Muscle specificity in tests of cervical flexor muscle performance

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Abstract

The deep cervical flexor (DCF) muscles are considered to be of substantial clinical importance in the management of neck pain. While conventional cervical flexion (CF) dynamometry methods have been used frequently to assess the capacity of the cervical flexor muscles, it has been suggested that cranio-cervical flexion (CCF) methods may provide a more specific test of DCF muscle performance. This study compared the activation of the deep and superficial cervical flexor muscles between tests of isometric cranio-cervical flexion (CCF) and conventional cervical flexion (CF) dynamometry. Normalised root-mean-square values were recorded for the deep cervical flexor (DCF), sternocleidomastoid (SCM), anterior scalene (AS), and sternohyoid (SH) muscles during isometric CCF and CF tests at maximal voluntary contraction (MVC), 50% MVC, and 20% MVC in ten healthy volunteers. The results demonstrated significantly greater electromyography (EMG) amplitude for the SCM ($P < .001$–.002) and AS ($P < .001$–.001) muscles in the CF test conditions (MVC, 20%MVC, and 50%MVC) compared to CCF test conditions. Moreover, the SH muscle demonstrated significantly greater EMG amplitude during CF compared to CCF but only in the 50% MVC and 20% MVC conditions ($P = .007$ and .02 respectively). These results demonstrate that dynamometry tests of CF result in greater activity of the superficial cervical flexor muscles compared to tests of CCF. As a result, CCF dynamometry may provide a more specific method to assess and retrain DCF muscle performance, compared to conventional CF in which superficial muscle activity may mask impaired performance of the DCF muscles.

1. Introduction

Impaired cervical flexor muscle performance has been shown to be a factor in painful neck disorders [1–11], and in accordance, assessment and retraining of their performance is advocated in clinical practice [12–14]. There are two basic methods that have been described in research and clinical literature to assess and retrain the cervical flexor muscles. The first method is conventional cervical flexion (CF) where the subjects head and neck are flexed together on the thorax [1–7,15–27]. The second method involves cranio-cervical flexion (CCF) where the head is flexed on the cervical spine [10,11,13,28,29]. Cranio-cervical flexion has been advocated as the method of choice to assess and retrain the contractile performance of the deep cervical flexor (DCF) muscles ($longus capitis$ and $longus colli$) [13]. This recommendation is based on structural anatomical grounds in that the CCF method emphasises upper cervical flexion in association with a mild flattening effect of the cervical lordosis, an anatomical action of the deep $longus capitis$ and $longus colli$ muscles [30–34]. In contrast, superficial cervical flexor muscles such as the sternocleidomastoid (SCM) and the anterior scalene (AS) muscles are not prime movers of CCF [31,34], and structurally are more suited to assist in flexing the lower cervical spine on the thorax [31] as would be required for the CF method.

In clinical practice muscle tests and exercise are applied to target the function of specific muscle groups. In recent years evidence has accumulated of impairment in DCF muscle function in neck pain sufferers [9,10,28,35] supporting the use of CCF muscle test methods, as opposed to conventional CF methods, in the clinical management of neck pain [13]. While it would appear that the predictions of muscle
activation with the CCF and CF methods are accurately based on structural anatomical grounds, no investigations have been performed to compare the activation of the deep and superficial muscles between these different tests of cervical flexor muscle performance. In order to test this hypothesis, the purpose of this study was to compare myoelectric signals from the deep and the superficial cervical flexor muscles between isometric dynamometry tests of CCF and CF. It is anticipated that this study will provide preliminary data that may assist in the appropriate application of the CCF and CF methods as muscle tests and therapeutic exercise methods in the management of cervical spine disorders.

2. Methods

2.1. Subjects

Ten volunteers (5 females, 5 males) with no history of neck pain and a mean age of 31.6 ± 10.8 years (range 20–55 years) participated in the study. Participants were excluded if they had suffered neck pain over the previous year, had a history of orthopaedic disorders affecting the neck or neurological disorders, or if they had specifically trained their neck or shoulder girdle muscles over the previous six months. Subjects were also screened for contraindications for the use of Xylocaine® spray local anaesthetic1 and for the use of nasopharyngeal suctioning technique [37] which were a part of the EMG technique for measuring activity of the DCF muscles [8,9,38]. After receiving verbal and written information each subject signed a consent form containing information about the nature of the study. Ethical approval for the study was granted by the Institutional Medical Research Ethics Committee. All studies were conducted in accordance with the declaration of Helsinki.

3. Instrumentation and measurements

3.1. Electromyography

Myoelectric signals were detected from the right DCF muscles using custom made bipolar electrodes [38]. The apparatus consisted of silver wire electrode contacts (dimensions: 2 mm × 0.6 mm, inter-electrode distance: 10 mm) inbuilt into a suction catheter (size 10FG), with a heat sealed distal end. The bipolar electrode was inserted via the nose to the posterior oropharyngeal wall at approximately the level of the C2/3 intervertebral disc. The longus capitis and longus colli (superior portion) muscles are situated posterior to the oropharyngeal wall at this vertebral level providing an ideal location to make recordings via the mucosal wall without requiring intramuscular recording techniques [9,38]. Once this position was achieved, the electrode contacts were fixed to the mucosal wall with a suction pressure of 30 mmHg via a portal between the two contacts. Prior to insertion, the nose and pharynx were anaesthetised with three metered doses of Xylocaine® spray1 administered via the nostril and three metered doses to the posterior oropharyngeal wall on the same side, via the mouth. Each electrode catheter was individually packed and sterilized using standard gas sterilization procedures.

Recordings of EMG activity for the SCM, AS and sternohyoid (SH) muscles were detected using surface electrodes (Grass Telefactor2). Following careful skin preparation, surface electrodes were positioned over the lower one third of the right SCM (20 mm Ag/Ag Cl disc electrodes) and AS (11 mm Ag/Ag Cl disc electrodes) muscles [39] and over the right SH muscle (11 mm Ag/Ag Cl disc electrodes) midway between its inferior attachment at the manubrium and clavicle, and its superior attachment onto the body of the hyoid bone [31]. This location was chosen to minimise cross-talk signals from the SCM muscle that overlies the inferior portion of the SH muscle. Recordings were made from the SH muscle as it is the most superficial of all the infrahyoid muscles and thus the most amenable to surface EMG detection. Recordings from the suprathyroid muscles were not possible as the positioning of the electrodes would have interfered with the positioning of the resistance arm during the CCF dynamometry method. The ground electrode was placed on the upper thoracic spine. EMG data were amplified (Gain = 1000), band pass filtered between 20 Hz–1 kHz and sampled at 2 kHz (NeuroLog3). Data were sampled with Spike software4 and converted into a format suitable for signal processing with Matlab software5.

3.2. Dynamometry equipment

Isometric CCF was performed in the supine position with a CCF dynamometer (Fig. 1A) that has demonstrated reliability in the measurement of isometric cranio-cervical flexor torque [29]. With this dynamometer, cranio-cervical flexion is resisted at the under-surface of the mandible by the dynamometer resistance arm producing torque at the dynamometer axis that in turn is aligned to the axis of rotation of the subjects’ 0/C1 motion segment. Torque is measured with a load cell (TBS Series6) connected to an amplifier (PM4-SG-240-5E-A7) and a personal computer installed with a custom written program (LabView 6i Virtual Instruments8) that is calibrated to convert voltage

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1 Astra Pharmaceuticals®, 50 Otis St, Westborough, MA 01581.
change from the load cell to the appropriate torque measurement in Newton-meters (Nm).

Isometric CF was performed with a dynamometer consisting of a load cell attached to a block padded for contact with the subjects’ forehead (Fig. 1B). The load cell was rigidly attached to the supporting couch. The subjects’ effort to flex the cervical spine was resisted at the forehead and a resultant change in voltage from the load cell (STC Series9) was amplified (PM4-5G-240-5E-A7) and transmitted to the personal computer and custom written program (LabView 6i Virtual Instruments9) calibrated to give an appropriate force measurement in newtons (N).

For both isometric dynamometry methods, a visual feedback graph was displayed to the subject on a visual display unit. The visual feedback graph would increase or decrease in accordance with muscular effort. The computer software was programmed such that a subject’s maximal voluntary contraction (MVC) could be recorded, and then visual indicators were displayed to the subject on the visual display unit. These visual indicators served as targets so that subjects achieved contraction intensities at 20% and 50% MVC. EMG activity of the DCF, SCM, AS and SH were recorded with both dynamometry methods at MVC, 50% MVC, and 20% MVC.

4. Procedure

All tests were performed in the supine position with the legs suspended on slings such that the hips and knees were flexed to 45°, the arms folded across the chest, and soft straps placed lightly over the shoulders to minimise movement of the trunk on the supporting surface. All procedures were performed in a neutral upper cervical spine position according to a standard anthropometric neutral position of the head (Frankfurt Plane—a vertical line bisects the orbitale and the tragion) [40,41].

To allow subsequent normalisation of the EMG data, subjects first performed a reference voluntary contraction which consisted of a combined CCF and CF [9]. The subject was asked to flex their head on their neck followed by a lift of their head to just clear the supporting surface and to sustain the position for 10s.

Subjects were set up on each apparatus and performed practice trials for familiarisation and warm up purposes. Signals from all four EMG channels were checked for artefacts to ensure high fidelity of the EMG recordings.

The order of testing of the CCF, and CF dynamometry methods was randomised between subjects to eliminate any possible order effects especially that of muscle fatigue. For the CCF dynamometry tests, subjects were instructed to nod their head into flexion such that their jaw pushed downwards on the padded bar while the back of their head maintained contact with the supporting surface. For CF dynamometry tests, subjects were asked to attempt to lift their head off the supporting surface such that their forehead pushed into the padded block. Subjects were also instructed that during CF, they were neither to tuck their chin in or let their chin protrude so as to keep the cranio-cervical motion segments neutral. For both CCF and CF, subjects first performed an MVC sustained for 3–5 s, followed by a contraction at 20% MVC for 10 s, followed by a contraction at 50% MVC for 10 s. Due to the time restraints associated with the nasopharyngeal suctioning technique, only 10 s rest was given between the 3 contractions (MVC, 20% MVC, 50% MVC) using each method. During all testing procedures verbal encouragement as well as visual feedback was given.

5. Data management and statistical analysis

To obtain a measure of EMG signal amplitude, the root mean square (RMS) was calculated for each muscle using a custom designed software program (Matlab (6.1)5). Due to the short duration of the MVC test, RMS values were calculated over a 1-s epoch. For all other tests, RMS values

9 Celtron Technologies Inc, Santa Clara, CA, 95054.
were calculated over a 5-s epoch. RMS values for the CCF and CF dynamometry methods were normalised against the RMS values from the reference voluntary contraction.

Paired *t*-tests were used to compare EMG amplitude for each muscle between the two isometric dynamometry tests (CF and CCF) for each test condition (MVC, 50% MVC, 20% MVC). Significance was set at *P* < .05.

### 6. Results

Table 1 presents the normalised RMS values (means and 95% confidence intervals) for the within muscle comparisons for the DCF, SCM, AS and SH muscles between dynamometry tests (CF and CCF) across all test conditions (MVC, 50% MVC, 20% MVC). Significantly greater EMG amplitude was evident for the SCM (*P* < .001–.002) and AS (*P* < .001–.01) muscles in all CF test conditions compared to the CCF tests. SH muscles similarly demonstrated significantly greater EMG amplitude during CF dynamometry compared to CCF dynamometry but only in the conditions of 50% MVC and 20% MVC (*P* = .007 and .02 respectively).

#### 7. Discussion

When managing patients with painful neck disorders, it is recommended clinically that a CCF method be employed to specifically assess and retrain DCF muscle performance [13]. It is speculated that the CCF method is more specific to the anatomical action of the DCF muscles (*longus capitis* and *longus colli*), and less specific to the anatomical action of the superficial cervical flexors, than a conventional CF method and consequently may be a more specific test/exercise of DCF muscle performance. The results of this study support this clinical hypothesis. The superficial SCM and AS muscles demonstrated significantly greater normalised RMS values for the CF method than for the CCF method across all test conditions (MVC, 50% MVC, 20% MVC) (Table 1). This is also the case for the SH muscle at 50% and 20% MVC. The DCF muscles on the other hand demonstrated no significant differences in normalised RMS values between the two isometric methods across all test conditions, indicating their role in exerting upper cervical flexor moments during both methods. It would appear that while both methods have similar activation of the DCF muscles, reduced DCF muscle activation could potentially be masked by superficial muscle activity during the CF method.

Of the superficial cervical flexors, only the SH muscle at MVC showed similar activation during both the CCF and CF methods. Theoretically, if working in conjunction with the suprahyoid muscles, the SH muscle (along with other infrahyoid muscles) can contribute to CCF and may therefore be recruited when maximal efforts are required. The findings for the SH muscle suggest that the specificity of exposing impairment of the DCF muscles would appear to be optimal at lower intensities (20% MVC, 50% MVC) of muscle contraction, as has been a finding in other studies utilising a CCF method [9,10,28,35].

From a structural anatomical perspective the AS, *longus capitis*, and superior portion of the *longus colli* muscles form a continuous line of muscle from the first rib to the cranium with common attachments at the transverse processes of C3-6 vertebrae [31,33]. It is not possible to infer from our data that either method can test the DCF muscles in isolation. It is feasible that greater AS activity is required at higher contraction intensities of the DCF muscles to provide a stable anchor point. Rather, the results indicated that less superficial cervical flexor muscle activity occurs during a CCF method compared to a CF method, indicating that the former may be a more specific test of DCF muscle activation.

In this study participants were instructed to maintain a neutral cranio-cervical orientation while performing CF. Some previous studies utilising conventional CF methods have instructed subjects to initiate the test by tucking their chin in first before commencing CF [3,4,22]. While these later instructions possibly facilitate greater activity of the DCF muscles during these tests, our results suggest that the additional CF manoeuvre will significantly activate the superficial cervical flexors, which lessens the specificity of the CF method as a test/exercise for the DCF muscles.

The authors do acknowledge the potential influence that EMG cross-talk could have on results of this study, however, it would be occurring during both test conditions (CCF, CF) and therefore is unlikely to explain the differences observed in this study.

Whilst the sample size (10) used allowed adequate power to detect differences between the dynamometry methods,
we would urge caution in extending inferences to the broader population. The small sample size reflects to some extent the invasive nature of the nasopharyngeal suctioning technique. Additionally, in this study individuals without a history of neck pain were tested in order to evaluate neck flexor muscle activation in the absence of muscle impairment and pain when performing the different cervical flexor actions. The same investigations need to be performed in individuals with a history of neck pain and muscle impairment to establish the influence of symptoms on muscle activation when performing these test/exercise methods.

8. Conclusion

In this study we evaluated the activation of the deep and superficial neck flexor muscles when performing different dynamometry tests. Greater activation of the superficial cervical flexor muscles (SCM, AS, SH) was recorded during isometric dynamometry tests. Greater activation of the superficial neck flexor muscles when performing different actions. The same investigations need to be performed in individuals without a history of neck pain and muscle impairment to establish the influence of symptoms on muscle activation when performing these test/exercise methods.

References

Shaun O’Leary graduated with a Bachelor of Physiotherapy in 1993, and a Masters in Manipulative Physiotherapy in 2000, from the University of Queensland, where he has since completed his doctoral degree. Shaun’s doctoral thesis investigated the effectiveness of dynamometry in the measurement of specific neck muscle performance. Shaun presently continuing clinical practice as a Musculoskeletal Physiotherapist in Brisbane, Australia, and research within the Physiotherapy Division at the University of Queensland. His research focus is in the functional and clinical anatomy of the cervical spine, and the development of assessment and rehabilitation methods for the management of cervical spine disorders.

Deborah Falla received her PhD from the University of Queensland, Australia in 2003. In 2005 she was awarded fellowships from the International Association for the Study of Pain and the National Health and Medical Research Council of Australia to undertake postdoctoral research at the Center for Sensory-Motor Interaction, Aalborg University, Denmark. Her research focus involves the integration of neurophysiological and clinical research to evaluate the pathophysiology underlying muscle impairment in people with neck pain. Her research interests also include investigation of the physiological mechanisms that underpin the efficacy of therapeutic exercise for the treatment of patients with neck pain.

Gwendolen Jull is a Professor and Head of the Division of Physiotherapy in the School of Health and Rehabilitation Sciences at The University of Queensland, Australia. She is a Consultant Musculoskeletal Physiotherapist and leads the Cervical Spine and Whiplash Research Unit at The University of Queensland. Her research and clinical interests are in understanding the patho-physiology of neck pain in terms of the sensory, motor and psychological features of both idiopathic and whiplash induced neck pain as a basis for diagnosis, treatment and prevention of recurrence of cervical musculoskeletal disorders. This research is also concerned with testing the efficacy of specific exercise programs for the management of neck pain, as well as investigating the physiological mechanisms of effect of therapeutic exercise for the cervico-brachial region.

Bill Vicenzino is an Associate Professor within the Division of Physiotherapy at the University of Queensland, Australia. Bill has postgraduate qualifications in sport and musculoskeletal physiotherapy. He is the director of the Musculoskeletal Pain and Injury Research Unit, coordinator of undergraduate and postgraduate sports physiotherapy programs, and has published extensively in journals relating to the musculoskeletal system and physical treatment, co-authored several book chapters on the topic area, as well as being a member of the international panel for Manual Therapy. He has presented his work at international and national multidisciplinary sports, musculoskeletal and pain conferences, as well as at workshops across a number of continents.