AN ELECTROMYOGRAPHIC STUDY OF THE INTRAMUSCULAR EFFECTS OF THE CHIROPRACTIC ADJUSTMENT

A PILOT STUDY

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Abstract: There have been many attempts to record changes in the activity of the superficial spinal musculature following manipulative therapy by means of Electromyography (EMG). However, the question asked in this study was “By utilising bipolar intramuscular electrodes (BIM) can an association between intrinsic muscle action potentials and the chiropractic subluxation be demonstrated?”

The rotatorae muscles are the deepest of the intrinsic muscle groups and are intimately associated with the intrinsic movements of the thoracic motion segment. The areas chosen for this study included segments from T1 to T4 as the rotatorae muscles at these levels are the most developed.

All EMG activity was monitored using a Medelec MS6 mainframe recording unit. The BIM electrodes were paired, 71µm diameter polyurethane coated copper wires, threaded through a 41 mm length of 27 gauge dental needle and bent back to achieve an interelectrode distance of 2mm. This was then inserted to the desired depth of 4cm and then withdrawn to leave the BIM electrodes imbedded in the rotatorae muscle. Control electrodes were placed 4 spinal segments lower than the experimental level on the homolateral side of experimental spinal segment.

It was found that the fixated segment’s rotatorae muscles has an EMG background reading at rest. It was postulated that this facilitated state of the muscle was generated at the neuromere as a result of aberrant afferent input from the associated general somatic afferents directly innervating that spinal segment. A decrease in amplitude and frequency of the action potential was observed in the rotatorae muscles, after spinal adjustment. Control readings were taken to assess the change in EMG activity associated with habituation to the experimental procedure with time. It was found that there was no change in the action potential that could be attributable to habituation.

This pilot study suggests a potentially effective way of analysing the effects of spinal manipulative therapy on the intrinsic muscles of the spine. Preliminary data indicated an increase in action potential, of the rotatorae muscles associated with a national chiropractic subluxation, and de-facilitation of those muscles following a chiropractic adjustment.

Key Index Terms: (MeSH) Electromyography (EMG), intramuscular (IM), chiropractic, subluxation, adjustment.

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INTRODUCTION

It is a common belief held by chiropractors (2) that spinal manipulation affects those muscles spanning a hypomobile spinal joint (facet or apophyseal joints). There have been attempts to record changes in paraspinal muscle activity following manipulative therapy by means of surface electromyography (SEMG) (3)(4)(5). However, the physiological anatomical nature of the paraspinal muscles enables SEMG to record from the most extrinsic superficial groups only. To reduce background noise from tissue resistance the bulk of the erectae muscles and to determine a specific intersegmental muscle reading, it is important to measure the activity of the intrinsic muscle group with the use of IM electrodes (1).
The rotatorae muscle of the upper thoracic spine chosen for the insertion of the IM electrode was performed on the homolateral side, at the level of the determined chiropractic fixation. The areas chosen for this study include segments from T1 to T4, since the rotatorae muscles at these levels are the most developed. The rotatorae muscles are small and somewhat quadrilateral in form. Each connect the superior, posterior aspect of the transverse process of one vertebra to the lower lateral surface of the lamina of the vertebra above, the fibres extend to the root of the spinous process (6). The rotatorae muscles extend and rotate the vertebral column and are supplied segmentally by branches of the dorsal primary rami of the spinal nerves (6)(7).

Many of the skeletal muscles are, at any one time, in a state of reflex contraction known as muscle tone (8). This applies particularly to the muscles which are opposing the effects of gravity, such as paraspinal muscles. Hypertonus (or spasm) of a muscle can result either from injury to the muscle itself or as a reflex response to nociceptor irritation of a joint and its associated tissues (8). The concept that restricted joint movement may result from segmental muscle spasm is supported by the knowledge that muscles not only impart movement but also impede movement (9), such is the case with the chiropractic lesion commonly termed the subluxation (10)(11). One common clinical criterion which is thought to be associated with the chiropractic subluxation is adjacent paraspinal muscle spasm (myopathy/facilitation). Based on clinical observations and supportive research with the use of SEMG, it has been demonstrated that the facilitated extrinsic (hypertonic) muscles that accompany a chiropractic subluxation, are influenced by the chiropractic adjustment into a relaxed state (2)(5).

The spinal muscles and joints are functionally interdependent (8). It therefore follows that dysfunction in either of them may subsequently effect the other. The sensory component important in the control of muscle contraction is the neuromuscular spindle. The tone of the muscle is controlled directly by alpha motor neurons which innervate the skeletomotor muscle fibres and indirectly by gamma motor neurons which innervate the neuromuscular spindle. Hyperactivity of either alpha or gamma motor neurons results in facilitation of the muscles spanning the motion segment.

Irritation of the zygapophyseal joints can be caused by a direct mechanical or chemical stimulation of the nociceptors of the synovial joint capsule and associated connective tissues (8)(12). The joint receives its innervation from the medial branch of the posterior primary ramus (13). Small myelinated and unmyelinated nerve fibres have been described in the epiphysis and metaphysis (8) of the zygapophyseal joints.

The activity of skeletal muscle may be determined by the myoelectric potential. EMG enables the continuous recording of muscle action potentials. The smallest group of muscle fibres employed voluntarily or in a reflex action is the motor unit. This is composed of the anterior horn cells, the corresponding motor axons and the muscle fibres they innervate. This is composed of the anterior horn cells, the corresponding motor axons and the muscle fibres they innervate. These muscle fibres are often widely spread within a muscle, which means that even when only a few motor units are active, the force is generated diffusely (8). With the activation of one motor unit, IM EMG recording apparatus will detect the action potential from each fibre of the motor unit within the pick up volume of the electrode. The resultant EMG will be a spatial-temporal superposition of the contributing fibres (14)(16). The shape of the motor unit action potential will remain constant, provided the position of the electrodes within the active muscle fibres remains unaltered (16). The shape, amplitude and frequency of the motor unit action potentials are dependent on the orientation of the recording electrode contact, diameter of the muscle fibres, neuromuscular excitability, distance between the active muscle fibres and recording site, and the filtering properties of the electrode (14)(17).

The premise tested in this study was that; an increase in muscle action potentials (MAP) evident with the facilitated muscle is related to an adjacent hypomobile segment as a result of a vertebral subluxation. The IM EMG technique was adopted to record the action potentials before and after chiropractic spinal adjustments, to determine any changes that may occur.

METHODS

Subject Preparation

The subjects used in this pilot study were two male and one female volunteers ranging from 19 to 23 years. A registered chiropractor screened the subjects by motion palpation (18) in order to opine the presence and level of an upper thoracic vertebral subluxation. Ethics approval was granted by Macquarie University’s Human Ethics Committee. Preparation of the subjects included shaving the upper thoracic area and sterilisation using an alcohol swab.
Monitoring and displaying the EMG signal

All EMG activity was monitored using a Medelec MS6 mainframe EMG recording unit, with a cathode ray oscilloscope and fibre optic face plate for producing a photographic record. An audio amplifier was also used with the mainframe for monitoring the EMG signal.

Electrode Preparation

The intramuscular electrodes were paired, 71µm diameter polyurethane coated copper wire (IWA biceflx). The pair of wires were threaded through a 41mm length of 27 guage dental needle. Both ends of each wire were manually stripped with a Stanley knife and examined under a binocular microscope. The end to be inserted into the muscle was bared 1mm and the other end bared 1cm. One of the 1mm bared ends of the pair of wires was bent back along the needle 1mm and the second was bent back 4mm to give an interelectrode distance of 2mm, figure 1. The needles and wires were sterilised by gas over night.

Electrode Placement

The hypodermic needles containing the intramuscular electrode were inserted into the desired depth of 4cm and then withdrawn to leave the intramuscular electrode embedded in the muscle. The electrode was inserted at a level between T1 and T4 according to the site of fixation, at two fingers breadth lateral to the spinous process with approximately 45° angle of inclination and 30° angle to the midline. The bevelled end of the needle was faced down so that the IM electrode was imbedded potentially along the direction of the rotatorae fibres. Phospho-bronze springs (7mm long) were used to grip the bared ends of the electrode so that the electrode could be secured to the subject and then connected to the EMG recording apparatus. Before use, the springs had been soaked in concentrated chromic acid for 10 minutes, washed in water and dried to remove any oxidative residue.

Controls

Control electrode placement positions in the thoracic spine were chosen at 4 motion segments lower than the experimental levels in the upper thoracic spine on the homolateral side. Pre and post EMG readings were taken from the control segments.

Recording EMG Activity

a) The subject was asked to relax in a seated upright position in a chair. A recording was then taken (Neutral head position).

b) The subject then rotated their head/neck to the homolateral side of electrode placement. At the end of full cervical rotation they held that position for 5 seconds then an EMG reading was taken.

c) The procedure was repeated as described above post chiropractic adjustment and EMG recordings taken, within 2 minutes after the adjustment.

Delivery of the Chiropractic Adjustment

The level of fixation found by chiropractic motion palpation (18) was adjusted with the subject in a prone position from the contralateral side to electrode placement. Using a spinous process thumb contact on the fixated vertebra as the primary contact and the cervical spine rotated to the homolateral side and stabilised by the secondary contact. The pre adjustment set up indirectly stretches the paraspinal muscles as a result of cervical homolateral rotation. An adjustment; a dynamic thrust of controlled velocity, amplitude and direction (11), was performed with the intent to reduce the chiropractic subluxation.

Electrode Removal

When removing the electrodes care was taken to remove them slowly and gently with a continuous gentle traction on the wires to prevent them from breaking off. After removal of each intramuscular electrode a binocular microscope was used to inspect the measure their length to ensure full electrode withdrawal from the subjects. The total time for the whole procedure did not exceed 30 minutes.

RESULTS

IM readings with erect posture

IM EMG recordings were made at both control and experimental levels. All EMG data is presented raw for direct visual comparisons of rotatorae action potentials. On visual comparison of the EMG data, it was noted that all subjects (figures 2a, 3a, 4a and 5a) demonstrated a facilitated rotatorae activity in the pre adjustment states. This was markedly reduced at post adjustment readings as was observed particularly in
IM readings with homolateral rotation

IM readings were taken in all subjects at full homolateral cervical rotation. It was observed in the two male subjects (figures 2c, d and 3c, d) that the action potentials of the rotatorae muscles at T2 were markedly reduced in post adjustment. The action potential train demonstrates in both subjects a reduction in amplitude and frequency. The third subject demonstrated only a reduction in the frequency of the action potential, (figure 4c, d). Further, no observable differences were noted in the control readings, (figure 5c, d).

DISCUSSION

The EMG signal is the electrical manifestation of the neuromuscular activation associated with a contracting muscle. It is an exceedingly complicated signal which is affected by the anatomical and physiological properties of muscles, the control scheme of the peripheral nervous system, and the characteristics of the instrumentation used to detect and observe it. Most of the relationships between the EMG signal and the properties of a contracting muscle which are presently employed have evolved as a result of empirical studies.

EMG analysis and specificity

Under normal conditions, an action potential propagating down a motor neurone activates all the branches of the motor neurone. These in turn activate all the muscle fibres of the motor unit (19). When the presynaptic membrane of the muscle fibres is depolarised, the depolarisation propagates in both directions along the fibres. The membrane depolarisation accompanied by ion transfer, generates an electromagnetic field in the vicinity of the muscle fibres (1)(19). A recording electrode located in this field will detect the action potential. In order for indwelling needle electrodes to be able to detect an action potential they must be less than 1.5mm from the motor unit to be tested (1). Therefore, the individual muscle fibre action potentials represent the contribution that each active muscle fibre makes to the signal detected at the electrode site. In this study the amplitude of the action potentials is dependent on the diameter of the muscle fibres, the distance between the active muscle fibres and the recording site, the discharging motor unit and the filtering properties of the electrode. This study incorporated a 2mm interelectrode distance within the body of the rotatorae muscles for all subjects for standardisation. The other variables are expected to remain constant except the rate of discharge of the motor units within the pickup volume of the electrodes may alter.

In this study the subjects were positioned in an upright seated position where IM electrode readings were taken pre and post chiropractic adjustment. Experiment 1 (figure 2a) demonstrates the right rotatorae muscle EMG readings at T2, with the subject looking ahead. This figure shows the resting action potential of that muscle before the adjustment. The frequency and amplitude of the action potentials were demonstrated to be uniform for that muscle. The state of the facilitated muscle before the adjustment was indicated by the amplitude of those spikes in neutral head position at 10 microvolts. It is postulated that the facilitated state of the muscle could be generated at the neuromere as a result of aberrant afferent input from the zygapophysial joint receptors and other associated structures. A decrease in amplitude and frequency was observed in figure 2b after the application of a chiropractic adjustment. So much so that the post EMG recording is silent. This reading was taken within 2 minutes of the adjustment at the level of T2. This protocol was repeated for the other two subjects figure 3a, b and figure 4a, b. It was observed in figure 3a and b that there was no detectable change in pre and post EMG reading. In figure 4a and b a similar decrease in EMG amplitude and frequency was observed. However, the reduction in response in figure 4b did not lead to complete silencing of that muscle as observed in figure 2b.

On full cervical rotation EMG readings were taken to evaluate the myoelectric potential. During active contraction of the rotatorae, there was an obvious change in muscle rate of activity in pre and post adjustment. The most striking change was observed in figure 2c and d. On full right cervical rotation, coupling of the upper thoracic segments takes place, so that rotation of the upper thoracic is achieved at the end of full cervical rotation. This suggests that full contraction of those rotatorae is then achieved. The action of rotatorae muscle was first noted by Morris et al., (1962) (20) during ipsilateral rotation of the spine, without any external intervention to those muscles beyond active trunk rotation. Further, a marked reduction in amplitude of EMG response was observed in two of the three subjects (figure 2c, d and 3c, d), following chiropractic intervention.
Control readings were taken to assess the change in EMG activity associated with habituation to the experimental procedure with time. To establish whether the changes observed in EMG activity were localised to those rotatorae at the fixated segments, control readings were taken at 4 spinal segments lower. It was demonstrated in figure 5a and b, with the subject in neutral upright position, that no observable change was detected in pre and post adjustment readings. The observed muscle action potentials at the control levels may be attributed to the normal activity of the muscles against gravity. Further, on full cervical rotation of the control to the right, figure 5c and d, demonstrate no detectable change in EMG readings. As each individual subject may possess a unique pattern of rotatorae EMG activity, raw data was required to enable direct visual comparison. Quantification by online computer analysis may be preferable in a larger population sample and is currently under development for further research in this area.

It was observed that the male subjects enable a better electrode placement and recording (figures: 2 & 3) than the female subject. This may be attributed to a larger more developed rotatorae in the males subjects. It may be found that future IM EMG studies using the rotatorae muscle may benefit from exclusive use of male subjects for ease of electrode placements.

**Possible Mechanism of EMG changes Post Adjustment**

a) Direct stretch of the muscle.
Travell and Simon (1983)(21), considered that direct stretching of a muscle may lead to a relaxation of that muscle. The mechanical nature of the chiropractic adjustment applied to right T2 may indirectly stretch both extrinsic and intrinsic muscle groups. In this study however, the stretch of the muscles spanning the control segment as well as that of the fixated segment were monitored and no EMG change was observed at the control level post adjustment (figure 5).

b) Somatosomatic reflex via proprioceptive mechanism
Somatosomatic reflexes constitute that class of reflexes that have both their receptor and effector in somatic tissue (21). Notional spinal fixation in the upper thoracies was found to correspond with facilitated rotatorae muscle activity in the pre adjustment readings. This may be attributed to the chiropractic fixation at those levels, along with background action potentials as a result of the upright posture and hence antigravity effects. EMG readings post adjustment with subjects looking ahead have shown an observable decrease in two out of three subjects (figure 2b and 3b). Control EMG readings were observed not to alter as a result of the chiropractic intervention, even though the chiropractic pre adjustment positioning involved a stretch of the paraspinal muscles over several thoracic segments. Further support for the somatosomatic hypothesis comes from the comes from the interpretation of the functional readings. Full contraction of the rotatorae at the experimental level, post adjustment, revealed a decrease in the recruitment of motor units (figure 2c, d & figure 3c d). No such alteration was observed in the comparison of the pre and post adjustment state of the control level (figure 5c, d).

This pilot study suggested a potentially effective method for analysing the effects of the chiropractic adjustment on the intrinsic muscles of the spine. Preliminary results indicated an increase EMG activity of the rotatorae associated with a notional chiropractic fixation and de-facilitation of those muscles following adjustment, possible as a result of general somatic afferent activation at those joints influenced by the chiropractic adjustment.

To further define the association between the chiropractic adjustment and IM EMG a larger population sample is needed. Even though electrode placement was performed so that the target tissues would be the rotatorae muscles, there is the possibility that the BIM electrode may embed in the multifidus muscle. Future studies hope to incorporate either CAT scan or Ultra Sound measures to ensure visual confirmation of electrode placement in the desired muscle belly. Also, long term EMG reading of the rotatorae muscles post adjustment may be of interest to determine if a sustainable effect of the chiropractic adjustment can be measured.

**REFERENCES**

1. Basmajian J.V. Muscles Alive. 4th Ed. Williams & Wilkins, 1979: 23-51.
2. Shambaugh P. Changes in electrical activity in muscles resulting from chiropractic adjustment: A pilot study. JMPT 1987; 10(6): 300-04.
3. England R., Deibert P. Electromyographic studies. Part I: Consideration in the evaluation of osteopathic therapy. J. Am. Osteop. Assoc. 1972.
4. Grice A.S. Muscle Tonus Changes Following Manipulation. The Journal of the Canadian Chiropractic Association. 1974.
5. Gentempo P. Characterising the Vertebral Subluxation complex With Paraspinal Electromyography. International Review of Chiropractic 1990; July/August.
6. Warwick R., Williams P. Gray’s Anatomy. 35th ed. Longman Group. 1978: 512.
7. Moore K.L. Clinically Oriented Anatomy. 2nd ed. Williams & Wilkins. 1985: 599.
8. Oliver J., Middleditch A. Functional anatomy of the spine. Butterworths 1991: 83-125.
9. Bergmann T.F., Peterson D.H., Lawrence D.J. Chiropractic Technique: Principles and Practice. Churchill Livingstone 1993: 301-3.
10. Korr I.M. ed. The Neurobiologic Mechanisms in Manipulative Therapy. Plenum Press, 1978: 29-40.
11. Halderman S. Principles and Practice of Chiropractic. 2nd ed. Appleton & Lange, 1992: 250.
12. Grieve G.P. Common Vertebral Joint Problems. 2nd ed. Edinburgh: Churchill Livingstone, 1988: 522.
13. Giles L.G.F., Taylor J.R. Human Zygopophyseal Joint capsule and synovial fold innervation. Bri. J. Rheumatol. (1987a). 26: 993-998.
14. De Luca C.J. Physiology and Mathematics of Myoelectric Signals. IEEE tans Biomed. Eng. BME. (1979). 26(6).
15. Guld C., Rosenfalck A., Williams R.G. Report of the committee on EMG instrumentation. Electroenceph. Clin. Neurophysiol. (1970). 28: 299-413.
16. Ekstedt J., Stalgerg E. Single fibre electromyography for the study of microphysiologe of human muscle. Clin. Neurophysiol. (1973). 1:89-112.
17. Oh S.J. Clinical Electromyography: Nerve Conduction Studies. 2nd ed. Williams & Wilkins, 1993: 19.
18. Schafer R.C., Faye L.J. Motion Palpation and chiropractic Technics: Principles of Dynamic Chiropractic. The Motion Palpation Institute. 1989: 159-67.
19. Bern R.M., Levy M.N. eds. Physiology. Mosby, 1983: 35-41.
20. Morris J.M., Benner g., Lucas D.B., An Electromyographic Study of the Intrinsic Muscles of the back in man. J.Anat. Lond., (1962). 96(4): 509-20.
21. Travell J.G., Simons D.G. Myofascial Pain and Dysfunction: The Trigger Point Manual. Williams and Wilkins. 1983: 89.
22. Swenson R.S. Clinical Investigations of Reflex Function. In: Haldman S. ed. Principles and Practice of Chiropractic. Appleton & Lange, 1993: 105-14.

Figure 1:
Demonstrates the bevelled end of the hypodermic needle, the position of the polyurethane coated copper wires and the interelectrode distance of 2mm.

Figure 2a and b: Illustrates EMG activity of the rotatorae muscle at the right T2 level with erect posture and subject looking ahead, (a) pre-adjustment and (b) post-adjustment. Note the difference in the amplitude of the recordings as compared to pre and post adjustment. In figure 2b the EMG amplitude and frequency has decreased. Figure 2c and d: Illustrates EMG activity of the rotatorae muscle at right T2 level with erect posture and subject rotating the head to the end of full right cervical range of motion, (c) pre-adjustment (d) post-adjustment. Note the difference in the height of the spikes in comparison between the pre and post adjustments. In figure 2d the amplitude and frequency of the muscle action has decreased.

Figure 3:
Figure 3a and b: Illustrates EMG activity of the rotatorae muscle at the right T2 level with erect posture and subject looking ahead, (a) pre-adjustment and (b) post-adjustment. There appears to be no detectable difference between the pre and post adjustment readings. Figure 3c and d: Illustrates EMG activity of the rotatorae muscle at the right T2 level with erect posture and subject rotating the head to end of full right cervical range of motion, (c) pre-adjustment and (d) post-adjustment. Note the difference in the height of the spikes in comparison between the pre and post adjustments. In figure 3d the EMG spikes and frequency has decreased.

Figure 4:

Figure 4a and b: Illustrates EMG activity of the rotatorae muscle at the right T2 level with erect posture and subject looking ahead, (a) pre-adjustment and (b) post-adjustment. There appears to be no detectable difference between pre and post adjustment readings. Figure 4c and d: Illustrates EMG activity of the rotatorae muscle at the right T2 level with erect posture and subject rotating the head to end of full right cervical range of motion, (c) pre-adjustment and (d) post-adjustment. Note the difference in waveform between pre and post adjustments (fig: d). Further the EMG amplitude and frequency has decreased here.

Figure 5:

Figure 5a and b: Illustrates control readings for EMG activity of rotatorae muscles at the T7 levels with subject rotating the head to full right cervical range of motion. Note that the pre-adjustment reading was at 50 microvolts and the post adjustment readings was at 20 microvolts, therefore no direct comparison can be made. However, apart from amplitude the waveform appears to be the same. Figure 5c and d: Illustrates control readings for EMG activity of the rotatorae muscle at the T7 level with subject rotating the head to full right cervical range of motion. Note the difference in the amplitude in comparison between the pre and post adjustment readings. In 5d, the amplitude has increased and the frequency decreased.