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ABSTRACT

This single group, randomized, cross-over study explored whether manual therapy alters motor tone of deep thoracic back muscles by examining resting electromyographic activity (EMG) after 2 types of manual therapy and a sham control intervention. Twenty-two participants with thoracic spinal pain (15 females, 7 males, mean age 28.1±6.4 years) had dual fine-wire, intramuscular electrodes inserted into deep transversospinalis muscles at a thoracic level where tissues appeared abnormal to palpation (AbP) and at 2 sites above and below normal and non-tender to palpation (NT). A surface electrode was on the contralateral paraspinal mass at the level of AbP. EMG signals were recorded for resting prone, two 3-second free neck extension efforts, two 3-second resisted maximal voluntary isometric contractions (MVIC), and resting prone before the intervention. Randomized spinal manipulation, counterstrain, or sham manipulation was delivered and EMG re-measured. Participants returned 1 and 2 weeks later for the remaining 2 treatments. Reductions in resting EMG followed counterstrain in AbP (median decrease 3.3%, P=.01) and NT sites (median decrease 1.0%, P=.05) and for the surface electrode site (median decrease 2.0%, P=.009). Reduction in EMG following counterstrain during free neck extension was found for the surface electrode site (median decrease 2.7%, P<.01). Spinal manipulation produced no change in EMG, whereas counterstrain technique produced small significant reductions in paraspinal muscle activity during prone resting and free neck extension conditions. The clinical relevance of these changes is unclear.

Keywords: electromyographic, spinal manipulation, paraspinal muscles

BACKGROUND

For practitioners of manual medicine, palpation of soft tissue texture, subtle joint motion, and tissue tenderness are important components for the assessment of spinal segmental joint dysfunction (Greenman 2003). Further, the tissue texture abnormality of spinal segmental dysfunction has been claimed to be palpable as hypertonicity in the deep muscles of the medial, paravertebral groove or 'gutter' (Chaitow 2003, Greenman 2003, Isaacs & Bookhout 2001). The cause of this palpable tissue texture change in these deep tissues has been proposed as abnormal contraction of the deep fourth layer paraspinal muscles, particularly rotatores and multifidus muscles (Chaitow 2003, Greenman 2003, Isaacs & Bookhout 2001). Abnormal contraction of these deep muscles is also claimed to disturb motion at that segment (Chaitow 2003, Denslow et al 1947, Greenman 2003, Isaacs & Bookhout 2001).

In the 1940s, Denslow, Korr, and colleagues investigated paraspinal muscles using needle electromyography (EMG) and reported increased segmental muscle activity at spinal levels associated with clinically detected segmental dysfunctions (Denslow & Clough 1941, Denslow et al 1947). Although the concept of muscle contraction as a cause of paraspinal tissue hardness remains popular, recent research using intramuscular fine-wire EMG of the deep thoracic paraspinal muscles failed to find evidence of abnormal activity in regions detected as tender and abnormal to palpation within the paravertebral gutter (Fryer et al 2010a). Low-level resting EMG activity of the deep musculature appears to be highly variable between individuals.

Manual therapy techniques, such as spinal manipulation, have been proposed to 'reset' the resting tone of muscles associated with palpable tissue texture and tenderness (Korr 1975). Spinal manipulation is one of a large range of manual techniques commonly used by osteopaths, chiropractors and other manual therapists to treat musculoskeletal conditions involving tissue texture tenderness and palpable abnormalities (Fryer et al 2010b, Fryer et al 2009). It involves the use of a high-velocity, low-amplitude thrust to mobilize and cavitate a spinal joint, often producing an audible click or pop (Gibbons & Tehan 2008, Greenman 2003). Counterstrain is a commonly used non-thrust manual technique which involves passively shortening a tissue until pain and palpated tenderness are reduced and holding that position for 90 seconds or until tissue relaxation (Friedman et al 2000).

Some studies have suggested that spinal manipulation produces a decrease in resting paraspinal EMG activity (Lehman 2012), but the evidence is inconclusive because of conflicting results, lack of controls, or poorly described methods and data (Fryer et al 2004a). Most studies examining the effect of manipulation on EMG have used surface EMG techniques. Surface EMG is non-invasive and suitable to examine superficial muscles, but not the deeper musculature. Few studies have examined the response of deeper paraspinal muscles to spinal manipulation or other manual techniques using needle or indwelling electrodes.

The current study was designed to determine whether there were immediate changes in EMG activity of deep thoracic paraspinal muscles following spinal manipulation during resting and active conditions. Evidence of muscle relaxation following manipulation would implicate the deep paraspinal muscles as having a role in the reported changes to segmental tissue texture and motion following manual therapy. Additionally, this study aimed to compare the effect of spinal manipulation with a non-thrust manual technique, counterstrain. It is possible that different manual techniques have different effects on the resting tone of paraspinal muscles. The paraspinal sites chosen for investigation were based on palpatory findings, because authors of manual therapy texts (Chaitow 2003, Greenman 2003, Isaacs & Bookhout

2001) claim that abnormally hard, tense, and tender tissues represent contracted deep muscles and some studies reported relaxation when areas of superficial tense musculature were investigated (Lehman 2012). The change in activity at the palpated target site was compared to changes at normal to palpation sites above and below the target site. Both spinal manipulation and counterstrain technique were hypothesized to produce a reduction of EMG activity in the deep thoracic paraspinal muscles at rest and the change in EMG would be greatest at the target site compared to adjacent sites.

METHODS

Participants

The current study was a single group, randomized, cross-over design. Participants were recruited from the student and employee population at A.T. Still University and Truman State University in Kirksville, Missouri, USA, over a 3-month period. There was little evidence available on which to base the calculation of effect sizes and power and study samples for this study. Due to the expense and invasiveness of intramuscular procedures, studies that have examined the multifidus muscle using intramuscular electrodes have used small sample sizes (Andersson et al 2002, Hodges et al 2003, Hodges & Richardson 1997, Moseley et al 2002). Based on a medium effect size, α at 0.05, within-subject correlation of at least 0.60, and analysis with ANOVA or non-parametric equivalent, 25 participants would provide 80% power for the study.

Participants were included if they presented with pain in the thoracic region (>3 on a numerical scale of 0 to 10), had pain for 5 of 7 days during the preceding 2 weeks, had a site in the thoracic region that was tender and abnormal to palpation, had a body mass index less than 30, and were aged between 18 and 50 years.

Symptomatic participants were included for better generalisability to patients seen in practice and provided a greater likelihood that the palpatory findings may be clinically relevant.

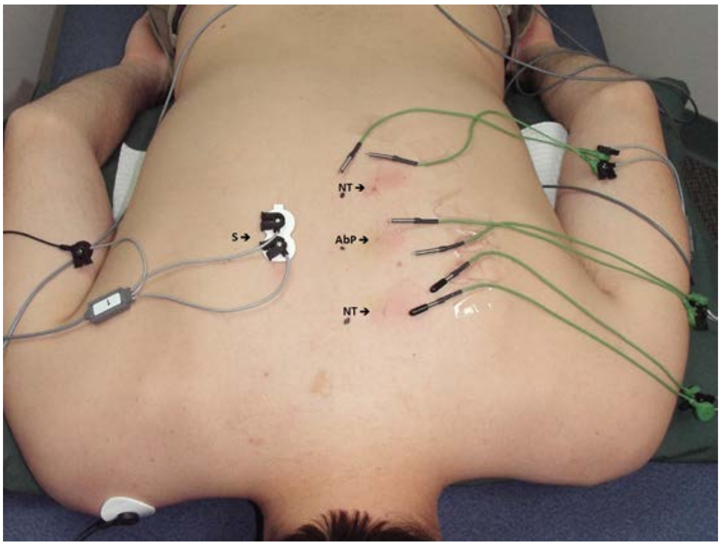
Participants were excluded if the examiner could not identify an abnormal site, the participant received thoracic spinal manipulation in the last 7 days, or there were medical conditions prohibiting fine-wire EMG testing, such as abnormal blood pressure, postural hypotension, medical blood disorders, needle phobia, syncopal attacks, pregnancy, or skin conditions and sensitivity to adhesives. Participants over 50 years were excluded to avoid the possible influence of spinal degenerative joint disease.

Procedures were approved by the A.T. Still University-Kirksville Institutional Review Board and all participants provided informed consent. The research was conducted on the A.T. Still University-Kirksville campus.

Electromyography

Disposable, paired hook-wire electrodes (44 gauge, insulated nickel alloy wire, Viasys, Neurocare, USA) were used for intramuscular EMG data. Electrodes were inserted using 30 mm (27 gauge) and 50 mm (25 gauge) hypodermic needles by a medical practitioner with extensive experience in EMG and insertion of intramuscular electrodes (B.R.). Wires were stripped of insulation for 2 mm at their terminal ends; 2 mm of one wire and 5 mm of the other extended from the tip of the needle. During preliminary testing before the main study, the optimal site of needle insertion and orientation was determined by varying the insertion site medially and laterally, and the needle placement within the deep transversospinalis musculature was confirmed using diagnostic ultrasound (Phillips iU22, Netherlands). Using a medial insertion location approximately 2 cm lateral to the midline spinous process and directing the needle anteriorly and slightly medially (Chiodo et al 2006, Kim et al 2005), the needle was inserted in the deep transversospinalis muscles (multifidus and rotatores). The deep thoracic multifidus and rotatores cannot be distinguished by ultrasonography, so activity was likely recorded from both muscles (Lee et al 2005).

The skin around the marked regions (see below) of each participant was swabbed with alcohol, and surface electrode sites were abraded and swabbed. Electrodes were inserted at marked sites until the needle met the resistance of the lamina. The needle was withdrawn, leaving the electrode in situ. Spring-coil connector leads were attached to the free wires, and the leads were taped to the participant’s back, keeping a loop of approximately 5 cm free for movement. The skin was abraded and swabbed with alcohol for attachment of the adhesive dual surface electrodes (Ag/AgCl, Noraxon, USA). A surface reference electrode was connected to the participant’s acromion process on the same side as the other electrodes (Figure 1).



EMG data was collected at 2000 Hz using a TeleMyo 2400G2 wireless telemetry EMG system with pre-amplified leads (Noraxon, USA) and was processed using MyoResearch XP Master Edition software. Raw EMG data was pre-amplified, band-pass filtered (10–1000 Hz) and smoothed with a root mean squared (RMS) 20 millisecond window (Standards for Reporting EMG Data 2016).

Procedures

Participants were enrolled and reported age, height, weight, location of thoracic pain, and intensity of pain on a numerical rating scale (current and estimated average pain over the last week; 0=no pain, 10=most pain experienced) to a researcher (G.F.). They exposed their back (females wore open-backed disposable gowns) and lay prone on a treatment table with their face in the midline face hole.

An experienced osteopathic manipulative practitioner (G.F.) with 17 years of practice experience palpated the deep tissues in the thoracic paravertebral gutter region from T3 to T11 using deep, short, gliding movements of the fingertips to determine the site of the most marked tissue texture abnormality (hard, boggy, or ropy deep tissues). Although reliability between examiners palpating abnormal tissue texture has not been high (Paulet & Fryer 2009, Seffinger et al 2004), palpation of abnormal tissue texture in the paravertebral gutter reliably identifies thoracic paraspinal sites with significantly lower pressure pain thresholds (Fryer et al 2004b). Because sites abnormal to palpation are more sensitive to pressure (Fryer et al 2004b), participants verbally indicated tenderness, reinforcing palpatory findings. When an abnormal to palpation site (AbP) was located, the skin was marked with light pressure from the end of a plastic tube. Sites 2 vertebral segments above and below the AbP site were palpated to ensure they were relatively normal to palpation and not sensitive or tender (NT). If any were abnormal, a different NT site a segment above or below was chosen (Fryer et al 2010a). NT sites were marked in the same manner as the AbP site. AbP and NT sites were determined for each session.

Intramuscular electrodes were inserted at these 3 sites (Figure 1). A surface electrode (sEMG) was placed over the erector spinae bulk at the same spinal level but on the contralateral side to the AbP electrode. EMG activity was collected from 4 electrodes:

1. Normal site *above* AbP site, intramuscular electrode (NT1).
2. AbP site, intramuscular electrode.
3. Normal site *below* AbP site, intramuscular electrode (NT2).
4. sEMG on the contralateral side of the spine at the same level as the AbP, surface electrode.

EMG activity was visually verified on the scope and resting baseline activity established. EMG data were collected under the following conditions:

1. Prone resting baseline (Rest 1).
2. Free neck extension (Ext). This was a functional, sub-maximal contraction task where the participants lifted and extended their neck to look directly forward for 5 seconds. Ext was performed twice, with a 5-second rest between contractions. This measurement has excellent reliability (Fryer et al 2008).
3. Maximal voluntary isometric contraction (MVIC) task. In prone with the arms at sides, participants lifted their head and chest as hard as possible against the resistance of the examiner (both hands were placed on the participant's upper thoracic region). MVIC was performed twice for 3 seconds, with a 5-second rest between contractions. Although a true maximal effort cannot be assumed in a symptomatic cohort, this task had excellent repeatability in a similar symptomatic cohort and is therefore suitable to be used for EMG normalization (Fryer et al 2010a, Fryer et al 2008).
4. Prone resting post-MVIC (Rest 2).

Participants were randomized using a lottery draw (M.B.) to receive 3 interventions in sequences using an orthogonal Latin squares design (J.J.). The researcher who inserted the electrodes was blinded to the intervention and a single practitioner (G.F.) delivered all the interventions. The first intervention of the randomly allocated sequence was performed with the participant in prone position:

1. Spinal manipulation (high-velocity, low-amplitude thrust) to the involved segment (Gibbons & Tehan 2008). The examiner contacted the transverse process of the upper segment on one side and the transverse process of the lower segment on the other with the hypothenar eminences of both hands and applied a pre-thrust load (downward pressure) with caudal (lower segment) and cephalad (upper segment) force, adding slight extension, side bending, and rotation as necessary. A high-velocity, low-amplitude thrust was directed in a downward and caudal or cephalad direction (Figure 2).
2. Counterstrain for the posterior tender point around the AbP site on the transverse or spinous process (Friedman et al 2000). The participant's arm was elevated on the side of the tender point and placed alongside the head, supporting with a pillow and further elevating as needed using cephalad traction. The head was laterally flexed and rotated away from the involved side. The position was fine-tuned until baseline tenderness on palpation decreased to at least 30 (on a scale of 0-100). The position was held for 90 seconds and then slowly returned to neutral (Figure 3).
3. Sham control. Participants received a sham application of laser acupuncture (laser not activated) over the involved region for 30 seconds. Participants were told laser acupuncture was commonly used for treatment

of tender points and any sensation of heat or burning should be reported to support the treatment as genuine.

Following the intervention, EMG activity during rest and the 3-second MVIC conditions were recorded. EMG activity was not recording during the application of any intervention because of the likelihood of movement artifacts. Participants returned 1 and 2 weeks later to receive the other interventions.

Statistical analysis

Two-second periods from each electrode at Rest 1, during Ext and MVIC intervals, and at Rest 2 were processed; mean amplitude (μV) was calculated for each period. Data from the 2 measurements for Rest, Ext, and MVIC were analyzed for reliability using 2-way mixed model intraclass correlation coefficients (ICC) and associated 95% confidence intervals (CI). Data for the sham control were analyzed for reliability between pre-intervention and post-intervention measurements using ICCs. EMG scores at Rest 1 and Rest 2 and the 2 Ext measurements were averaged and normalized to the highest pre-intervention MVIC score. Data normalized to an MVIC allows the EMG activity to be expressed as a percentage of maximal activity and is necessary when comparing activity between sites or individuals because of the variability in raw EMG associated with individual electrode placement (Lehman & McGill 1999). Normalized rest and Ext scores for NT intramuscular sites were averaged (NTavg). Summary statistics are reported as mean and standard deviations (SD) or median and quartiles. Within- and between-intervention effect sizes were calculated using Cohen's d.

Some data was not normally distributed so nonparametric tests were used for inferential analysis. Wilcoxon signed rank tests were used for comparisons of pre-intervention to post-intervention normalized Rest and Ext scores for each treatment at each site and for carryover effects from the previous intervention (i.e., whether a 1-week washout period was sufficient). Friedman tests were used for comparisons between intervention on change in muscle activity from pre-intervention to post-intervention and between AbP and NT sites on muscle activity pre-intervention (averaging over interventions) and change in muscle activity from pre-intervention to post-intervention for each intervention. The data were analyzed using SAS statistical software (version 9.3, SAS Institute Inc) and the α level was set at 0.05.

RESULTS

Twenty-two participants were recruited: 15 females, 7 males; mean (SD) age, 28.1 (6.4) years; BMI (SD), 23.5 (4.2). Mean (SD) current pain intensity rating was

3.2 (1.1) and estimated weekly average was 6.8 (1.7). Two participants withdrew after the first session due to discomfort of indwelling electrodes and vasovagal symptoms. The AbP site was commonly located at T4 (15/60 sessions, 25%) and on the right (34/60, 57%). Audible cavitations from spinal manipulation were noted in all but 3 participants. No adverse events were reported by the participants. Summary statistics for normalized muscle activity and within-intervention change are provided in Table 1.

Table 1. Summary statistics for normalized muscle activity and pre-post intervention changes

Task	Site	Intervention	Pre-intervention (%) Median (Q1, Q3)	Post-intervention (%) Median (Q1, Q3)	Change (%) Median (Q1, Q3)	*P* Value[a]	Cohen's d[b]
Rest	AbP	SM	4.7 (2.1, 24.4)	7.7 (2.6, 28.2)	0.7 (-1.2, 4.2)	.26	0.29
		Counterstrain	15.5 (3.1, 23.1)	8.8 (3.1, 17.0)	-3.3 (-7.9, 0.2)	.01	-0.33
		Control	14.6 (3.2, 19.5)	10.2 (2.9, 21.8)	0.0 (-1.3, 4.7)	.83	0.04
	NTavg	SM	13.3 (4.0, 23.4)	13.4 (2.6, 25.5)	0.5 (-2.5, 3.2)	.59	0.08
		Counterstrain	13.9 (6.3, 20.4)	10.4 (3.8, 19.3)	-1.0 (-4.5, -0.1)	.05	-0.24
		Control	14.9 (5.0, 22.3)	10.1 (5.7, 20.3)	-0.8 (-4.7, 0.3)	.10	-0.18
	sEMG	SM	14.8 (9.8, 17.1)	15.6 (9.2, 17.1)	0.6 (-2.0, 2.4)	.40	0.33
		Counterstrain	17.3 (11.9, 21.6)	14.2 (10.3, 20.0)	-2.0 (-5.8, 0.0)	.009	-0.29
		Control	16.7 (8.9, 20.1)	16.6 (7.8, 20.8)	-0.8 (-2.5, 0.4)	.25	-0.08
Ext	AbP	SM	57.3 (44.0, 82.0)	52.9 (39.8, 72.7)	-6.1 (-20.5, 11.8)	.55	-0.20
		Counterstrain	70.2 (59.7, 84.9)	68.5 (51.8, 94.6)	-2.6 (-14.3, 7.6)	.81	0.07
		Control	73.8 (52.2, 86.4)	74.6 (54.1, 81.0)	-2.1 (-8.5, 0.4)	.13	0.01
	NTavg	SM	59.1 (45.7, 84.7)	62.3 (42.9, 92.4)	4.7 (-6.5, 18.1)	.26	0.33
		Counterstrain	72.0 (59.5, 77.0)	70.2 (52.7, 86.4)	0.3 (-5.0, 5.8)	.84	-0.01
		Control	70.7 (57.6, 84.5)	73.2 (53.9, 77.8)	-3.8 (-11.4, 2.0)	.13	-0.22
	sEMG	SM	47.2 (31.2, 72.3)	47.2 (36.3, 71.5)	-0.1 (-3.8, 4.2)	.95	0.04
		Counterstrain	51.4 (44.1, 81.3)	50.0 (38.4, 60.6)	-2.7 (-10.1, 0.1)	.003	-0.20
		Control	60.2 (40.0, 74.9)	56.8 (40.7, 72.7)	-0.3 (-6.4, 1.4)	.39	-0.03

[a] Wilcoxon signed ranks test comparing pre-intervention to post-intervention muscle activity.

[b] Effect size (Cohen's d) for within-intervention change in muscle activity from pre-intervention to post-intervention.

Abbreviations: AbP, abnormal to palpation site; Ext, free neck extension; NTavg, average of 2 not tender sites above and below abnormal to palpation site; Q1, quartile 1; Q3, quartile 3; sEMG, surface electrode on contralateral erector spinae mass; SM, spinal manipulation.

Reliability of EMG recordings

Reliability for the 2 sets of pre-intervention Rest, Ext, and MVIC ranged from good to excellent for intramuscular sites, with lesser reliability for Rest 1 (ICC, 0.75; 95% CI, 0.69-0.82) and excellent concordance for Ext (ICC, 0.97; 95% CI, 0.96-0.98) and MVIC (ICC, 0.98; 95% CI, 0.97-0.99). Reliability for pre-intervention and post-intervention measures following the inert control intervention for intramuscular sites had similar reliability, with lesser reliability for Rest (ICC, 0.70; 95% CI, 0.56-0.83) and excellent reliability for Ext (ICC, 0.96; 95% CI, 0.94-0.98) and MVIC (ICC, 0.92; 95% CI, 0.87-0.96). Pre-post reliability for the control for sEMG had lower reliability for Rest (ICC, 0.81; 95% CI, 0.66-0.97) and MVIC (ICC, 0.82; 95% CI, 0.67-0.97) and excellent reliability for Ext (ICC, 0.92; 95% CI, 0.86-0.99).

Pre-intervention and post-intervention comparisons

A significant reduction in EMG for rest followed counterstrain intervention in AbP (median decrease 3.3%, *P*=.01), NTavg (median decrease 1.0%, *P*=.05), and sEMG (median decrease 2.0%, *P*=.009) electrodes, but there were no significant changes after spinal manipulation or the sham control interventions. A significant reduction in EMG following counterstrain during Ext was found (median decrease 2.7%, *P*=.003). EMG activity from other sites following other interventions was not significantly changed.

Carryover effects

No significant changes in pre-intervention muscle activity (Rest, Ext, MVIC) were found for any intervention at any sites. Therefore, order of intervention was ignored for between-intervention comparisons.

Between-intervention comparison

A significant difference in change of Rest from pre-intervention to post-intervention for sEMG was found (*P*=.02); the magnitude of the change for counterstrain (median decrease 2.0%) was larger than that of spinal manipulation (median increase 0.6%). No other significant differences between the interventions were found (Table 2).

Table 2. Effect sizes comparing interventions on change in muscle activity from pre-intervention to post-intervention

Task	Site	SM vs Counterstrain Cohen's d[a]	SM vs Control Cohen's d[a]	Counterstrain vs Control Cohen's d[a]	*P* Value[b]
Rest	AbP	0.53	0.23	-0.31	.08
	NTavg	0.25	0.37	0.11	.61
	sEMG	0.58	0.36	-0.30	.02 (↓CS > ↑SM)
Ext	AbP	-0.25	-0.13	0.06	.94
	NTavg	0.31	0.44	0.35	.21
	sEMG	0.49	0.09	-0.45	.21

[a] Effect size (Cohen's d) for between-intervention differences on change in muscle activity from pre-intervention to post-intervention.

[b] Friedman test comparing between interventions on change in muscle activity from pre-intervention to post-intervention.

Abbreviations: AbP, abnormal to palpation site; Control, sham control intervention; CS, Counterstrain; Ext, free neck extension; NTavg, average of 2 not tender sites above and below abnormal to palpation site; sEMG, surface electrode on contralateral erector spinae; SM, spinal manipulation.

Between-site comparison

A significant difference for pre-intervention Ext (P=.03) was found; normalized NT1 was higher than normalized NT2. No other significant differences were found between sites on pre-intervention muscle activity or change in muscle activity from pre-intervention to post-intervention for any interventions.

DISCUSSION

To our knowledge, the current study was the first to examine the EMG activity of deep thoracic paraspinal muscles during rest and a functional task following 2 commonly used manual techniques. A small significant decrease in resting EMG activity followed counterstrain, but not following spinal manipulation or the sham control intervention. This result represented a 3.3% decrease in normalised EMG activity and produced a small effect size. The change was larger at the AbP site but also occurred at NT and sEMG sites. A small decrease in EMG following counterstrain was also found during the Ext task at the sEMG site. Given the small magnitude of decreases in EMG and lack of specificity for site, the clinical relevance of these changes is unclear. As in previous studies (Fryer et al 2010a), we found no evidence that abnormal sites were associated with increased contraction of underlying deep musculature pre-intervention.

The mechanism for the reduction in EMG is unclear. Because counterstrain application places the tissues in a position of comfort and reduced tenderness for 90 seconds, this long relaxation phase may facilitate general relaxation, as evidenced by small reductions in EMG at all sites. It is also possible that a change in participant posture following counterstrain may have influenced the resting activity. However, the researchers took care to not disturb the participant’s trunk position and to return the participant's arm to the original position, so we do not believe that changes in position were likely following this intervention. It is unclear whether the small change in muscle activity would be detectable using palpation or contribute to clinical improvement. The focus of the study was on immediate motor changes rather than clinical outcomes, and there was no expectation of lasting clinical improvement from the application of single, isolated techniques.

Few studies have examined responses of deep back muscles to manual therapy interventions using intramuscular electrodes. In a pilot study, Hayek et al (1995) used needle electrodes in upper thoracic vertebrae determined as fixated to examine the effect of spinal manipulation on deep paraspinal muscles in 3 participants. EMG tracings suggested paraspinal activity decreased after spinal manipulation, but no statistical analyses were reported. In a case report, Tunnell (2009) reported that isometric trunk rotational force improved after spinal manipulation even though multifidus EMG decreased, suggesting a change in recruitment and motor control of the paraspinal musculature.

The use of intramuscular electrodes during dynamic movement or spinal manipulation present many challenges for researchers, such as migration of electrodes and loss of signal, and may explain why few studies have been conducted in this area. In preliminary testing for the current study, loss of signal and migration of intramuscular electrodes occurred during dynamic movement and changes of posture, so participants were required to be prone during all testing in the current study. The reliability of our EMG recordings for the active tasks of Ext and MVIC were excellent, whereas recordings from the resting conditions were adequate but less reliable. This variability of low-level EMG activity from resting paraspinal muscles using fine-wire EMG has been noted in previous studies (Fryer et al 2010a, Fryer et al

2008). In several participants, EMG signals from the electrodes were lost during the session, most likely because of electrode migration within the muscle. In a few participants, the wires were slowly expelled from the site when the participant performed MVIC. As with previous studies (Fryer et al 2010a, Fryer et al 2008), we noted that the wires were often kinked on removal, illustrating the strong intramuscular shear forces from paraspinal muscle contraction. These problems required vigilance by the researchers to ensure that EMG signals were consistent throughout the measurement session, but the excellent reliability of the Ext and MVIC pre and post measurements in the control intervention suggest there was little migration during these tasks.

Indwelling fine-wire EMG is a valid tool to investigate deep muscle motor activity and the procedure itself does not affect the muscle or its EMG activity (Jacobson et al 1995). It might seem possible that the intramuscular procedure potentially has a therapeutic effect akin to acupuncture. We believe such an effect is unlikely given that the hypodermic needle is inserted and immediately removed and that the fine-wires are considerably thinner than acupuncture needles. Further, there have been no reports of therapeutic effect or changes to motor activity following insertion of fine-wire electrodes. In any case, potential therapeutic effects from the procedure would be consistent for the treatment and sham groups equally, so we do not believe a potential treatment effect from the insertion of electrodes posed a problem for the current study.

In contrast to intramuscular EMG, surface EMG is non-invasive, simple to apply, and well suited to the study of dynamic motor activity, but it is more useful for recording activity from superficial muscles rather than deep muscles (Lehman 2012). Using surface electrodes, researchers have reported short-lived EMG responses from paraspinal muscles during and after spinal manipulation (Herzog et al 1999), and responses appeared to be related to the force (Nougarou et al 2013) and speed (Page et al 2014) of the application of spinal manipulation. However, the clinical relevance of these responses is unknown.

Several studies have reported reductions in resting paraspinal EMG using surface EMG after spinal manipulation (DeVocht et al 2005, Krekoukias et al 2009, Lehman et al 2001). Lehman et al (2001) reported that painful lumbar segments had exaggerated paraspinal EMG responses to mechanical pressure compared to non-tender segments and these responses significantly decreased after spinal manipulation. Other researchers have used surface EMG to investigate the effects of spinal manipulation during dynamic movement. Alterations in the flexion-relaxation response of lumbar paraspinal muscles in people with low back pain has been well established (Neblett et al 2013) and some studies have reported improvements in paraspinal relaxation during the flexion-relaxation phase following spinal manipulation (Bicalho et al 2010, Harvey & Descarreaux 2013, Lalanne et al 2009).

The current study has a number of limitations. It examined EMG changes in participants who were generally young, healthy, and mildly symptomatic and it is possible that different results would have been found in participants experiencing greater pain intensity. Although the target sample of 25 participants was not achieved, the achieved sample of 22 was close and calculation of effect sizes ensured that we considered the magnitude of change, not just probability of a difference. The study examined the immediate effect of a single application of a manual intervention so the longevity of the reduction in EMG is unknown. The use of a single technique does not reflect manual therapy practice, where a combination of manual approaches are typically used, and our results may have been different if a pragmatic treatment approach was implemented or the treatment program was conducted over a longer period.

Researchers have explored the possibility that some patients are ‘responders’ or ‘non-responders’ to spinal manipulation. Attempts have been made to identify responders using clinical prediction rules (Cleland et al 2010, Puentedura et al 2012) and, more recently, biomechanical characteristics (Wong et al 2015). Wong et al (2015) reported that spinal manipulation responders had reductions in spinal stiffness and increases in multifidus thickness ratios, representing stronger muscle contraction during a sub-maximal task, following spinal manipulation. The current study did not find changes in EMG at rest or during Ext following spinal manipulation and it is possible that our participants were non-responders to spinal manipulation. However, we think this is unlikely given that analysis of the pre-post changes did not reveal a bimodal distribution that would indicate responder and non-responder groups. Further, the purpose of this exploratory study was to examine the immediate neurophysiological responses from a single manual intervention and there was no expectation of lasting clinical benefit. However, given the recent evidence of biomechanical differences in responders and non-responders, we recommend consideration of this in future studies.

In recent years, a method of surface EMG data collection, high density EMG, has been developed with multiple, closely spaced electrodes overlying a restricted area of the skin, which allows recording of spatial EMG activity and evaluation of single motor unit characteristics (Drost et al 2006). This method may be more suitable than conventional EMG for the examination of muscle activation following spinal manipulation. Rather than measure the EMG activity of the musculature to determine motor changes, researchers have used neurophysiological techniques to determine changes in the motor cortex of the brain and nervous system following manual therapy. Spinal manipulation reduced spinal motor neuron excitability using H-reflexes (Dishman et al 2002, Fryer & Pearce 2012, Niazi et al 2015, Suter et al 2005) and influenced motor neuron excitability (Dishman et al 2008, Fryer & Pearce 2012, Fryer & Pearce 2013, Haavik et al 2017, Taylor & Murphy 2008) using transcranial magnetic stimulation (TMS) to examine motor evoked potentials. Additionally, cortical somatosensory evoked potentials produced by TMS have been shown to be influenced by spinal manipulation (Haavik-Taylor & Murphy 2007, Lelic et al 2016). However, these sensory and motor cortex changes appear to be transient, and the relationship of these findings to muscle activity or clinical outcomes has yet to be established. Turker and Powers (2005) discussed the errors associated with exploring neuronal pathways in the brain and estimating the characteristics of connections between nerve cells using surface and intramuscular EMG. They described a new method called peristimulus frequencygram (Türker & Powers 2003, Türker & Powers 2005), which may improve the accuracy of TMS estimates of motor neuron activity (Todd et al 2012). Additional exploration of the effect of manual therapy on sensory and motor excitability of the brain is warranted.

Given the findings of the current and previous study (Fryer et al 2010a), we do not recommend further investigation of resting EMG activity of muscles associated with palpatory findings using conventional fine-wire EMG techniques, but investigations using newer EMG and neurophysiological methods are warranted. Future studies might focus on phenomena already known to occur in participants with spinal pain, such as the loss of the flexion-relaxation response (Neblett et al 2013). Other non-invasive techniques, such as ultrasonic imaging of multifidus contraction (Wong et al 2015), high density EMG (Drost et al 2006), and TMS (Fryer & Pearce

2012, Haavik et al 2017) may be useful to determine changes to the motor system following spinal manipulation.

CONCLUSION

To our knowledge, the current study was the first to examine the immediate effect of spinal manipulation and counterstrain on resting EMG activity of deep thoracic paraspinal muscles. A small significant decrease in resting EMG was found following counterstrain treatment, but not following spinal manipulation or the sham control. The decrease in EMG did not appear to be specific to the AbP site since decreases in EMG also occurred at NT and sEMG sites. Given the small magnitude of change and lack of specificity for the targeted site, the relevance to palpated tissue texture, the biomechanics of the segment, or clinical outcomes is unclear. It is likely that manual techniques such as spinal manipulation and counterstrain produce clinical effects by mechanisms other than relaxation of deep muscles around the manipulated segment.

COMPETING INTERESTS

The authors declare they have no competing interests. GF is an osteopath.

AUTHOR CONTRIBUTION

GF, MB & JJ developed the study design. GF, MB & BR undertook data collection. JJ and GF analysed the data. GF wrote the manuscript. All authors approved the manuscript.

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