PAIN® 155 (2014) 944–953

PAIN®

www.elsevier.com/locate/pain

Reduced task-induced variations in the distribution of activity across back muscle regions in individuals with low back pain

Deborah Falla [a,b,*], Leonardo Gizzi [a], Marika Tschapek [a], Joachim Erlenwein [a], Frank Petzke [a]

[a] Pain Clinic, Center for Anesthesiology, Emergency and Intensive Care Medicine, University Hospital Göttingen, Göttingen, Germany
[b] Department of Neurorehabilitation Engineering, Bernstein Focus Neurotechnology (BFNT) Göttingen, Bernstein Center for Computational Neuroscience, University Medical Center Göttingen, Georg-August University, Göttingen, Germany

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

ARTICLE INFO

Article history:
Received 12 September 2013
Received in revised form 23 January 2014
Accepted 28 January 2014

Keywords:
Low back pain
Multichannel EMG
Pressure pain threshold
Exercise

ABSTRACT

This study investigated change in the distribution of lumbar erector spinae muscle activity and pressure pain sensitivity across the low back in individuals with low back pain (LBP) and healthy controls. Surface electromyographic (EMG) signals were recorded from multiple locations over the lumbar erector spinae muscle with a 13×5 grid of electrodes from 19 people with chronic nonspecific LBP and 17 control subjects as they performed a repetitive lifting task. The EMG root mean square (RMS) was computed for each location of the grid to form a map of the EMG amplitude distribution. Pressure pain thresholds (PPT) were recorded before and after the lifting task over a similar area of the back. For the control subjects, the EMG RMS progressively increased more in the caudal region of the lumbar erector spinae during the repetitive task, resulting in a shift in the distribution of muscle activity. In contrast, the distribution of muscle activity remained unaltered in the LBP group despite an overall increase in EMG amplitude. PPT was lower in the LBP group after completion of the repetitive task compared to baseline (average across all locations: pre: 268.0 ± 165.9 kPa; post: 242.0 ± 166.7 kPa), whereas no change in PPT over time was observed for the control group (320.1 ± 162.1 kPa; post: 322.0 ± 179.5 kPa). The results demonstrate that LBP alters the normal adaptation of lumbar erector spinae muscle activity to exercise, which occurs in the presence of exercise-induced hyperalgesia. Reduced variability of muscle activity may have important implications for the provocation and recurrence of LBP due to repetitive tasks.

1. Introduction

Low back pain (LBP) affects 50%-80% of the population at some stage of their lives [3,7]. While many individuals recover within 1 month of their first episode, most people will have recurrence of pain within 12 months [12,14]. A contributor to the persistence or recurrence of LBP is altered neuromuscular control of the trunk [13,23].

Numerous studies have shown changes in muscle activation in LBP, including reduced transversus abdominis activity during walking [48], and repetitive arm movements [24], increased erector spinae activity during the stride [1,57,63] and swing [5,31] phase of gait, and increased trunk muscle co-activation during sudden unloading of the spine [45] and during unexpected, multidirectional translation perturbations [22,28]. These studies have utilized classic bipolar electromyography (EMG). In these applications, electrodes are placed over a small portion of a muscle. The amplitude of the EMG signal can be measured to evaluate the magnitude of muscle activation, the frequency content analyzed to assess myoelectric manifestations of fatigue, or the onset of activity detected to evaluate reaction times. However, as consistently shown, the responses in patients with LBP are highly variable and may even be contradictory [25,55,60]. This is not surprising given the limited information that can be obtained from a single pair of electrodes placed over a small muscle region. In contrast, high-density, 2-dimensional surface EMG provides a measure of the electric potential distribution over a large surface area [20,65]. This method provides a topographical representation of EMG amplitude, and can identify relative adaptations in the intensity of activity within regions of a muscle/s [65]. This novel technique has been applied in healthy individuals and has revealed spatial heterogeneity in muscle activity under various conditions

* Corresponding author at: Pain Clinic, Center for Anesthesiology, Emergency and Intensive Care Medicine, University Hospital Göttingen, Robert-Koch-Str. 40, Göttingen 37075, Germany. Tel.: +49 0 551 3920109; fax: +49 0 551 3920110.
E-mail address: deborah.falla@bccn.uni-goettingen.de (D. Falla).

http://dx.doi.org/10.1016/j.pain.2014.01.027
0304-3959/

[18,20,26], indicating a nonuniform distribution of motor units or spatial dependency in the control of motor units [27]. For example, studies in asymptomatic individuals show a change in the distribution of lumbar erector spinae muscle activity during sustained lumbar flexion [56].

Variation in the distribution of activity within the same muscle is functionally important to maintain motor output in the presence of altered afferent feedback (eg, pain or fatigue) [20]. This mechanism is potentially relevant to avoid overload of the same muscle fibers during prolonged activation and is particularly relevant for muscles commonly exposed to repetitive or sustained activation, such as the lumbar erector spinae [2]. It is unknown whether this mechanism of adaptation of muscle activity is altered in people with LBP during repetitive work. Such knowledge may have important implications for the provocation of LBP due to repetitive tasks.

We investigate the topographical distribution of EMG amplitude in the lumbar erector spinae muscle of healthy controls and people with chronic LBP during a repetitive lifting task. It was hypothesized that the mechanisms of adaptation of muscle activity across regions of the lumbar erector spinae would be altered in the presence of LBP. In addition, we obtained multiple measures of pressure pain threshold over the same area of the lower back to assess the effect of the task on pressure pain sensitivity.

2. Methods

2.1. Subjects

Nineteen people with chronic nonspecific LBP aged between 18 and 45 years were sought for the study through referral from physiotherapy practices, general practitioners, or through general advertising in the popular press. Patients were considered for the study if they were suffering from nonspecific episodic LBP lasting longer than 3 months, with continuous LBP over the last 3 months or periods of symptom aggravation and remission in the last 6 months. Each episode of LBP should have lasted at least 1 week, with sufficient intensity to limit function.

Seventeen age- and gender-matched healthy individuals were recruited to act as the control group. Pain-free participants were included if they had no relevant history of back or lower-limb pain or injury that limited their function and/or required treatment from a health professional. Patients and control subjects had to have the capacity to give consent at his/her own will.

Participants were excluded from both groups if they had any major circulatory, neurological, or respiratory disorders, recent or current pregnancies, previous spinal surgery, back pain radiating below the knee, current treatment for low back pain from health care providers, or participation in trunk muscle exercise in the past 12 months. Patients who reported that they were in an acute "flare up" of their LBP condition were excluded due to the nature of the task. Participants were also excluded from both groups if they were taking medication such as opioids, anticonvulsives, antidepressants, or regularly high-dosed nonsteroidal antiinflammatory drugs (NSAIDs), while NSAIDs as needed were allowed. Initial screening was accomplished by telephone, and eligible persons attended a baseline evaluation appointment. Both groups were asked not to take NSAIDs for the day of the experiment.

Ethical approval for the study was granted by the local Ethics Committee and the procedures were conducted according to the Declaration of Helsinki.

2.2. Questionnaires

A questionnaire was administered to obtain information on subject demographics, history, duration of pain, average intensity of pain, and localization of pain. Patients completed the short form of the state scale of the Spielberger State-Trait Anxiety Inventory (SF-STAI). It is a 6-item questionnaire that has been shown to be a reliable and sensitive measure of anxiety [51]. The Oswestry Disability Index was used to assess pain-related disability specifically related to LBP (7 items [16]). Patients also completed the Short Form (SF)-36 Health Survey [9], a measure of the general health status of the patient, and the Tampa Scale for Kinesiophobia (TSK; 17 items [62]), a measure to assess fear-avoidance behavior and fear-avoidance beliefs. The Pain Catastrophizing Scale (PCS) was implemented to assess catastrophic thinking related to pain; in this 13-item questionnaire, respondents rate the frequency with which they experience different thoughts and feelings when in pain [43].

Finally, the patient's activity-related pain was monitored during the repetitive task. For this, participants were asked to verbally rate their level of perceived pain intensity on an 11-point numerical rating scale anchored with "no pain" (0) and "the worst possible pain imaginable" (10) every 40 seconds during the lifting task.

2.3. Experimental procedure

Subjects were asked to repetitively move a box ($40 \times 20 \times 30$ cm) with hole-shaped handles, loaded with a weight of 5 kg, between 2 shelves placed at knee (lateral epicondyle of femur with the knee extended) and shoulder (position of the clavicle while standing) height. An absolute weight was selected, rather than a relative weight, to better represent a functional task that may be encountered by the participants. The weight was placed in the center of the box and kept in position by means of light packaging foam. Starting from the lower shelf, the subjects were instructed to lift the box to the upper shelf in one second, wait for 3 seconds (without interrupting contact with the box), move it back to the lower shelf (in one second), and wait 3 seconds before commencing the next cycle. The task was performed to the beat of an electronic metronome for a total of 25 cycles ($\sim$200 seconds). Subjects practiced the movement sequence for $\sim$1 minute without the weight prior to data recording. The duration of the task was selected based on pilot tests, which confirmed that patients could successfully complete the task without the need to interrupt the task due to pain or excessive fatigue.

2.4. Pressure pain thresholds

Pressure pain thresholds (PPT) were measured with an electronic algometer (Somedic Production, Stockholm, Sweden) over 8 locations distributed across the lumbar region, on the side of greatest pain for the people with LBP, and on the right side for the control group (Fig. 1A). The distance between the locations was 2.5 cm each starting from L5 (detected via palpation) in the cranial direction, and 2.5 cm in the lateral direction starting from the spine.

The algometer probe tip (1 cm^2) was applied to the skin at a rate of 30 kPa/second and the participant was instructed to depress a handheld switch at their first perception of pain, at which point the application of pressure ceased. An explanation of the PPT measurement procedure, followed by a demonstration on the patient's forearm or thigh, was performed prior to 2 consecutive PPT measures at each location in a randomized order. The mean of the 2 PPT measures at each location was used for further analysis. Topographical maps of the PPT were generated from the mean values (Fig. 1B). The same researcher performed the PPT measurements in all subjects before and after the repetitive lifting task.

2.5. Motion analysis

Tridimensional tracking of body movement was achieved by means of an 8-camera stereo-photogrammetry system (Oqus