Manual Therapy 16 (2011) 80–86

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

Association between neck muscle coactivation, pain, and strength in women with neck pain

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ARTICLE INFO

Article history:
Received 14 April 2010
Received in revised form
7 July 2010
Accepted 12 July 2010

Keywords:
Neck pain
Coactivation
Preferred direction
Neck muscles

ABSTRACT

This study investigates the relationship between neck muscle coactivation, neck strength and perceived pain and disability in women with neck pain. Surface electromyography (EMG) was acquired from the sternocleidomastoid (SCM) and splenius capitis (SC) muscles of 13 women with chronic neck pain and 10 controls as they performed 1) maximal voluntary contractions (MVC) in flexion, extension and left and right lateral flexion, 2) ramped contractions from 0% to 50% MVC in flexion and extension and 3) circular contractions in the horizontal plane at 15 N and 30 N force. Higher values of EMG amplitude were observed for the SC (antagonist) during ramped neck flexion and for the SCM during ramped extension in the patient group ($P < 0.05$). The patients displayed reduced values of directional specificity in the surface EMG of the SCM and SC for the circular contractions ($P < 0.05$). The EMG amplitude of SC during cervical flexion was positively correlated with the patients' pain ($R^2 = 0.35$, $P < 0.05$) and perceived disability ($R^2 = 0.53$, $P < 0.01$). An inverse correlation was evident between the amount of activation of SC during cervical flexion and strength ($R^2 = 0.54$, $P < 0.01$). These observations indicate a relationship between alterations in neuromuscular control in patients with neck pain and functional consequences, including impaired motor performance and increased levels of perceived disability.

1. Introduction

Chronic neck pain is a common musculoskeletal disorder (Picavet and Schouten, 2003; Webb et al., 2003). Epidemiological studies show a lifetime prevalence of neck pain between 43% and 66.7% (Bovim et al., 1994; Côté et al., 1998, 2004; Guez et al., 2002), a one-year prevalence rate which ranges between 17.9% (Croft et al., 2001) and 64% (Niemeläinen et al., 2006), and a point prevalence around 20% (Côté et al., 1998; Picavet and Schouten, 2003). Neck pain is also associated with a high recurrence rate (Ghaffari et al., 2006; Holmberg and Thelin, 2006) and, subsequently, high economic costs (Korthals-de Bos et al., 2003).

Altered activation of the neck muscles is a well-known feature of neck pain. Patients with neck pain show increased antagonistic activity of their superficial neck muscles (Falla et al., 2004a; Fernández-de-las-Peñas et al., 2008). Reduced specificity of sternocleidomastoid muscle activation was observed in patients with neck pain when performing isometric contractions with continuous change in force direction in the range 0–360°, resulting in increased activation of the muscle when acting as an antagonist (Falla et al., 2010). This result supports the consistent finding of augmented activity of the superficial neck muscles in patients with neck pain (Falla et al., 2004b; Szeto et al., 2005; O'Leary et al., 2007; Johnston et al., 2008). These observations are also in agreement with experimental pain studies which show a pain-induced reorganization of the motor strategy characterized by reduced activity of the agonist muscle and increased activity of the antagonist muscle (Graven-Nielsen et al., 1997). Possible explanations for these findings include the direct effects of nociception on motor neuron output, effects of pain on sympathetic activity, and changes in motor planning.

Although increased coactivation of the neck muscles may be beneficial in the presence of acute pain to enhance cervical stability by reducing velocity and range of movement, it may reduce neck strength and contribute to recurrent pain by altering the load distribution on the spine and irritating pain sensitive structures. However, the relationship between neck muscle coactivation, strength and pain intensity is unknown. Therefore, the purpose of this study is to investigate the relationship between the extent of neck muscle coactivation, the maximum amount of neck strength and perceived pain and disability in women with persistent neck pain.

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doi:10.1016/j.math.2010.07.006

2. Methods

2.1. Subjects

Thirteen women with chronic neck pain greater than 1 year (mean ± SD: 7.1 ± 6.1 yrs) participated in the study. Subjects were excluded if they previously had cervical spine surgery, previous neck trauma, presented with neurological signs in the upper limb or had participated in a neck exercise program in the past 12 months.

Ten women were recruited as controls. Control subjects were free of shoulder and neck pain, had no past history of orthopedic disorders affecting the shoulder or neck region and no history of neurological disorders. Ethical approval for the study was granted by the Ethics Committee (nr *20070045*) and the procedures were conducted according to the Declaration of Helsinki.

2.2. Procedure

Participants were seated with their head rigidly fixed in a device for the measurement of multidirectional neck force (Aalborg University, Denmark) with their back supported, knees and hips in 90° of flexion and their torso firmly strapped to the seat back. The device is equipped with eight adjustable contacts which are fastened around the head to stabilize the head and provide resistance during isometric contractions of the neck. The force device is equipped with force transducers (strain gauges) to measure force in the sagittal and coronal planes. The electrical signals from the strain gauges were amplified (LISiN – OT Bioelettronica, Torino, Italy) and their output was displayed on an oscilloscope as visual feedback to the subject.

Following a period of familiarization with the measuring device and practice of the contractions, subjects performed two maximum voluntary contractions (MVC) for cervical flexion, extension, left lateral flexion, and right lateral flexion, with 1-min rest between contractions. Verbal encouragement was provided to the subject to promote higher forces in each trial. The highest value of force recorded over the 2 maximum contractions for each direction was selected as the reference MVC, and used to calculate the submaximal force targets. The order of the MVC contractions was randomized between movement directions.

A rest of 30 min followed the MVCs. Subsequently, the subjects performed a linearly increasing force contraction from 0% to 50% MVC in 3 s (ramp contraction) in cervical flexion and extension. Visual feedback on force was provided to the subject during these contractions. A rest of 2-min was provided between contractions which were randomized for force direction.

Following a further 10 min of rest, the subjects performed an isometric contraction at 15 and 30 N force in the horizontal plane against the head restraint with change in force direction in the range 0–360° (circular isometric contractions). Circular templates were superimposed on the oscilloscope to provide force feedback to the subjects during these contractions. Following a period of ∼10 min to practice for the task, the subjects performed the 15 and 30 N contractions in both clockwise and counter-clockwise directions with 2-min of rest between contractions. Each circular contraction had a duration of ∼12 s and was performed at constant velocity by the subjects under guidance of a counter for time and visual feedback on force direction and magnitude. The direction of the contractions was randomized and each contraction was followed by rest periods of 2-min.

2.3. Electromyography recordings

Bipolar surface electromyography (EMG) signals were detected from the sternal head of the sternocleidomastoid and splenius capitis muscles bilaterally with pairs of electrodes (Neuroline 72001-k; Medicotest, Denmark) positioned 20 mm apart following skin preparation. For the splenius capitis, electrodes were positioned over the muscle belly at the C2–C3 level between the uppermost parts of trapezius and sternocleidomastoid. For the sternocleidomastoid muscle, electrodes were placed over the distal portion of the muscle belly (Falla et al., 2002). The bipolar EMG signals were amplified (128-channel surface EMG amplifier, LISiN-OT Bioelettronica, Torino, Italy; −3 dB bandwidth 10–500 Hz) by a factor of 2000, sampled at 2048 Hz, and converted to digital form by a 12-bit A/D converter. A ground electrode was placed around the right wrist.

2.4. Signal analysis

For the ramped contractions, the force signal was low-pass filtered (anti-causal Butterworth filter of order 4, cut-off frequency 10 Hz) and normalized with respect to the MVC force. The average rectified value (ARV) was estimated from the EMG signals over 5 intervals of 250-ms duration, during which the average force level was 10–50% MVC (10% MVC increments).

During the circular contractions, the surface EMG ARV was estimated in intervals of 250 ms and analyzed as a function of the angle of force direction (directional activation curve). The directional activation curves represent the modulation in intensity of muscle activity with the direction of force exertion and represent a closed area when expressed in polar coordinates. The line connecting the origin with the central point of this area defined a directional vector, whose length was expressed as a percent of the mean ARV during the entire task. This normalized vector length represents the specificity of muscle activation: it is equal to zero when the EMG amplitude is the same in all directions and corresponds to 100% when the EMG amplitude is exclusively in one direction (the muscle is active in only one direction). In addition, the EMG amplitude was averaged across the entire circular contraction to provide an indicator of the overall muscle activity. Since no significant differences were observed for the data extracted from the circular contractions in the clockwise and counter-clockwise directions, the data were combined to obtain an average.

2.5. Statistical analysis

A two-way analysis of variance (ANOVA) was used to evaluate differences between patients and controls for maximum neck strength with group (patient, control) as the between subjects variable and direction (flexion, extension, right lateral flexion, left lateral flexion) as the within subject variable.

The ARV of the sternocleidomastoid and splenius capitis muscles during the ramped contractions was assessed with muscle (left and right sternocleidomastoid and splenius capitis) and force (10–50% MVC in 10% increments) as the within subject variables and group (patient, control) as the between subjects variable.

A three-way ANOVA was conduced to assess differences in the directional specificity of sternocleidomastoid muscle activity (vector length) with force (15 N, 30 N) and muscle (left and right sternocleidomastoid and splenius capitis) as the within subject variables and group (patient, control) as the between subjects variable. Significant differences revealed by ANOVA were followed by post-hoc Student–Newman–Keuls (SNK) pair-wise comparisons.

Linear correlation analysis was used to determine the association between the patient's average neck pain intensity, Neck Disability Index (NDI) and the ARV of the sternocleidomastoid and splenius capitis during the ramped contractions. Results are reported as mean and SD in the text and SE in the figures. Statistical significance was set at $P < 0.05$.