

Effect of pain on the modulation in discharge rate of sternocleidomastoid motor units with force direction

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ABSTRACT

Objective: To compare the behavior of sternocleidomastoid motor units of patients with chronic neck pain and healthy controls.

Methods: Nine women (age, 40.4 ± 3.5 yr) with chronic neck pain and nine age- and gender-matched healthy controls participated. Surface and intramuscular EMG were recorded from the sternocleidomastoid muscle bilaterally as subjects performed isometric contractions of 10-s duration in the horizontal plane at a force of 15 N in eight directions (0 – 360° ; 45° intervals) and isometric contractions at 15 and 30 N force with continuous change in force direction in the range 0 – 360° . Motor unit behavior was monitored during the 10-s contractions and the subsequent resting periods.

Results: The mean motor unit discharge rate depended on the direction of force in the control subjects ($P < 0.05$) but not in the patients. Moreover, in three of the nine patients, but in none of the controls, single motor unit activity continued for 8.1 ± 6.1 s upon completion of the contraction. The surface EMG amplitude during the circular contraction at 15 N was greater for the patients (43.5 ± 54.2 μ V) compared to controls (16.9 ± 14.9 μ V; $P < 0.05$).

Conclusions: The modulation in discharge rate of individual motor units with force direction is reduced in the sternocleidomastoid muscle in patients with neck pain, with some patients showing prolonged motor unit activity when they were instructed to rest.

Significance: These observations suggest that chronic neck pain affects the change in neural drive to muscles with force direction.

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1. Introduction

The cervical spine is a complex structure responsible for the stabilization of head posture, and the control of head movement. Moreover, the cervical region is involved in proprioception and reflexes that control postural orientation, stability and oculomotor control (Roberts, 1978; Wilson, 1984; Taylor and McCloskey, 1988; Dutia, 1991). The control of the cervical spine includes a continuous demand for stabilization of the head in a three-dimensional space, in addition to the execution of voluntary movements, for example to

follow a visual stimulus through coordinated control of eye and head movement (Schor et al., 1988; Dutia, 1991).

The coordinated activity of all muscles influences the orientation of the cervical spine and head position (Dutia, 1991). More than 20 pairs of muscles act on the cervical vertebrae and head to generate multidirectional force and movements (Blouin et al., 2007). However, some neck muscles have similar lines of action and therefore different groups of muscles can be recruited to perform the same task (Keshner et al., 1989; Vasavada et al., 2002). A single action of the head and neck can be accomplished through a variety of muscle patterns (Keshner et al., 1989).

The motor control problem in the cervical spine is the simplification or reduction of the degrees of freedom for efficient and timely production of an optimal movement pattern (Keshner, 2004). Thus, the maximal excitation of a muscle when participating in a task is related to a specific direction of motion (Keshner

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et al., 1989, 1992, 1997). The activation of neck musculature is based on consistent muscle synergies that generate multidirectional patterns of force and eliminate the redundancy of the system (Keshner et al., 1989; Vasavada et al., 2002; Blouin et al., 2007). Movements are executed by translating the task-level commands into muscle activation patterns that depend on the direction of force.

The presence of pain induces modifications of cervical motor control. For example, patients with neck pain show different activation of the superficial neck flexor muscles with respect to healthy controls in standardized isometric contractions of cervical and cranio-cervical flexion (Jull et al., 2004; Falla et al., 2004b,d) and reduced ability to relax their neck muscles following contraction (Falla et al., 2004a; Johnston et al., 2008). Moreover, increased co-contraction of the neck muscles has been observed in headache patients (Fernandez-de-las-Penas et al., 2008). These results suggest that pain may alter the task-related modulation of neck muscle activity so that the motor control problem in the cervical spine is solved by alternative combinations of muscle synergistic activities.

In this study, we investigated the neural drive to the sternocleidomastoid muscle from the discharge rate of individual motor units as a function of the direction in force production in the horizontal plane. It was hypothesized that changes in motor unit discharge rate with force direction would be different in people with neck pain with respect to controls. Based on previous observations that patients with neck pain have a reduced ability to relax their neck muscles after contraction, we also analyzed motor unit activity immediately following the contractions. It was hypothesized that motor unit activity would persist in patients. Therefore, the aim of the study was to compare the behavior of individual motor units in the sternocleidomastoid muscle of patients with chronic neck pain and healthy controls both during and immediately following multidirectional isometric tasks.

2. Methods

2.1. Subjects

Nine women (age, mean $\pm$ SD: 40.4 ± 3.5 yr; height: 170.8 ± 5.5 cm; weight: 73.7 ± 10.1 kg) with chronic, non-traumatic neck pain greater than 3 months (years, mean $\pm$ SD: 12.3 ± 11.1 ; range: 1–33) participated in the study. Subjects were excluded if they previously had cervical spine surgery, presented with neurological signs in the upper limb or had a history of torticollis. The patients' average score for the Neck Disability Index (0–50) (Vernon and Mior, 1991) was 16.5 ± 8.8 (range: 5–31) and their average pain intensity rated on a visual analog scale (0–10) was 4.3 ± 1.5 (range: 2.0–6.9).

Nine women were recruited as controls (age, mean $\pm$ SD: 35.4 ± 7.5 yr; height: 164.8 ± 7.7 cm; weight: 65.0 ± 12.3 kg). 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. The two subject groups did not differ in age, weight or height ($P > 0.05$). Women were not tested during menstruation or ovulation, as self-reported, to avoid times of rapid change in hormone levels (Greenspan et al., 2007). Ethical approval for the study was granted by the Ethics Committee (No. 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, their torso firmly strapped to the seat back and their hands resting comfortably in their lap (Fig. 1).

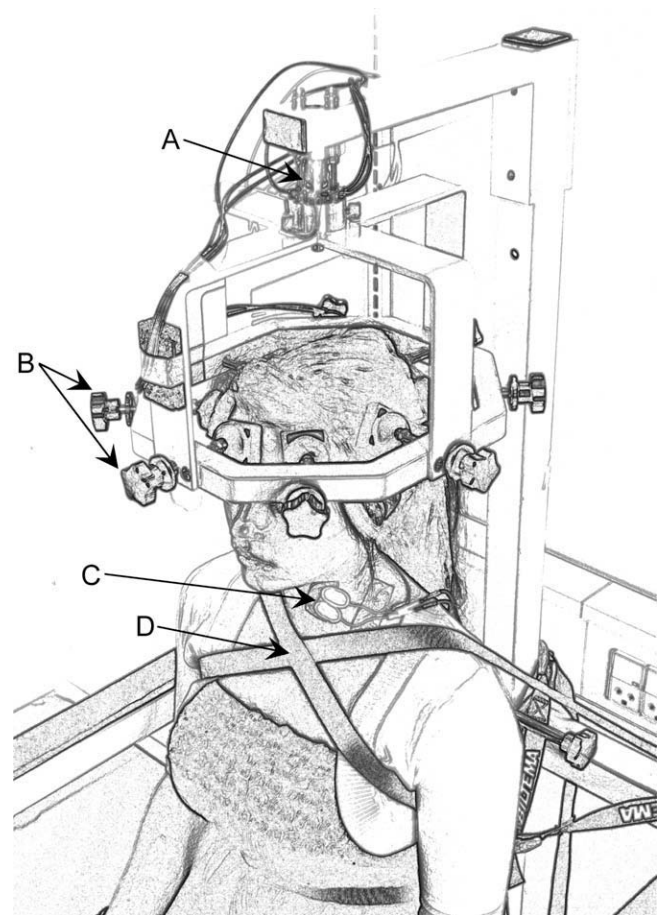


Fig. 1. Device for the measurement of multidirectional neck force. The device is equipped with force transducers (strain gauges) to measure force in the sagittal and coronal planes (A). Participants are seated with their head fixed in a head piece. The head is rigidly secured via eight contacts which are fastened around the head (B). Surface and intramuscular EMG was acquired from the sternocleidomastoid muscle bilaterally (C). The subjects back and torso are firmly strapped to the seat back (D).

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 a period to practice the desired contractions, subjects performed two maximum voluntary contractions (MVC) of 3–4 s duration separated by 1 min of rest, for cervical flexion, extension, left lateral flexion, and right lateral flexion. 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 maximal force. The order of the MVC contractions was randomized between movement directions.

A rest of 30 min followed the MVCs. Subsequently, the subjects performed isometric contractions of 10-s duration (constant force direction) exerting a force of 15 N in eight directions (45° intervals) in the range 0 – 360° (0° : flexion, 90° : right lateral flexion, 180° : extension, 270° : left lateral flexion) (Fig. 2A). Upon completion of each contraction, the subject was informed to completely relax their neck muscles. An absolute level of force was selected as the target to eliminate variation due to differences in strength between the two groups. Real-time visual feedback of force direction and

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