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Reflex Responses of Neck, Back, and Limb Muscles to High-Velocity, Low-Amplitude Manual Cervical and Upper Thoracic Spinal Manipulation of Asymptomatic Individuals—A Descriptive Study

Q1 Lindsay M. Gorrell, MChiroprac, MRes,[a] Philip J. Conway, DC,[b] and Walter Herzog, PhD[a]

Abstract

Objective: The purpose of this research was to determine the extent of reflex responses after spinal manipulative therapy (SMT) of the cervical and upper thoracic spine.

Methods: Eleven asymptomatic participants received 6 commonly used SMTs to the cervical and upper thoracic spine. Bipolar surface electromyography electrodes were used to measure reflex responses of 16 neck, back, and proximal limb muscles bilaterally. The percentage of occurrence and the extent of reflex responses of these muscles were determined.

Results: Reflex responses after cervical SMT were typically present in all neck and most back muscles, whereas responses in the outlets to the arm and leg were less frequent. This trend was similar, although decreased in magnitude, after thoracic SMT.

Conclusion: Reflex responses were greatest after upper cervical SMT and lowest with thoracic SMT. (J Manipulative Physiol Ther 2019;xx:1-10)

Q2 **Key Indexing Terms:** *Manipulation, Chiropractic; Electromyography*

Introduction

Spinal manipulative therapy (SMT) is an effective conservative treatment for neck and back pain.[1-3] Although positive clinical outcomes such as increased range of motion and decreased pain are commonly reported after SMT, the mechanisms underlying these changes are not fully understood. Three main mechanisms have been suggested in the literature: mechanical, neurophysiologic, and reflexogenic. The mechanical and neurophysiological mechanisms associated with SMT are transient movements between adjacent vertebrae and changes in the chemical environment of the central nervous system, respectively, which are thought to be responsible for the positive effects associated with the intervention.[4-9] Although many studies have been conducted to investigate the mechanical and neurophysiological responses to SMT, there has been comparatively little investigation into reflexogenic responses associated with the treatment.

In support of a reflexogenic mechanism, it could be argued that SMT is associated with reduced tone in hypertonic muscles in addition to a reflexogenic decrease in pain mediated by the dorsal horn, but this hypothesis requires further investigation.[10-12] Previous studies investigating reflex responses associated with SMT using both manual[10,13] and instrument[14,15] techniques at several sites along the spine have been conducted. Collectively, the results from these studies suggest that reflex responses after manual SMT are both local and nonlocal in addition to being reproducible both within and between participants. Nonlocal effects after manual SMT, that is, effects that occur in tissues not directly related to the target area, have also been reported elsewhere in the literature,[16,17] and the hypothesis that there is a connection between the autonomic nervous system and pain perception after SMT has been investigated.[18,19] Reports of changes in skin conductance, respiratory rate, blood pressure, and heart rate in healthy populations after mobilization or manipulation of specific areas of the spine support this hypothesis.[19,20] Of more

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importance to the current discussion, however, are reports that cervical SMT also affects changes in the somatic nervous system.[21,22]

Studies investigating the effect of cervical SMT on lateral epicondylalgia have described an increase in hand grip strength,[23,24] whereas in other studies changes in motor activity have been reported, highlighting that manual cervical SMT may have effects distal to the target site.[25,26] However, despite these studies, there has been no systematic investigation of the reflex responses occuring subsequent to manual cervical and upper thoracic SMT. Furthermore, although several studies have examined electromyography responses after cervical and thoracic SMT in a symptomatic population,[12,27-29] there has been little investigation into the responses occurring in an asymptomatic population.

Thus, the purpose of this study was to determine the extent of reflex responses associated with manual SMT applied to the cervical and upper thoracic spines in an asymptomatic population. Asymptomatic participants were chosen to establish a baseline response in normal people and to test whether the extent of the electromyography response was repeatable between participants.

Methods

Participants

The study was designed as a descriptive observational investigation, with all participants receiving the same interventions. Asymptomatic individuals aged 18 to 40 years responded to the researcher's call for volunteers and attended an initial session where they were screened for contraindications preventing their inclusion into the study. Contraindications to cervical and upper thoracic SMT included history of a connective tissue disorder, cervical or upper thoracic pain that was not due to mechanical dysfunction or did not originate from the cervical or upper thoracic spines, current use of anticoagulant therapy, history of recent surgery or neck trauma, facial or intra-oral anesthesia or paresthesia, visual disturbances, dizziness, and vertigo. In addition to this, a person was excluded if they were pregnant or had received cervical or upper thoracic mobilization or manipulation within the preceding 1 month.

At this time, if no contraindications to cervical and upper thoracic SMT were present, a targeted medical history and physical examination were performed by a registered, practicing chiropractor. In accordance with the current literature and clinical practice guidelines, vertebral artery safety tests were not performed.[30-32] Once the chiropractor was confident no contraindications were present and that the volunteer met all inclusion criteria, participants were scheduled to attend a testing session occurring at the University of Calgary not more than 4 days after the initial visit. At approximately 24 hours after the testing session, a follow-up email was sent to all participants asking them to report all possible adverse events related to their involvement in the study.

Treatments

Each participant received 6 diversified-style manual SMTs to the cervical and upper thoracic spines. These SMTs were delivered in a set order—C1, C2, C6, C7, T1, and T4—by a second registered and practicing chiropractor with over 30 years of experience in the delivery of manual SMT. A coin flip determined that the right side was the first to be treated, and each subsequent manipulation was alternated between the left and right sides. The order of SMT was the same for all participants, and there was a 2-minute rest period between each manipulative thrust. This rest period was implemented to safeguard against residual reflex activity from previous thrusts contaminating subsequent electromyography traces in addition to optimizing participant comfort, ensuring that recorded electromyography activity was due to reflex responses and not voluntary muscular contraction.

For all cervical SMT, the participant was positioned supine with the head supported by the clinician's hands. The articular process of the involved vertebrae was contacted by the anterolateral aspect of the proximal phalanx of the second digit of the clinician's index finger. The head was then taken into flexion, ipsilateral lateral flexion, and contralateral rotation to the pre-manipulative position. A rapid, controlled low-amplitude thrust was applied in a further posterior-anterior line of drive to achieve the manipulation.[33] Ipsilateral in this instance means the same side as the contact, that is, for manipulation of C1, the right side of the participant's neck was contacted and rotation of the head occurred to the left.

For all upper thoracic manipulations, the participant was positioned prone on the treatment table. The transverse processes of the involved vertebrae were contacted with a bilateral hypothenar-heel contact in which the hands are perpendicular to each other, specifically the fingers of the right hand faced superolaterally (to the left shoulder) and the fingers of the left hand faced superolaterally to the right shoulder. A body drop was used in a posterior-anterior and inferior-superior direction to achieve the manipulation.[33] Throughout the study, and at the discretion of the treating clinician, if the first thrust was deemed unsuccessful, a second thrust was immediately applied as often occurs in wider clinical practice.

Electromyography Recordings

Reflex responses after SMT were measured using bipolar surface electromyography electrodes (Biovision, Wehrheim, Germany). Sixteen pairs of electrodes were

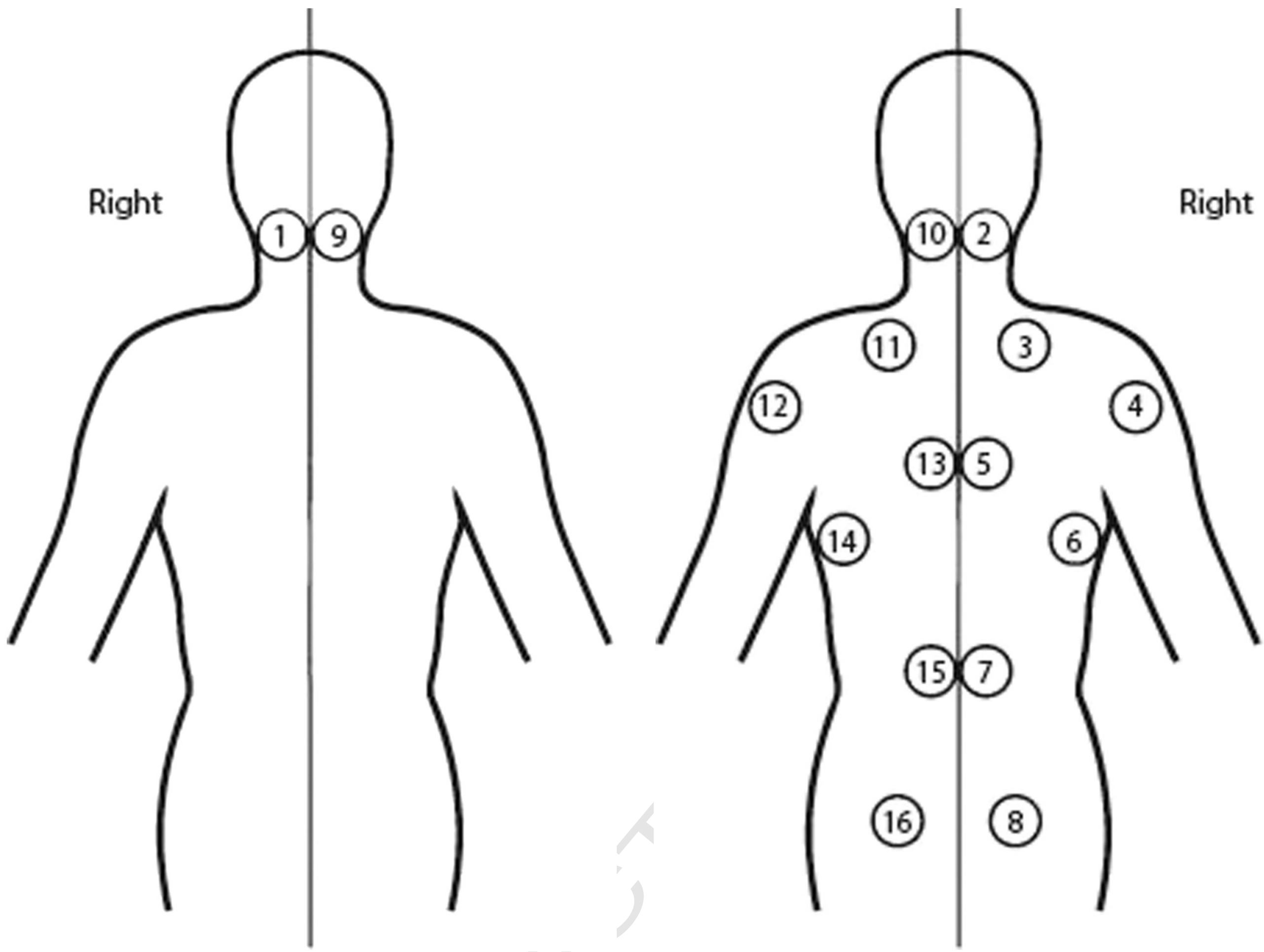


Fig 1. *Schematic drawing of electromyography electrode placement (anterior and posterior).*

carefully placed at the following sites (see Fig 1): right (1) and left (9) sternocleidomastoid, right (2) and left (10) splenius cervicis, right (3) and left (11) upper trapezius, right (4) and left (12) posterior deltoid, right (5) and left (13) middle trapezius, right (6) and left (14) latissimus dorsi, right (7) and left (15) longissimus thoracis, and right (8) and left (16) gluteus maximus. Before the placement of electrodes on each of the target areas, the skin was thoroughly cleansed using gauze soaked in a 70% ethanol solution and skin debridement was achieved using a disposable razor. After electrode placement, ensuring an inter-electrode distance of 30 mm, conductance was tested using an impedance meter and where necessary, the skin preparation and electrode placement process was repeated until all electrode impedance values were below 5 kΩ. Once the leads were attached, flexible tape (Fixomull transparent) was applied over the electrodes and used to secure the leads to the participant to prevent noise within the electromyography recording. Amplification (x2500) of the signals was performed in a preamplifier located no farther than 100 mm from the recording electrodes. A reference ground electrode was placed on the right lateral epicondyle of all participants. Electromyography signals were collected (2000 Hz, WinDaq [data acquisition software], on a 486-mHz personal laptop computer) for approximately 10 seconds in each trial, 5 seconds preceding and after each manipulative thrust (see Fig 2). Data were stored on the computer for offline analysis.

Time of Onset of Manipulation

To ensure that the reflex responses were associated with the applied SMT, the time of onset of each manipulation was recorded using a thin, flexible pressure pad measuring force. This pressure pad was placed between the clinician's contact and the participant's neck.[34,35] The pressure pad is 2.2 mm thick and contains 99 sensors that detect pressures in the range of 20 to 600 kPa with a resolution of 2.5 kPa. The 2 measurement systems were synchronized using a 5-V electrical pulse sent from the force measurement (Pedar)

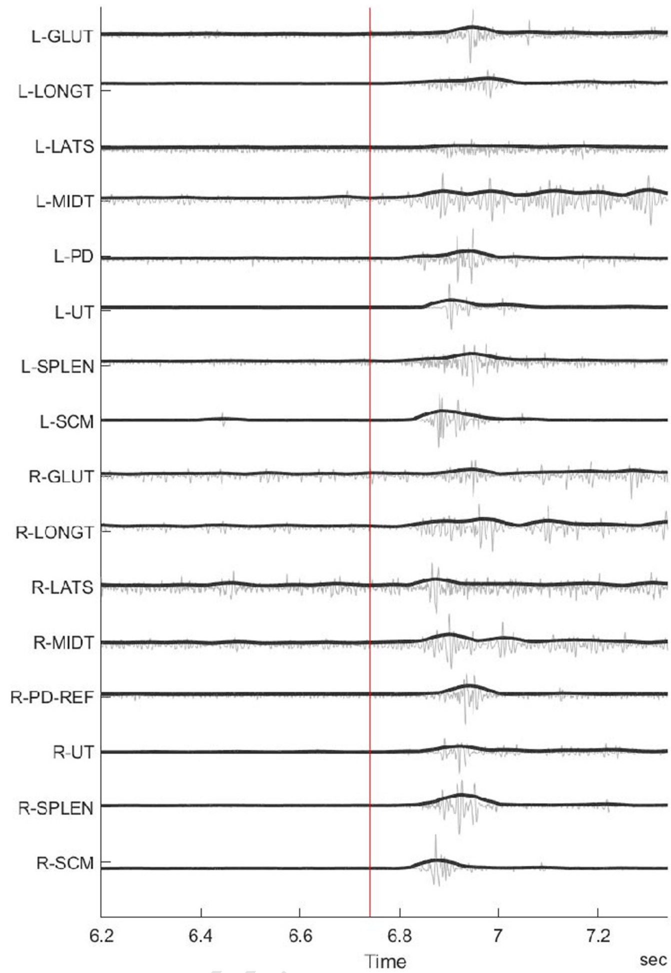


Fig 2. *Representative raw data of the reflex responses at all 16 electromyography recording sites after T4 manual spinal manipulative therapy.* GLUT, *gluteus maximus;* L, *left;* LATS, *latissimus dorsi;* LONGT, *longissimus thoracis;* MIDT, *middle trapezius;* PD, *posterior deltoid;* R, *right;* REF, *reference electrode;* SCM, *sternocleidomastoid;* SPLEN, *splenius cervicis;* UT, *upper trapezius.*

system. Force data were collected to the hard drive of a second 486-mHz personal laptop computer for approximately 10 seconds for each trial, 5 seconds preceding and after each manipulative thrust. Data were stored on the computer for offline analysis.

Data Analysis

The presence of a reflex response, defined as an increase in electromyography signal of at least 2 standard deviations above baseline and occurring within 500 ms of the onset of manipulation, was evaluated by visually inspecting the electromyography recordings for each SMT thrust. Baseline was defined as the 500 ms preceding the SMT thrust. The presence or absence of a reflex response, measured simultaneously at all of the 16 sites, was then recorded for each of the 6 SMTs delivered to each participant. If 2 thrusts were delivered to a segment, the second thrust was considered successful and used for analysis. The number of positive responses was then tabulated and expressed as a percentage.

All procedures were approved by the Conjoint Health Research Ethics Board at the University of Calgary (REB16-0296_REN2).

Results

Twelve asymptomatic participants aged between 24 and 35 years (mean: 29, SD: 3.2), volunteered to participate in the study. Of these 11, 5 male participants (45%) and 6 female participants (55%), provided informed consent and were enrolled in the study. Electromyography responses in all neck and most back muscles were typically present after cervical SMT, whereas responses in the outlet to the upper arm (posterior deltoid) and leg (gluteus maximus) were less frequent. This trend was similar, although decreased in magnitude, with upper thoracic SMT (see Table 1).

Table 1. *Electromyography Responses of Muscles Associated With Manual Spinal Manipulative Therapy*

	Positive Reflex Responses (%)					
	C1	C2	C6	C7	T1	T4
Muscles on right side of body						
Sternocleidomastoid	10/10 (100)^	10/10 (100)	11/11 (100)	10/11 (91)	8/11 (73)	7/11 (64)
Splenius cervicis	9/10 (90)	10/10 (100)	9/11 (82)	10/11 (91)	10/11 (91)	9/11 (82)
Upper trapezius	10/10 (100)	7/10 (70)	10/11 (91)	10/11 (91)	9/11 (82)	7/11 (64)
Posterior deltoid	10/10 (100)	9/10 (90)	10/11 (91)	10/11 (91)	7/11 (64)	9/11 (82)
Middle trapezius	8/10 (80)	9/10 (90)	10/11 (91)	10/11 (91)	5/11 (45)	8/11 (73)
Latissimus dorsi	9/10 (90)	9/10 (90)	8/11 (73)	10/11 (91)	7/11 (64)	8/11 (73)
Longissimus thoracis	8/10 (80)	6/10 (60)	7/11 (64)	7/11 (64)	7/11 (64)	7/11 (64)
Gluteus maximus	6/10 (60)	4/10 (40)	6/11 (55)	3/11 (27)	4/11 (36)	2/11 (18)
Muscles on left side of body						
Sternocleidomastoid	10/10 (100)	10/10 (100)	10/11 (91)	11/11 (100)	10/11 (91)	9/11 (82)
Splenius cervicis	10/10 (100)	9/10 (90)	10/11 (91)	7/11 (64)	9/11 (82)	7/11 (64)
Upper trapezius	7/10 (70)	6/10 (60)	11/11 (100)	7/11 (64)	10/11 (91)	9/11 (82)
Posterior deltoid	4/10 (40)	6/10 (60)	7/11 (64)	11/11 (100)	9/11 (82)	7/11 (64)
Middle trapezius	8/10 (80)	9/10 (90)	8/11 (73)	9/11 (82)	8/11 (73)	8/11 (73)
Latissimus dorsi	4/10 (40)	5/10 (50)	7/11 (64)	6/11 (55)	5/11 (45)	3/11 (27)
Longissimus thoracis	7/10 (70)	5/10 (50)	7/11 (64)	8/11 (73)	6/11 (55)	8/11 (73)
Gluteus maximus	1/10 (10)	3/10 (30)	4/11 (36)	7/11 (64)	5/11 (45)	4/11 (36)

Note. 10/10 (100) indicates a positive reflex response in 10 of 10 participants for which data were recorded at this level.

Cervical Spine

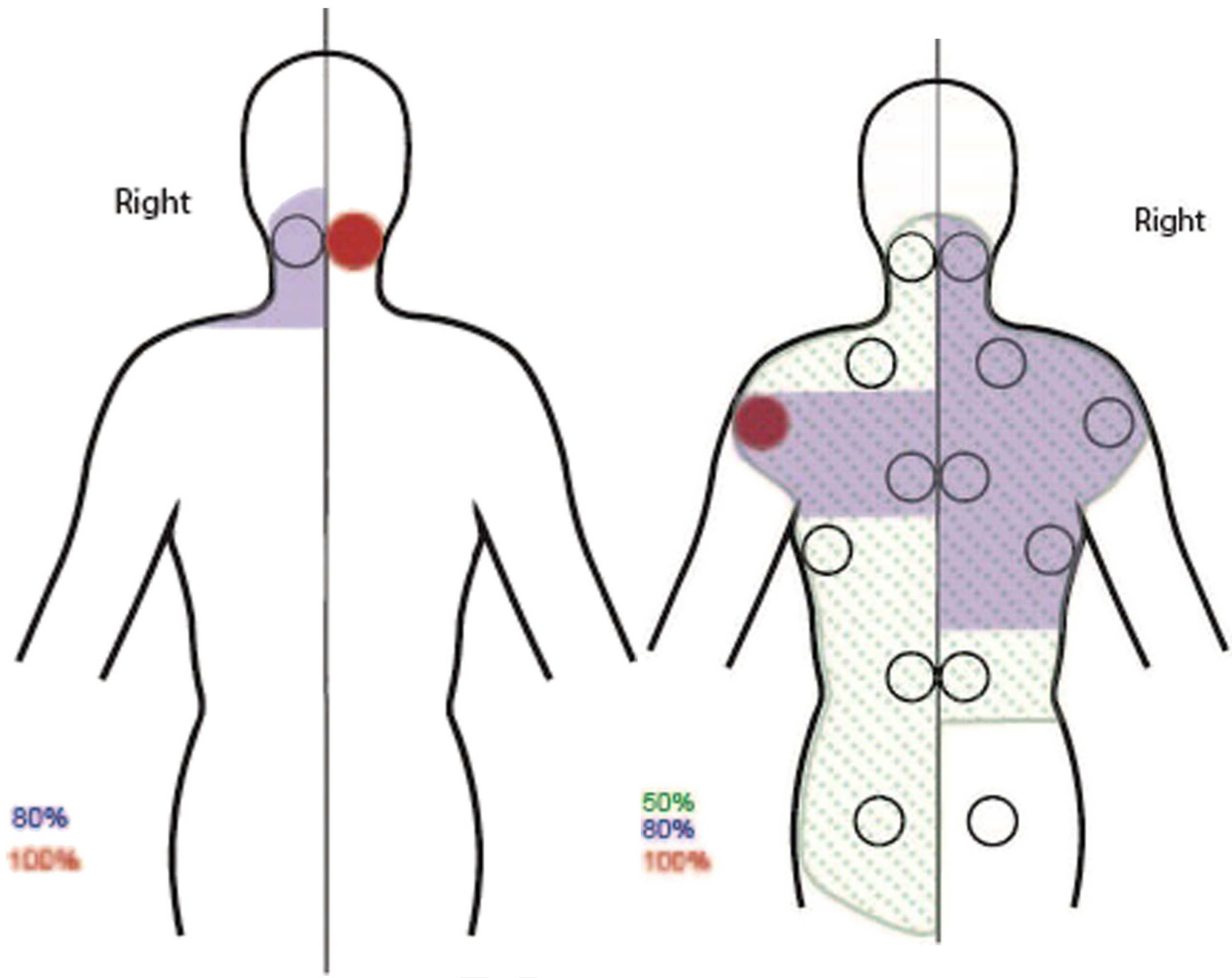
Manipulation of the upper (C1 and C2) and lower (C6 and 7) cervical segments was associated with reflex responses in 74% and 77% of the 16 recorded electromyography channels, respectively. The greatest number of reflex responses, 77%, occurred after manipulation of the C7 vertebrae (see Fig 3).

Reflex responses in neck muscles (sternocleidomastoid and splenius cervicis) were recorded 98% of the time after upper cervical SMT and 88% after lower cervical SMT. Reflex responses after upper cervical SMT were extremely consistent across all participants, and manipulations with electromyography responses occurred 100% and 95% of the time in the sternocleidomastoid and splenius cervicis, respectively. Responses after lower cervical SMT were more variable, occurring 95% and 81% of the time in the sternocleidomastoid and splenius cervicis, respectively. Back muscles (upper trapezius, middle trapezius, latissimus dorsi, and longissimus thoracis) responded 77% of the time after lower cervical SMT and 73% after upper cervical SMT. Reflex responses in back muscles were variable after both upper cervical and lower cervical SMT (see Table 1).

The upper limb muscles (posterior deltoid) responded 87% of the time after lower cervical SMT and 73% of the time after upper cervical SMT. The lower limb muscles (gluteus maximus) responded 35% of the time after upper cervical SMT and 46% after lower cervical SMT.

Upper Thoracic Spine

Manipulation of the upper thoracic spine (T1 and T4) was associated with reflex responses in 66% of the 16 recorded electromyography channels. The least number of reflex responses, 64%, occurred after manipulation of the T4 vertebrae (see Fig 4). Upper thoracic SMT was associated with reflex responses in neck muscles (sternocleidomastoid and splenius cervicis) 78% of the time, back muscles (upper trapezius, middle trapezius, latissimus dorsi, and longissimus thoracis) 65% of the time, the upper limb muscles (posterior



Q7 **Fig 3.** *Extent of reflex response associated with manipulation of the C7 vertebrae (anterior and posterior).*

deltoid) 73% of the time, and the lower limb muscles (gluteus maximus) 34% of the time.

Reflex responses in neck muscles were fairly consistent after upper thoracic SMT, occurring 77% and 80% of the time in the sternocleidomastoid and splenius cervicis, respectively. However, responses in the back, posterior deltoid, and gluteus maximus were highly variable (see Table 1).

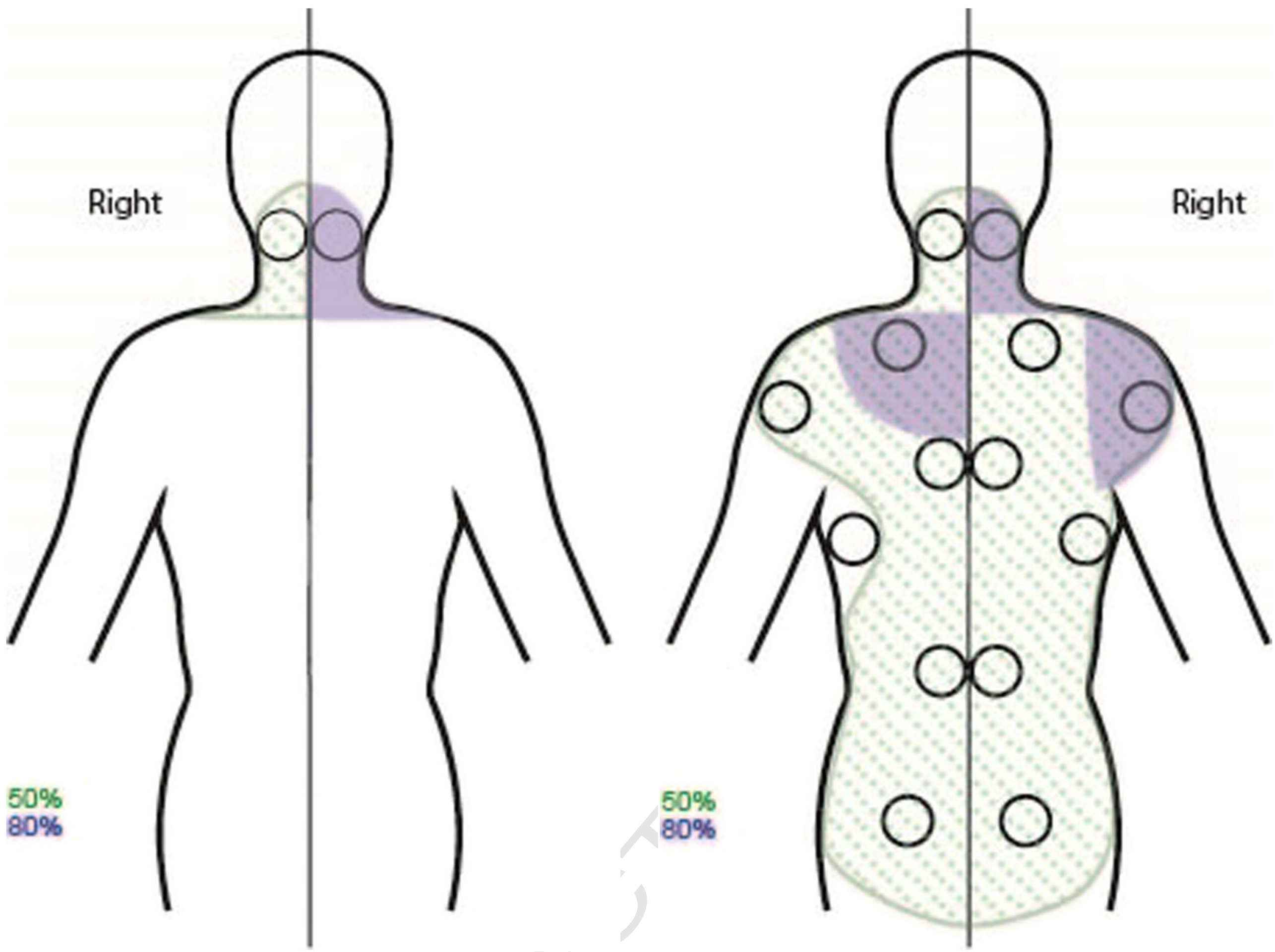
Adverse Events

No adverse events were reported either immediately post-treatment or at 24-hour follow-up.

Discussion

The results from this study are congruent with the published literature and support the finding that SMT is associated with consistent reflex responses from neck and back muscles in asymptomatic participants.[10,14] The onset, shape, and duration of the electromyography traces observed in this study suggest that a muscle's response to SMT is composed of a series of temporally and spatially nonsynchronized motor unit action potentials of various origin. These origins likely include cutaneous mechanoreceptors, zygapophyseal joint mechanoreceptors, muscle spindles, and Golgi tendon organs, all of which contribute to the complexity of the electromyography signal. In addition to stimulating different mechanoreceptors, manual SMT is associated with reflex responses in muscles that are distant to the treated area,[10,36] a finding that is not observed with all SMT techniques.[14,15]

Although the greatest activation levels in the current study were observed in muscles directly innervated by spinal nerves exiting from the target region, that is, neck with upper cervical SMT and arm with lower cervical SMT, systematic activation was still recorded in regions distal to the target site. The activation of muscles local to the treatment area is intuitive if one considers the origin, insertion, and innervation of these muscles but is less



Q8

Fig 4. *Extent of reflex response associated with manipulation of the T4 vertebrae (anterior and posterior).*

straightforward when considering activation of nonlocal regions. For example, the sternocleidomastoid has both its origin (sternum and clavicle) and insertion (mastoid process of the cranium) in the neck region, is innervated by the accessory nerve (cranial nerve XI), and receives direct nerve branches from both the C1 and C2 levels of the cervical plexus[37]; thus, we could reasonably expect activation of this muscle after cervical SMT. However, there is no obvious anatomical link between the origin, insertion, or innervation of the gluteus maximus muscle to the cervical spine,[37] yet after manipulation applied to the left side of C7, the left gluteus maximus displayed reflex responses 64% of the time, supporting the hypothesis that manual SMT may affect areas that are distal to the treatment site. This finding is in direct conflict with Dishman et al's finding that cervical SMT had no significant effect on lumbar motoneuron activity, leading the authors to suggest that SMT effects are regional rather than global.[26] Indeed, it is possible that when analyzing the component parts of the electromyography response, specifically the Hoffman reflex as was the case in the Dishman study, this may be true. However, the current study was interested in observing the reflex response associated with SMT in its entirety rather than its component parts, and thus the apparent conflict is likely due to methodological differences in the 2 studies. In the current study, the possible effect of SMT at areas distal to the treatment site was greatest in the lower cervical spine, specifically C7. Surprisingly, on the left (ipsilateral to the target site), 6 of the 8 electrodes were activated 91% of the time and the longissimus thoracis and gluteus maximus were activated 64% and 27% of the time, respectively. This activation pattern is repeated on the left side, albeit to a lower level: 3 electrodes were activated ≥80% of the time, 1 electrode ≥70% of the time, and the remaining 4 electrodes ≥55% of the time.

Some authors believe that cervical SMT is superior to manipulation applied to other areas of the spine because it generates a greater response from the central and peripheral nervous systems.[38,39] This occurs as the cervical spine has a higher density of zygapophyseal joint mechanoreceptors and muscle spindles,[40,41] in addition to extensive connections between cervical afferents and vestibular nuclei and propriospinal neurons.[42,43] These connections allow for facilitation and inhibition of motor neurons at all levels of the spinal cord and could be one reason for the highly systematic activation of both local and nonlocal muscles after cervical SMT seen in our study.[26,41-43]

Limitations

It is possible that the electromyography responses recorded in this study were inconsistent owing to a number of factors. Firstly, variation in electrode placement may have occurred, resulting in the recording of electromyography responses from different parts of the same muscle among participants. However, all possible care was taken to ensure that electrode placement was consistent among participants despite differences in body size, shape, and anatomy. Second, it is possible that these differences among participants may have affected the biomechanical components of SMT, such as the line of drive, level of force applied, and speed of the thrust. These differences could feasibly have changed the anatomy affected by the thrust and thus the reflex responses associated with SMT.

Furthermore, because 10 of 11 participants were naïve to SMT before their enrollment in this study, it is possible that uncertainty regarding the nature of the intervention may have resulted in various levels of muscle guarding, thus resulting in variable reflex responses. For example, it is possible that a thrust delivered to an anxious participant with significantly hypertonic muscles in the target area may have occurred at a shorter muscle length (thus affecting the number of muscle spindles activated) and have required a greater force or speed (to overcome the muscle guarding) compared to that delivered to a relaxed participant with normotonic muscles. However, the clinician delivering the SMT was instructed to provide the same line of drive for each participant as much as possible, while still effecting a clinically successful SMT. Furthermore, the clinician has in excess of 30 years' experience in private practice delivering manual SMT to patients.

Additionally, the order of the manipulations was nonrandom—each participant underwent manipulation from C1 to T4 in the same order and on the same side. Thus, it is possible that there may have been an order effect present. Specifically, there may have been descending effects from upper levels of the spine to those lower, that is, from upper to lower cervical and cervical to thoracic. However, there was no noticeable difference between either the magnitude or shape of electromyography responses recorded at the beginning to the end of the data collection session for any participant.

Also, as the participants in our study were asymptomatic, the results described here may not be representative of those occurring in a symptomatic population. However, asymptomatic participants were chosen to establish a baseline response in normal people and to test whether the extent of the electromyography response was repeatable among participants. Finally, we acknowledge that our results provide a purely descriptive analysis of the electromyography responses—the response was either present or absent and there was no attempt made to discern or analyze individual components of the reflex signal (eg, Hoffman reflex). This decision did not allow us to investigate the effects of SMT on the component parts of the electromyography response; however, this was not the purpose of our study and would have required highly invasive technology.

Conclusion

Cervical SMT was associated with electromyography responses in all neck and most back muscles, whereas responses in the outlet to the upper arm (posterior deltoid) and leg (gluteus maximus) were less frequent. This trend was similar, although decreased in magnitude, after upper thoracic SMT. Specifically, reflex responses were greatest after lower cervical SMT (C7) and lowest after thoracic SMT (T4). There was systematic activation of areas distal to the target site, supporting the literature that manual SMT may have both a local and nonlocal effect.

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Contributorship Information

Concept development (provided idea for the research): L.M.G., W.H.
Design (planned the methods to generate the results): L.M.G.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): L.M.G., W.H.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L.M.G., P.J.C.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L.M.G., W.H.
Literature search (performed the literature search): L.M.G.

Writing (responsible for writing a substantive part of the manuscript): L.M.G.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): L.M.G., P.J.C., W.H.

Practical Applications

- Cervical SMT is associated with reflex responses that are both local (eg, neck) and nonlocal (eg, back).
- This trend is similar, although decreased in magnitude, with thoracic SMT.
- Reflex responses are greatest after upper cervical SMT and lowest with thoracic SMT.

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