other stretching and movement related interventions may also contribute insight into mechanistic changes and influencing factors.

Although the ANCOVA results showed that initial stiffness was a significant contributor to stiffness response (and a significant correlation, table 3), results for sex as a covariate were more complex. Sex did not account for the variance in stiffness within the ANCOVA model and suggests that initial stiffness values have greater influence than sex on stiffness response, supported by similar correlation trends for males and females (table 3). This could be further investigated in a sex comparison study, given the known difference between male and female muscle composition (Granata et al., 2002; Nair et al., 2016; Owens et al., 2007). It is important to note that, while ODI, BMI, waist or height measurements do not contribute to stiffness response, they could still influence the initial stiffness values. Though previous studies have also found similar baseline and stiffness change correlations (Ferreira et al., 2009; Shum et al., 2013) this correlation has not been defined objectively as a clinical predictor for intervention response (Fritz et al., 2011; Nim et al., 2020; Wong et al., 2015). The availability of objective measurement tools for muscle health, such as a myometer, will enable monitoring of intervention effectiveness for types of responders, potentially developing stiffness thresholds for responders.

Similar results for muscle tone (fig. 2) and stiffness indicate that both variables respond to the intervention in a similar way. Pre- tone measures in the control and intervention conditions were very similar with less variation than pre- stiffness measures. Muscle stiffness and tone depict different aspects of muscle quality. The myometry form of muscle tone describes resting muscle tension and is mechanically represented by the acceleration frequency of the oscillations induced and recorded. The reduced variation in tone baseline and SEM values compared to stiffness may be explained by its intrinsic nature (required for resting tension) as oppose to responsive (Bizzini and Mannion, 2003; Schneider et al., 2014; Viir et al., 2006).

The ANCOVA results for tone response revealed BMI, waist circumference and sex as contributing factors, different to the contributing factors for stiffness response. Comparison of male and female trend lines demonstrated different patterns in their pre- intervention and tone change correlations (table 3) supporting sex as a contributing factor to muscle tone in the ANCOVA model. Though stiffness and tone display similar pattern changes in previous studies (Gervasi et al., 2017; Nair et al., 2016), the resultant difference in contributing factors between them may indicate key underlying differences in their response mechanisms. The electrical signals responsible for muscle tone, though likely still influenced by adaptive signalling, may result in a greater number of influencing factors compared to tissue stiffness.

A reduction in both tone and stiffness can be beneficial to populations with chronic pain and limited movement (Chuang et al., 2012; Fröhlich-Zwahlen et al., 2014; Wong et al., 2015). Hypertonia is associated with mobility restrictions and chronic pain in conditions such as stroke and Parkinson’s (Fröhlich-Zwahlen et al., 2014). It will therefore benefit clinicians to monitor these variables and relate to functional output in rehabilitative interventions together with changes in their patients’ pain.

Elasticity results show a higher degree of variance compared to stiffness and tone (fig. 3) which is consistent with previous literature (Gervasi et al., 2017; Schneider et al., 2014). An increase in dissipation of mechanical energy (logarithmic decrement) equates to a lower level of elasticity in the muscle and its ability to recover shape after deformation (Bailey et al., 2013; Chuang et al., 2012). Both control and intervention conditions resulted in decreased elasticity in this study, suggesting that both stationary relaxing and MT affected the elasticity of para-spinal muscles in a similar way. A similar report (Schneider et al., 2014) found a decrease in stiffness and tone and an increase in decrement after testing muscles in weightlessness conditions. The reason for this is unclear and was suggested to be the result of a relaxed state. The passive nature of the therapy may have resulted in an elasticity decrease because of the participant lying still with no active movements. Therefore muscles may require active movements to have an improved effect on elasticity and could be explored in future studies with MT compared to exercise type therapies to investigate this further.

Limitations and Future Study

The results in reduced muscle stiffness and tone after a 30-minute MT intervention are encouraging. This prospective study has provided promising preliminary data and warrants further investigation to better understand the influencing factors to this muscular response and the mechanisms responsible.

Though BMI was measured in this study, this variable does not give an accurate depiction of muscle to fat ratio. Adipose tissue could be beneficial to measure in future studies as a covariate due to potential influence on stiffness results (Fröhlich-Zwahlen et al., 2014). Although the factorial, within-participant analysis should reduce this influence on stiffness due to the relative change within each participant between groups, it would be beneficial to accurately measure and investigate this variable.

Increasing the number of participants recruited with higher levels of pain, together with more comprehensive methods to rate level of pain and post intervention pain, may assist in the development of this area of research to investigate the relationship between pain and stiffness. Physical activity levels were not controlled in this study and could be a factor in baseline levels of stiffness, tone and elasticity (Nair et al., 2016). Therefore, more investigation into potential lifestyle contributions to pain in LBP could give added information about potential influences on spinal stiffness. The previously reported optimum number of treatment sessions has been 12 (Ferreira et al., 2009; Haas et al., 2014), therefore, further investigation into treatment dose and number of sessions would contribute to knowledge on MTs.

Conclusions

The 30-minute spinal mobilisation intervention had a significant immediate effect on muscle quality showing a stiffness and tone reduction in sufferers of LBP when compared to a control intervention. Initial levels of stiffness contributed to reduction levels post intervention and there was more variance in contributing factors for tone and elasticity. Although significant differences between male and female stiffness results were found, sex was not a significant contributor to stiffness reduction and likely affected initial baseline levels. Preliminary results show an immediate muscular response after a MT intervention and further study could investigate an accumulated effect after repeated sessions with further explanatory measures.

Clinical Relevance

- Findings reported of an exploratory investigation providing new objective evidence of a spinal mobilisation intervention.
- Results reveal an immediate reduction in myometry measured muscle stiffness and tone with baseline stiffness, waist circumference, BMI and sex as significant contributors.
- Objective muscle data provided for an evidence-based contribution towards manual therapy treatments.

Keywords:
Lower back pain
Spinal mobilisations
Myometry
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Acknowledgements
Edinburgh Napier University
Medical Research Scotland
Pacla Medical Ltd.

Declaration of Interest
This study was supported by Medical Research Scotland and Pacla Medical Ltd. in a PhD Studentship. Pacla Medical Ltd. provided the rationale for the project but were not involved in study design, data collection and analysis.

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