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Reduced force steadiness in women with neck pain and the effect of short term vibration

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ABSTRACT

This study compares neck force steadiness in women with neck pain and controls and the way this is influenced by short term vibration of the neck. In the first experiment, 9 women with chronic neck pain and 9 controls performed 10-s isometric cervical flexion at 15 N. Intramuscular EMG was recorded from the sternocleidomastoid muscle. In the second experiment, 10 women with neck pain and 10 controls performed 10-s isometric cervical flexion at 25% of their maximal force before and after vibration to the neck (bursts of 50 Hz with duration 20, 40, 60 and 120 s). Surface EMG was acquired from the sternocleidomastoid and splenius capitis. In both experiments, force steadiness was characterized by the coefficient of variation (CoV) and the relative power in three frequency subbands (low: 0–3 Hz; middle: 4–6 Hz; high: 8–12 Hz) of the force signal. Women with neck pain exhibited decreased force steadiness (Exp 1: patients 3.9 ± 1.3%, controls 2.7 ± 0.9%, $P < 0.05$; Exp 2: patients 3.4 ± 1.2%, controls 1.7 ± 0.6%, $P < 0.01$) which was associated with higher power in the low-frequency band (patients 71.2 ± 9.6%, controls 56.7 ± 9.2%, $P < 0.01$). Following vibration, CoV (2.6 ± 1.1%, $P < 0.05$) and the power in the low-frequency band of the force signal decreased (63.1 ± 13.9%, $P < 0.05$) in the patient group. These effects were not present in controls. Motor unit behavior and surface EMG amplitude were similar between groups. In conclusion, women with neck pain have reduced force steadiness, likely due to alterations in Ia afferent input. Vibration, which modulates Ia afferent input, increases force steadiness in patients with neck pain.

1. Introduction

Recent studies have shown that pain is associated with reduced force steadiness, defined as the ability to maintain a steady force output during submaximal contractions (Tracy and Enoka, 2002). Patients with knee osteoarthritis (Hortobagyi et al., 2004) and patients with subacromial impingement syndrome (Bandholm et al., 2006) display reduced force steadiness accompanied by a deficit in proprioception (Hortobagyi et al., 2004; Bandholm et al., 2006). Patients with neck pain show reduced proprioception of the neck and disturbances in postural stability (Jull et al., 2008), which have been attributed to alterations in afferent information from the neck. Disturbances in the sensorimotor control of the neck may result from either a decrease or increase in cervical somatosensory afferent activity (Jull et al., 2008), which can be due to direct trauma or the influence of pain and sympathetic activation on muscle spindle sensitivity (Passatore and Roatta, 2006). It may be expected that patients with neck pain would also show reduced force steadiness as a consequence of a disturbance in afferent input (O'Leary et al., 2007).

The oscillations of force around a target value can be characterized with the power of the force signal in frequency subbands (Allum et al., 1978; Marsden, 1978). The low-frequency range (0–3 Hz) of the power spectrum of the force signal is influenced mainly by the net output of the motor neural pool, i.e. by the number of active motor units and discharge rate of these motor units (Allum et al., 1978). Moreover, high variability in the discharge rate of motor units has been associated with reduced force steadiness (Laidlaw et al., 2000; Moritz et al., 2005) and increased power in the low-frequency band (Allum et al., 1978). Further, input from Ia afferents also contributes to force fluctuations at low frequencies (⩽4 Hz) during non-fatiguing contractions (Yoshitake et al., 2004). In contrast, the short and long latency stretch reflexes contribute to

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oscillations in the subbands 8–12 and 4–6 Hz, respectively (Marsden, 1978).

This paper presents the results of two experiments that investigate force steadiness and the mechanisms underlying impaired force steadiness in patients with chronic neck pain. The first experiment compares force steadiness in people with neck pain and asymptomatic controls. The force signal was investigated with frequency analysis and single motor unit behavior was extracted from intramuscular EMG recordings during brief cervical flexion contractions. We hypothesized that neck pain patients would display poorer force steadiness compared to controls, consistent with previous data (O'Leary et al., 2007), and that this would be associated with increased power at low frequencies of the force spectrum, likely due to abnormal afferent information. The second experiment examined the immediate effects of vibration of the neck on force steadiness in neck pain patients and controls. Mechanical vibration can result in improved force steadiness through modulation of Ia afferents (Yoshitake et al., 2004), although this has only been examined in individuals free of pain. In this experiment, we hypothesized that force steadiness would improve in patients with neck pain following local vibration to the neck.

2. Methods

In the first experiment (Exp 1), motor unit discharge behavior and force steadiness were measured during brief, isometric cervical flexion contractions in women with chronic neck pain and asymptomatic controls. The second experiment (Exp 2) examined the effects of short-term vibration on force steadiness in neck pain patients and controls. The description of methods refers to both experimental tests unless otherwise specified.

2.1. Subjects

Exp 1 included nine women (age, mean ± SD: 40.4 ± 3.5 years; height, 171.1 ± 10.6 cm; body mass, 73.4 ± 10.6 kg) and Exp 2 included 10 women (age, mean ± SD: 35.3 ± 7.5 years; height, 169.7 ± 7.4 cm; body mass, 72.2 ± 8.5 kg) with chronic neck pain. Participants between the ages of 18–60 years were included if they reported a history of neck pain of greater than 6 months duration, scored 5 points or greater out of a possible 50 points on the Neck Disability Index (NDI) (Vernon and Mior, 1991), and demonstrated positive findings on a physical examination of the cervical spine (altered joint motion and painful reactivity to palpation). Patients were excluded if they previously had cervical spine surgery or presented with neurological signs in the upper limb.

Nine healthy women were recruited for Exp 1 (age, mean ± SD: 38.9 ± 10.5 years; height, 165.4 ± 8.2 cm; body mass, 63.6 ± 10.7 kg) and 10 healthy women were recruited for Exp 2 (age, mean ± SD: 35.4 ± 8.9 years; height, 168.1 ± 5.1 cm; body mass, 66.5 ± 11.8 kg) 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. The participants were recruited through local advertisement. The neck pain patients and control groups were different in the two experiments. Ethical approval for the study was granted by the local 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 to measure 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 were fastened around the head to stabilize the head and provide resistance during isometric contractions of the neck. The force device includes a force transducer (strain gauge) to measure force in the sagittal plane. The force signals were amplified (LISiN – OT Bioelettronica, Torino, Italy) and their output displayed on an oscilloscope to provide visual feedback.

Following a period of familiarization with the device and practice contractions, subjects performed two maximum voluntary contractions (MVC) of 3–4 s duration in cervical flexion. These contractions were separated by 1 min of rest. The subjects were verbally encouraged to achieve a higher force in the second trial. The highest value of force recorded over the two maximum contractions was selected as the reference MVC.

Following the maximal contractions, subjects performed isometric cervical flexion either at 15 N (Exp 1) or 25% MVC (Exp 2) for 10 s. The target force output was displayed on an oscilloscope located 80 cm in front of the subject with the gain adjusted to view ± 10% of the target force value on a 15-cm high display. The subjects were instructed to match the force output as closely as possible to the target force for the full duration of the contraction. Force variability is associated with strength (Sosnoff and Newell, 2006), thus in Exp 1, an absolute level of force was selected as the target to eliminate variations due to differences in strength between the controls and neck pain groups (Ylinen et al., 2004; Prushansky et al., 2005). In contrast, a relative level of force was used in Exp 2, which allowed us to test whether an eventual difference in force steadiness between patients and controls is only attributable to a reduction in muscular strength in the patient group. Moreover it is known that vibration may alter strength performance (Cardinale and Bosco, 2003). The duration of the contraction was minimized to avoid fatigue because patients with neck pain show greater fatigability than controls of the sternocleidomastoid during sustained cervical flexion contractions (Falla et al., 2003).

2.3. EMG recordings

In Exp 1, action potentials of single motor units were detected with a pair of Teflon-coated stainless steel wires (diameter: 0.1 mm; A-M Systems, Carlsborg, WA) inserted into the sternocleidomastoid muscle bilaterally, ~2-cm cephalad to the midpoint between the sternum and the mastoid process via a 25-gauge hypodermic needle. The wires were cut to expose only the cross section, and provided one bipolar signal which was amplified (Counterpoint EMG, DANTEC Medical, Skovlunde, Denmark), band-pass filtered (500 Hz–5 kHz), sampled at 10,000 Hz, and stored after 12-bit A/D conversion.

In Exp 2, surface EMG signals were acquired from the sternocleidomastoid and splenius capitis muscles bilaterally using bipolar surface electrodes (Ambu® Neuroline 720 01-K/12, Ambu A/S, Ballerup, Denmark) with an inter-electrode distance of 22 mm. Electrodes were positioned over the sternocleidomastoid muscle in the distal one third of the muscle (Falla et al., 2002a,b) and over the splenius capitis at the level of C2–C3 between the uppermost parts of sternocleidomastoid and upper trapezius muscle (Falla et al., 2007). The skin was prepared using abrasive paste and cleansed with water prior to electrode placement. A reference electrode was placed around the subjects' wrist. Surface EMG signals were amplified with a gain of 2000 (EMG-USB, LISiN, Politecnico di Torino and OT-Bioelettronica, Torino, Italy), filtered (−3 dB bandwidth, 10–400 Hz), sampled at 2048 Hz, and converted to 12-bit digital samples. Contrary to Exp 1, it was not possible to investigate individual motor unit behavior using intramuscular EMG signals in Exp 2. This was due to the vibration intervention that would have resulted in relative shifts of the intramuscular wires within the muscle, so that it would have been not possible to identify the same motor units pre and post vibration.