



The relation between neuromuscular control and pain intensity in fibromyalgia

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ABSTRACT

Fibromyalgia patients are shown to have a different neuromuscular control (differential activation) than healthy persons. Before clinical trials can be initiated, the relation between differential activations and pain intensity among fibromyalgia patients needs to be investigated. Twenty-seven fibromyalgia patients performed 3 min bilateral shoulder elevations with different loads (0–4 kg) with a high-density surface electromyographical (EMG) grid placed on the upper trapezius. Differential activation was quantified by the power spectral median frequency of the difference in EMG amplitude between the cranial and caudal parts of the upper trapezius. The average duration of the differential activation was described by the inverse of the median frequency of the differential activations. The relation between frequency and duration of differential activations as an average of the 4 loads and pain intensity the same day prior to the experiment was explored by Pearson's correlation coefficients. A strong negative relation between frequency of differential activations and pain intensity ($R = -0.67$, $p < 0.001$) and a strong positive association between duration of differential activations and pain intensity ($R = 0.66$, $p < 0.001$) were found. The significant association between frequency and duration of differential activations and pain intensity among the fibromyalgia patients indicates a relation between this neuromuscular control pattern and pain intensity. This finding support initiation of clinical trials for investigating effects on pain intensity of modifying differential activations among fibromyalgia patients.

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1. Introduction

The association between neuromuscular control and chronic muscle pain has been a topic of clinical interest for decades (Hough, 1902). Early observations of enhanced muscle activity and tender muscles at clinical examination in persons with pain (Abraham, 1977; Asmussen, 1956; Cobb et al., 1975; De Vries, 1966) supported the *viscous circle model* (Travell et al., 1942). This model proposes that a painful condition causes reflexive mediated muscle hyperactivity (spasm) which further enhances pain and dysfunction (Johansson and Sojka, 1991). However, acute muscle pain has predominantly been observed to inhibit rather than increase muscle activity (Falla et al., 2007; Farina et al., 2004; Lund et al., 1991; Svensson et al., 1998). Therefore, the *pain adaptation model* (Lund et al., 1991) has received increasingly attention. This model states that a painful condition reduces muscle activity when active as agonist and increases activity when active as antagonist which would limit movement and protect against further injury (Lund et al., 1991).

However, neither of the models are unequivocally supported by the literature, and the changes in muscle activity is considered to be more complicated than stated in the pain adaptation model (Murray and Peck, 2007). Therefore, the *integrated pain adaptation model* has been proposed (Murray and Peck, 2007). The model emphasizes how the redundancy of skeletal muscles provides many motor unit subpopulations available for performing a task, making different recruitment strategies plausible for avoiding or minimizing pain. An example of such a recruitment strategy is reciprocal reversals of activity between regions within a single muscle, defined as differential activation (Chanaud et al., 1991). Accordingly, we recently reported a lowered frequency of differential activations (shifts in activity between the caudal and cranial parts) of the upper trapezius in fibromyalgia patients compared with healthy controls (Gerdle et al., 2010). The lower frequency (measured as a lowered median frequency domain) of differential activations in fibromyalgia patients may cause overexertion and fatigue of the muscle region, and therefore be a plausible explanation for the maintenance of the peripheral nociception and the central alterations (i.e., central hyperexcitability and altered descending inhibition) resulting in severe pain of the fibromyalgia patients (Gerdle et al., 2010).

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This observation of a different neuromuscular control between fibromyalgia patients and healthy persons may provide the basis for treatment strategies for fibromyalgia. However, before clinical trials for investigating effects on pain intensity from modulating differential activations among fibromyalgia patients should be initiated, it is a need to know if and how the frequency of differential activation is related to the pain intensity of the fibromyalgia patients. Moreover, although the relation between neuromuscular control and pain intensity has been debated for decades (Hough, 1902; Lund et al., 1991; Travell et al., 1942), documentation of a relation between neuromuscular control and pain intensity is lacking.

Therefore, the aim of this study was to investigate the relation between frequency of differential activations and pain intensity among fibromyalgia patients.

2. Materials and methods

2.1. Subjects

Female patients with fibromyalgia ($N = 29$; age: 37 ± 5 years, weight: 69.3 ± 9.5 kg, height: 166 ± 5 cm) were recruited from the Pain and Rehabilitation Centre, University Hospital, Linköping, Sweden. It should be noted that not all of these patients were able to perform all tasks (see Section 3, drop-out and activity levels at the different loads). The patients were offered participation in the study after examination of medical records, positive response to information letter, and a phone conversation with a physician. The patients were clinically diagnosed according to the ACR criteria of 1990 for the classification of fibromyalgia (FM) (Wolfe et al., 1990). The mean duration of FM was 6.6 ± 3.2 years (minimum 2 years). Descriptive data of the fibromyalgia patients (i.e., age, anthropometric data, pain intensity recent week (minimum, average and maximum intensity), and data from ultrasound recording) have been presented previously (Gerdle et al., 2008). All subjects gave written informed consent to participate. The study conformed to the Declaration of Helsinki and the study protocol was approved by the local ethics committee at Linköping University.

2.2. Experimental setup

First, a high-density surface electromyographic (EMG) electrode-grid (modified ActiveOne, BioSemi, Amsterdam, Netherlands) consisting of 13 by 10 active electrodes (0.5 cm inter-electrode distance), covering 6×4.5 cm of the skin surface was placed on the skin above the right trapezius muscle in the middle of the line between the processus spinosus of the seventh cervical vertebra and the lateral edge of acromion. The base of the electrode-grid device is concave and semiflexible and thereby fitted well with the convex recordings area of the upper trapezius muscle. In this way, the recorded signals of all subjects were not affected by muscle-tendon transitions and similarly affected by the motor end plate region. To generate a stable pressure between electrodes and the skin, the electrode grid was held in place by two elastic straps around the shoulder and torso of the subject. The surface EMG signals were recorded from all electrodes (monopolar) with a common reference on the processus spinosus of the seventh cervical vertebra at 2048 Hz.

Then, the subjects performed symmetrical bilateral shoulder elevations with different loads. The loads were applied through the attachment of different weights on a harness. The harness consisted of 2 belts hanging on both shoulders on the level of the acromion to allow attachment of the weights. One additional belt was placed around the torso in order to fixate the other two belts. After attaching the harness and weights, the subjects were asked to lift the weights such that the shoulders were in a horizontal plane,

and to hold this position for 3 min. Weights of 0, 1, 2, and 4 kg were applied successively. The subjects were given 1-min rest between each contraction. The choice of absolute weights and not relative weights in relation to maximum performance was based on the difficulties for obtaining valid maximum voluntary contractions (MVC) in FM patients due to pain and/or psychological aspects such as fear-avoidance or kinesiophobia.

2.3. Ultrasound recordings

Ultrasound measurements were taken of the thickness (mm) of the trapezius muscle and the subcutaneous soft tissue (skin and fat tissue taken together) 2 cm lateral of the midpoint between the seventh process of the cervical spine and the lateral part of the acromion process using an Acuson 128XP/10 (Siemens).

2.4. Pain intensity recordings

The participants reported the pain intensity prior to the experiment (the same day) on a 100 mm visual analogue scale (VAS). As previously presented, the pain intensity prior to the experiment was highly correlated with the average pain intensity the last week (Gerdle et al., 2008).

2.5. Surface EMG analysis – quantification of differential activation

The differential activation analysis was previously described (Gerdle et al., 2010). The essence of the analysis was to examine the temporal changes of the difference in myoelectric activity between two regions within a muscle. While the EMG signals were recorded using a 2-D high-density EMG grid, a large part of the processing (most of step III below) was undertaken in order to reduce the data to signals originating from the caudal and cranial regions of the trapezius muscle. Multiple channels covering a large area were recorded to get a better estimate of the activation of the two muscle parts (Staudenmann et al., 2005). In short, the procedure involved;

- (I) Pre-processing: Prior to analysis, poor quality signals were omitted (Grönlund et al., 2005). The remaining signals were high-pass filtered at 10 Hz, and bipolar spatial filtering in the fiber direction (medial-lateral) was carried out.
- (II) Muscle activity: The muscle activity level of the EMG signals was described using the root-mean-square (RMS), calculated in 0.5 s non-overlapping time-windows. In order to compare the activity between regions within the muscle, the muscle activity signals were de-trended and normalized to their corresponding maximum RMS values (maximum over the whole 3 min contraction).
- (III) Muscle activity in the cranial – caudal direction: Muscle activity in the cranial – caudal direction (perpendicular to fibre orientation) was calculated by averaging the muscle activity recorded by electrodes of the grid along the fibre orientation (medial-lateral), providing 10 activity signals in the cranial – caudal direction.
- (IV) Activity difference: The difference in the normalized muscle activity between the cranial (average of the three most superior electrode positions) and the caudal (average of the three most inferior electrode positions) regions of the upper trapezius was calculated.
- (V) Median frequency and average duration of the differential activations: Differential activation was quantified using the power spectral median frequency (MDF) of the whole activity difference signal. The inverse of the median frequency of the differential activations was calculated to quantify the average duration of the differential activations.

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