The acute effects of spinal manipulation on neuromuscular function in a-symptomatic individuals: a preliminary study

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The acute effects of spinal manipulation on neuromuscular function in asymptomatic individuals: A preliminary study

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Abstract

Objectives

To analyse the acute effects of spinal manipulation on neuromuscular function in asymptomatic individuals.

Design

Randomised controlled, cross-over trial.

Settings

Spinal manipulation (SM) is used as therapeutic modality for various neuromuscular disorders and also in sport with asymptomatic individuals to improve range of motion and/or facilitate motor control. Experimental evidence of its effectiveness is lacking.

Participants

27 asymptomatic participants (15 males and 12 females) [age (mean ± standard deviation) 24 ± 3 years] were exposed to three separate treatments in random order: 1) Spinal Manipulation of the lumbar spine (MAN); 2) Stretching of the Lumbar spine (STR); 3) sham manipulation (SHA).

Main outcome measures

Before (PRE), after (POST) and 15 min after (15_MIN) each treatment, the participants were asked to perform three tasks always in the same order: 1) force fluctuation task; 2) Modified Sörensen's test; 3) sit and reach. Surface EMG was recorded from Gastrocnemius medialis and Erector Spinae muscles using linear arrays during task 1 and 2.

Results

MAN was not shown to determine improvements superior to other treatments in the control of force output and sEMG parameters.

Conclusions

Studies with larger populations are needed in order to ascertain the effectiveness of SM on neuromuscular function.

1. Introduction

Spinal manipulative therapies (Spinal Manipulation [SM] and Spinal Mobilisation [SMob]) have been used over the years as an alternative therapeutic approach to help patients with acute low back pain (LBP), neck pain and other neuromuscular disorders. In particular, SM has also extended to athletes to favour recovery, improve performance and/or as a treatment for acute and chronic muscle pain (George and Delitto, 2002, Haldeman, 1986 and Shrier et al., 2006). Spinal manipulation is characterised by mechanical inputs applied to tissues in the vertebral column. A cracking or popping sound usually accompanies the manipulation due

to the fluid cavitation caused by gapping the joint (Cascioli et al.,2003, Evans, 2002 and Haas, 1990). The consequences of this manipulative input are not only mechanical. In fact, some studies have suggested the possibility of acute alterations in motoneuron pool activity following spinal manipulation in a-symptomatic individuals (Dishman and Bulbulian, 2000, Dishman and Bulbulian, 2001 and Dishman et al., 2008). Due to the potential for such therapeutic techniques to acutely influence neuromuscular function, most applications have been focused on using it as a non-pharmacological treatment for pain. However, consensus on its effectiveness is controversial and studies directed to improve the understanding of the neurophysiological effects of SM recruiting a-symptomatic individuals are lacking.

To our knowledge, only one study has investigated the influence of SM on voluntary contractions. Keller and Colloca (Keller & Colloca, 2000) assessed the influence of SM on erector spinae's surface EMG (sEMG) during a maximal isometric back extension (MVC) in participants with low back pain. SM determined a mean increase of 21% in sEMG amplitude during MVC, which the authors attributed to an acute increase in the excitability of the alpha motoneuron pool and the inhibition of nociception.

SM has also been suggested to affect neural outputs to muscles related to the manipulated section of the spine due to the acute alterations in motoneuronal excitability caused by the spinal thrust. Suter et al., 1999 and Suter et al., 2000 showed that sacroiliac SM determines a decrease in muscle inhibition and increase in knee extensor strength, especially in the leg ipsilateral to SM in patients with anterior knee pain. Grindstaff et al. (Grindstaff, Hertel, Beazell, Magrum, & Ingersoll, 2009) showed a significant increase in quadriceps force immediately following SM in healthy individuals. Smith et al. (Smith, Dainoff, & Smith, 2006) investigated difficulty tasks related to Fitt's law (Fitts, 1992) and concluded that SM can elicit immediate changes in coordinated motor performance in patients with pain. Despite these promising results, recent work has also suggested a lack of evidence for manipulative therapy to enhance exercise performance (Ward, Coats, Ramcharan, Humphries, Tong, & Chu, 2012) and/or improve strength and basketball throws accuracy (Humphries, Ward, Coats, Nobert, Amonette, & Dyess, 2013). Furthermore, there seems to be no acute influence of SM on (Grindstaff et al., 2014) quadriceps spinal reflex excitability in asymptomathic subjects, putting into question some of the neurophysiological mechanisms hypothesised to be responsible for pain reduction with SM.

The use of motor tasks involving the production of constant levels of force has been utilised as a model to study various aspects of motor control (Taylor, Christou, & Enoka, 2003). The extent of the variability in maintaining the force target has been regarded as a measure of unsteadiness in motor control output and related to motor unit activity of the involved muscle groups. Since motor unit activity is controlled by the neural inputs to the α-motoneuron pool in the spinal cord (Taylor et al., 2003 and Tracy et al., 2005), the potential effect of afferent input to the force fluctuations has been postulated and recent evidence (Yoshitake, Shinohara, Kouzaki, & Fukunaga, 2004) has suggested that Ia afferent inputs contribute to the low-frequency force fluctuations in plantar flexion. Therefore, if SM is capable of acutely altering neuromuscular excitability in muscles affected by the SM procedure one should expect to observe an improvement in controlling force output.

Consensus on the clinical effectiveness of SM is far from being defined. Michaleff, Lin, Maher, & van Tulder (2012) suggested SM to be a cost-effective treatment to manage spinal pain and recent work suggested beneficial effects larger than conventional anti-inflammatory therapy (Von Heymann, Schloemer, Timm, & Muehlbauer, 2012). This despite systematic reviews suggesting some beneficial effects (Goertz, Pohlman, Vining, Brantingham, & Long, 2012) of SM on pain. The uncertainty over the clinical effectiveness of SM is accompanied by a paucity of well-controlled studies on the acute and chronic physiological consequences of this therapeutic modality.

Hence, the aim of this preliminary study was to analyse, in healthy asymptomatic participants, the acute effects of SM on: 1) force fluctuation and muscle activation of the leg neurologically related to the site of

SM; 2) spine and lower limbs range of motion (ROM). It was hypothesised that SM could acutely improve muscle activation, reduce the variability in producing force in an isometric task and improve ROM.

2. Methods

2.1. Study design

A randomised controlled-cross over design was adopted. 27 participants (15 males and 12 females) [age (mean ± standard deviation) 24 ± 3 years, BMI 23.6 ± 2.5 kg/m] were recruited and voluntarily participated in the study signing an informed consent. Sample size was determined based on repeatability data from Rainoldi, Galardi, Maderna, Comi, Lo Conte, & Merletti (1999) and assuming a medium effect size (f = 0.25), a power of 0.90 and α = 0.05. The study was approved by the Harrow Ethics Committee (reference number: 09/H0709/16). The participants were asked to report to the laboratory on four separate occasions: the first time for a familiarisation trial of the plantar flexion procedure and the three subsequent times to undergo the three different treatments in a randomised order. The three treatments were: 1) Spinal Manipulation of the lumbar spine (MAN); 2) Stretching of the Lumbar spine (STR); 3) sham manipulation (SHA). All treatments (MAN, SHA, STR) were administered by the same investigator (an experienced chiropractor).

Before (PRE), after (POST) and 15 min after (15_MIN) the intervention, the participants were asked to perform three tasks always in the same order: 1) a force fluctuation task: an isometric plantar flexion at 80% of MVC; 2) 10 s of modified Sörensen's test; 3) the sit and reach test.

2.2. Treatment procedures

MAN consisted of a standard side-lying posture manipulation aimed at the L5/S1 neurological level on the right hand side for each subject (high velocity low amplitude [HVLA] thrust). It was determined by cavitation of the facet joint and audible release.

STR involved placing the subject in the position as the MAN treatment, however no HVLA was applied. The stretch was held at this end-range position for 30 s.

SHA intervention involved placing the subject into the same side posture set-up position as the MAN intervention, however once joint tension was felt, the practitioner would decrease the rotation in the lumbar spine slightly to reduce joint tension, and apply a sham thrust to the joint to make sure no cavitation and audible release were occurring. The positions of the patients and therapist are shown in Fig. 1.
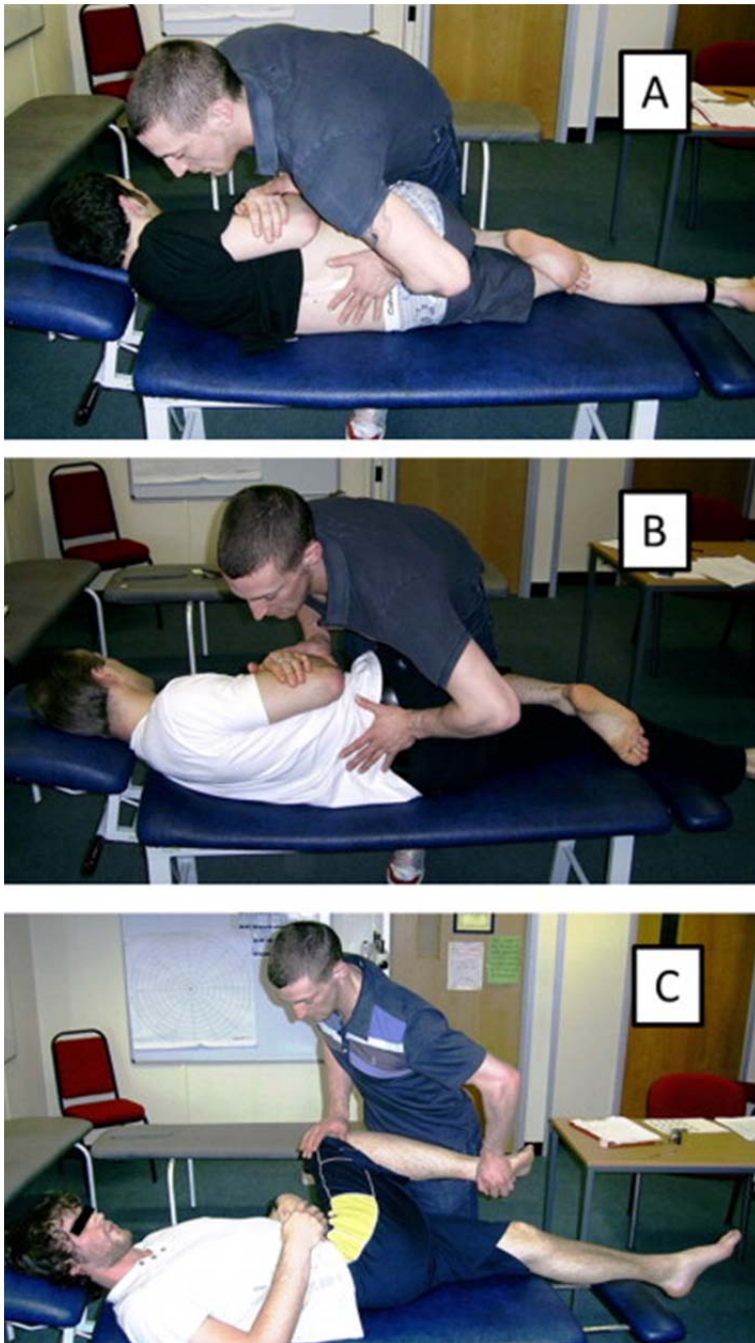
Fig. 1.

Picture of the 3 treatments employed in the study. A = Spinal Manipulation [SM]; B = Sham [SHA]; C = Stretching [STR].

The participants were informed that two SM strategies were compared to stretching, one with conventional techniques (cavitation of the facet joint) and one with no cavitation. This approach was taken to reduce expectancy of the effectiveness of manipulation and make sure the participants had no negative expectations from the sham intervention (McClung & Collins, 2007).

2.3. Force fluctuation task

For the plantar flexion task the participants were asked to lay in a prone position on a padded bed with the thigh secured to the bed by a strap and the foot placed on a foot plate mounted at 90° angle with the bed. Force was measured with a strain gauge transducer (ESYCC 300, Globus Italia, Treviso, Italy) positioned

between the foot plate and the bed (Fig. 2). The task was performed with the ankle joint at 90° angle. Force data from the strain gauge were sampled together with sEMG of gastrocnemius medialis muscle and synchronised (EMG-USB, 64 channel amplifier, LISIN – OT Bioelettronica, Turin, Italy).

Fig. 2.

Position in the dynamometer for the force fluctuation task.

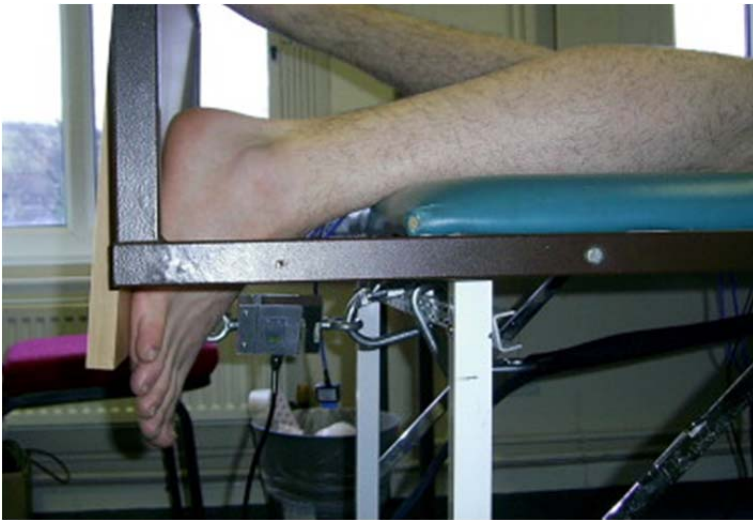In each experimental trial, the MVC procedure was performed at the beginning of sessions. Participants were asked to perform two submaximal contractions as a warm-up procedure and to practice the submaximal task and then three MVCs separated by 3 min each. The trial with the highest peak force was used as reference for the force fluctuation task. The force fluctuation during the plantar flexion task was assessed as described by Yoshitake et al. (Yoshitake et al., 2004). Briefly, participants were asked to maintain a plantar flexion force (target force was 80% MVC) for 30 s as steady as possible about the target displayed on a PC with visual feedback. The coefficient of variation of force produced during the plantar flexion task was used for analysis.

2.4. Modified Sorensen test

The participants were positioned on the examining table in the prone position with the anterior superior iliac spine aligned with the edge of the table fixed by straps (Biering-Sørensen, 1984). The surface EMG of the erector spinae was collected during the task. The Sorensen test was chosen as it represented a functional task for spine extensor muscles. As previous work from Keller and Colloca (Keller & Colloca, 2000) suggested an acute improvement in paraspinal muscle strength following SM, we used this assessment to test the hypothesis that SM provided an acute facilitation in paraspinal muscle activity.

2.5. Sit and reach test

Participants were requested to perform one trial of sit and reach test with the protocol of Jackson and Langford (Jackson & Langford, 1989). This test was used to determine the acute effects of SM on the flexibility of the lower back and hamstrings.

All the assessments were conducted to evaluate the acute effects of SM on neuromuscular function as well as the functional implications of the treatments.

2.6. EMG setup and procedures

Surface EMG was recorded from Erector Spinae and Gastrocnemius medialis muscles using two adhesive linear arrays (LISiN, Torino–SPES Medica, Battipaglia, Italy) of eight electrodes (silver bars 5 mm apart, 3 mm long, 1 mm diameter), in single differential (SD) configuration (LISiN, Torino–SPES Medica, Battipaglia, Italy). The silver–silver chloride interface was separated from the skin by a small cavity (1 mm deep) filled with 20–30 µl of conductive gel. Double differential configuration (DD) signals were computed off line for conduction velocity (CV) estimation. The skin was slightly abraded with adhesive paste and cleaned with water before electrode placement. The optimal position and orientation of the array were sought and selected on the basis of the visual inspection of the sEMG signals, as that providing: 1) motor unit action potentials (MUAPs) showing propagation from innervation zone to the distal tendon and 2) the most similar MUAP shape in different channels (Merletti, Rainoldi, & Farina, 2001).

The sEMG signals were amplified, bandpass filtered (3-dB bandwidth, 10–500 Hz, 12 dB/oct slope on each side), sampled at 2048 samples/s per channel and converted to digital data by a 12-bit A/D converter (EMG-USB, 64 channel amplifier; LISiN – OT Bioelettronica, Torino, Italy), displayed in real time, and stored on the disk of a personal computer.

On the erector spinae the array was placed at the level of the first lumbar vertebra (L1), as suggested by Roy et al. (Roy, De Luca, & Casavant, 1989) and Farina et al. (Farina, Gazzoni, & Merletti, 2003). The first channel of the array was placed on the dominant side, 3 cm beside and 1 cm above the spinous process of L1. On the gastrocnemius medialis muscle the probe was positioned along the medial side of the popliteus cavity to the medial side of the Achilles tendon insertion, as suggested by Rainoldi et al. (Rainoldi, Melchiorri, & Caruso, 2004). In order to ensure proper electrode re-positioning in subsequent days, their position was carefully marked on the skin with permanent ink.

2.7. EMG analysis

The EMG signals were analysed with a custom-developed Matlab routine (MathWorks Inc., MA). The SD channel with the largest amplitude was used to estimate average rectified value (ARV) and median frequency of EMG power spectrum (MDF) (Rainoldi et al., 1999). Double differential (DD) signals were computed off line for conduction velocity (CV) estimation. The DD signals with higher similarity and propagation were used to estimate CV (Rainoldi et al., 1999).

Initial value (i_val), rate of change (slope), and normalized rate of change (Nslope) calculated from the linear regressions of the time course of sEMG variables were analysed to establish the effects of each treatment.

2.8. Statistical analysis

The D'Agostino-Pearson omnibus test was carried out to establish if the data were normally distributed. Since the data were found to be normally distributed, a two-way ANOVA (3 Treatments × 3 Time) and Bonferroni post hoc comparisons were used for analysis. The treatments were: manipulation (MAN); stretching (STR); and sham (SHA). The Times were: PRE; POST; and 15_MIN (after intervention).

A one way ANOVA (3 time: PRE, POST, and 15_MIN) and Tukey's post hoc test for each treatment was applied if Bonferroni post hoc was unable to detect differences to test differences after the treatment. Alpha was set at $P < 0.05$. Data are all expressed as means ± standard deviation.

3. Results

The experimental setup allowed the collection of reliable (according to criteria reported in Merletti et al., 2003 and Rainoldi et al., 1999) EMG signals from both the gastrocnemius and the erector spinae muscle in all the participants used for statistical analysis.

3.1. Plantar flexion task

Two-way ANOVA conducted on COV of FORCE showed a significant effect for Treatment ($F(2,132) = 3.66$, $p = 0.03$). Bonferroni post hoc test detected no significant differences in Treatment. No significant effect were detected for Interaction ($F(2,132) = 1.8$, $p = 0.11$) and for Time ($F(2,132) = 0.64$, $p = 0.52$) (Table 1)

Table 1. Summary of the results.

	PRE	POST	15 MIN
COV FORCE (%)			
MAN	2.4 ± 1.0	1.9 ± 0.6*	1.9 ± 0.6*
STR	2.9 ± 1.8	3.1 ± 1.9	2.8 ± 1.7
SHA	2.4 ± 0.9	2.8 ± 1.3	2.6 ± 0.8
MDF (Hz)			
MAN	77.6 ± 13.0	77.1 ± 18.4	79.4 ± 14.9
STR	73.6 ± 12.2	79.3 ± 12.3*	77.6 ± 13.1
SHA	77.3 ± 12.5	80.8 ± 13.2*	78.2 ± 13.9
Sit & reach (cm)			
MAN	13.8 ± 10.7	16.1 ± 11.1***	16.4 ± 11.4
STR	13.0 ± 11.0	14.0 ± 11.3*	14.6 ± 11.2
SHA	12.6 ± 11.2	13.8 ± 11.1**	14.4 ± 11.5

* Denotes statistically significant difference from PRE with $P < 0.05$; ** Denotes statistically significant difference from PRE with $P < 0.01$; ***Denotes statistically significant difference from PRE with $P < 0.001$.

One-way ANOVA (3 time: PRE, POST, and 15_MIN) and Tukey's post hoc test was applied to test differences across time for each treatment independently.

One-way ANOVA detected a decrease of COV of Force after MAN. No significant differences were detected by one-way ANOVA after STR and after SHA.

3.1.1. sEMG data

Two-way ANOVA conducted on ARV, MDF, and CV of sEMG (i_val, slope, Nslope) detected no significant differences.

3.2. Modified Sorensen task

3.2.1. sEMG data

Two-way ANOVA conducted on MDF i_val showed a significant effect for Time ($F(2,142) = 3.78$, $p = 0.02$) (Table 1). No significant effects were detected for Interaction ($F(2,142) = 1.75$, $p = 0.14$) and Treatment ($F(2,142) = 0.15$, $p = 0.86$).

A one-way ANOVA (3 time: PRE, POST, and 15_MIN) and Tukey's post hoc test was applied for each treatment independently to test differences after the treatment.

One-way ANOVA detected an increase in MDF i_val of sEMG after STR ($p = 0.001$) and after SHA ($p = 0.006$). One-way ANOVA detected no differences in MDF i_val of sEMG after MAN.

Two-way ANOVA conducted on MDF (slope and Nslope), ARV and CV of sEMG (i_val, slope, Nslope) detected no significant differences.

3.3. Sit and reach test

Two-way ANOVA conducted on sit & reach test showed a significant effect on Time ($F(2,156) = 52.5$, $p < 0.001$) (Table 1). Bonferroni post hoc test detected significant increase between PRE vs POST for all treatments: MAN ($p = 0.001$); STR ($p = 0.05$); SHA ($p = 0.01$). Bonferroni post hoc test also detected a significant increase between PRE vs 15_MIN for all treatments: MAN ($p = 0.001$); STR ($p = 0.05$); SHA ($p = 0.01$).

A trend was detected for Interaction ($F(4,156) = 2.02$, $p = 0.09$). No significant effects were detected for Treatment.

4. Discussion

The findings from this study with asymptomatic participants provide evidence that neuromuscular responses to spinal manipulation are minimal and transient in nature. This is in agreement with previous studies which showed transient effects of spinal manipulation on motoneuron drive (Dishman and Bulbulian, 2000, Dishman and Bulbulian, 2001 and Dishman et al., 2002).

Spinal manipulation was shown to induce a significant improvement in force steadiness during a submaximal plantar flexion task as shown by a decrease in CV of force (Table 1). Whereas no study investigated force fluctuation, sacroiliac joint manipulation was previously shown to acutely increase strength of the leg extensor muscles (Grindstaff et al., 2009). Although there are numerous reports about the possible physiological effects of SM on the neuromuscular system, a unifying mechanism remains elusive and experimental evidence is scant. Force fluctuations during steady voluntary muscle contraction have been shown to be affected by multiple factors including force levels, inactivity and fatigue (Tracy et al., 2007 and Tracy et al., 2005). Several features of motor unit discharge have been suggested as potential mechanisms underlying the fluctuations (Taylor et al., 2003). Surprisingly, the acute reduction in force fluctuation during the plantar flexion task observed with MAN in our study was not related to any significant change in the measured sEMG parameters of the gastrocnemius medialis. Therefore, it is difficult to explain what we have observed. However, since previous work suggested acute reduction in the H/M ratio following SM which was evident only 10 s after the treatment (Dishman & Bulbulian, 2000), it is likely that either a central facilitation or reduced inhibition influenced the ability to control the force output. In fact a post-synaptic facilitation of motoneurons and/or corticomotor neurons has been previously suggested as the likely mechanism responsible for the transient increase in motor evoked potentials measured in the gastrocnemius muscle following SM (Dishman, Ball, & Burke, 2002).

MDF of sEMG in the erector spinae increased after the treatments in STR and SHA, whereas it remained stable after manipulation. The MDF increase observed after STR and SHA interventions could be related to higher neuromuscular activation (Solomonow et al., 1990). On the contrary, such increased activation was not detectable after MAN. This would suggest that SM could be capable of determining an increased neuromuscular efficiency in the erector spinae muscle, allowing the participants to perform the same task without having to increase the neuromuscular activity. However, central factors should not be excluded. Previous work in fact, showed a transient increase in motor evoked potentials in paraspinal muscles following SM in asymptomatic patients (Dishman et al., 2008) and a significant reduction of EMG activity (Bicalho, Setti, Macagnan, Cano, & Manffra, 2010) at full trunk flexion at the L2 erector spinae level in low back pain patients.

Flexibility of back and lower limbs was positively affected by all treatments and MAN was not shown to provide additional benefits. Recent work from Bicalho et al. (Bicalho et al., 2010) indicated the possibility of

an acute reduction in surface EMG activity of the paraspinal muscles during a forward flexion task similar to the one used in our study in parallel with an improvement in flexibility. Furthermore, previous work from Lehman's group suggested the possibility of acute reductions in EMG activity in paraspinal muscles following manipulation (Lehman & McGill, 2001). However none of the previous studies compared it to stretching or sham interventions like in this study. Therefore, the potential for SM to positively affect flexibility in asymptomathic patients to a larger extent than conventional therapeutic modalities remains to be proven. It is important to state that the lack of significant differences between treatments in our study is specific to the tasks and outcome measures used as well as specific to the asymptomatic population involved in the study. Furthermore, despite the fact that a relatively experienced chiropractor was involved in all treatments, it may be that the sham intervention used could have also affected the results. This study was a pilot investigation to ascertain the possibility to assess the acute effects of common SM techniques on neuromuscular function. Further studies are needed to assess the efficacy of such modality in the clinical setting.

5. Conclusions

The findings of this preliminary study do not provide a definitive answer on the acute effect of spinal manipulation on neuromuscular function in asymptomatic patients.

The current study represents the first evidence of a limited cause effect relationship of SM and neuromuscular function based on sEMG recording using linear array technique. More studies are in fact needed in order to elucidate the acute and chronic effects of SM on neuromuscular function. This study shows that the methods used can be employed to ascertain the effectiveness of SM on neuromuscular function and we hope similar studies will be conducted in patient populations to verify the acute and chronic efficacy of SM.

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