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Neuromuscular adaptations predict functional disability independently of clinical pain and psychological factors in patients with chronic non-specific low back pain

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ABSTRACT

Patients with chronic low back pain exhibit characteristics such as clinical pain, psychological symptoms and neuromuscular adaptations. The purpose of this study was to determine the independent contribution of clinical pain, psychological factors and neuromuscular adaptations to disability in patients with chronic low back pain. Clinical pain intensity, pain catastrophizing, fear-avoidance beliefs, anxiety, neuromuscular adaptations to chronic pain and neuromuscular responses to experimental pain were assessed in 52 patients with chronic low back pain. Lumbar muscle electromyographic activity was assessed during a flexion–extension task (flexion relaxation phenomenon) to assess both chronic neuromuscular adaptations and neuromuscular responses to experimental pain during the task. Multiple regressions showed that independent predictors of disability included neuromuscular adaptations to chronic pain ($\beta = 0.25$, $p = 0.006$, $sr^2 = 0.06$), neuromuscular responses to experimental pain ($\beta = -0.24$, $p = 0.011$, $sr^2 = 0.05$), clinical pain intensity ($\beta = 0.28$, $p = 0.002$, $sr^2 = 0.08$) and psychological factors ($\beta = 0.58$, $p < 0.001$, $sr^2 = 0.32$). Together, these predictors accounted for 65% of variance in disability ($R^2 = 0.65$ $p < 0.001$). The current investigation revealed that neuromuscular adaptations are independent from clinical pain intensity and psychological factors, and contribute to inter-individual differences in patients' disability. This suggests that disability, in chronic low back pain patients, is determined by a combination of factors, including clinical pain, psychological factors and neuromuscular adaptations.

1. Introduction

Acute low back pain (LBP) is a condition that many individuals will experience at least once in their life span (64–80% life prevalence) (Manchikanti et al., 2009). Typically, most episodes resolve in about six weeks, yet, for 5–10% of these individuals, pain persists and becomes chronic or recurrent and is of no clear origin (Manchikanti et al., 2009). In fact, chronic non-specific LBP is diagnosed by the exclusion of other spinal disorders rather than using objective diagnostic criteria (Cedraschi et al., 1999). Yet patients with chronic non-specific LBP exhibit common characteristics associated with functional disability. Among these characteristics, patients report intermittent changes in clinical pain intensity (Gheldof et al., 2006), psychological symptoms (Crombez et al., 1999; Meyer et al., 2009) and altered neuromuscular control of the trunk (Triano and Schultz, 1987).

Clinical pain intensity has been characterized as an important predictor of future disability in patients with chronic LBP (Sieben et al., 2005). Moreover, intermittent changes in clinical pain intensity are associated with fluctuations in the severity of functional disability (McGorry et al., 2000), which affect work productivity and quality of life.

The severity of functional disability in patients with chronic non-specific LBP is also related to psychological factors, such as pain catastrophizing, pain-related fear and avoidance beliefs (Boersma and Linton, 2006; Lundberg et al., 2011; Peters et al., 2005). These psychological factors, included in the fear-avoidance

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model of musculoskeletal pain, are believed to contribute to the transition from an acute episode of low back pain to chronic non-specific LBP (Vlaeyen and Linton, 2000). In accordance with this model, negative affects, along with past experience (past episodes of acute LBP) may lower the threshold at which a painful episode is perceived as threatening (Gheldof et al., 2006; Goubert et al., 2004). This threat yields to pain catastrophizing, which has been proposed as a precursor of pain-related fear in subsequent stages of LBP (Leeuw et al., 2007). As a result of the fear of pain, attention is directed towards the source of pain. Consequently, the individual is unable to disengage attention completely from LBP to perform a task efficiently (Asmundson et al., 2005; Crombez et al., 2005). This yields to avoidance behaviors and decreased performance (Geisser et al., 2000). Disuse and deconditioning are suggested as potential consequences of these behaviors but many studies failed to identify a significant relationship between avoidance behaviors and fitness levels in patients with chronic LBP (Verbunt et al., 2003). Moreover, fitness levels of patients with chronic LBP are often similar to those observed in healthy adults without LBP (Wittink et al., 2000) and usually not associated with disability observed in patients with LBP (Hendrick et al., 2011). A proposed corollary of avoidance behaviors is altered neuromuscular control. Accordingly, psychological factors (pain catastrophizing, pain-related fear and pain-related anxiety) are associated with altered electromyographic (EMG) activity of trunk muscles in patients with chronic low back pain (Geisser et al., 2004; Lewis et al., 2012; Watson et al., 1997).

While the psychological components are not always reported, many studies have found changes in the sensorimotor system of patients with chronic LBP. For instance, neuromuscular adaptations such as increased EMG activity in trunk muscles (Shirado et al., 1995; van Dieen et al., 2003) and altered movement patterns during dynamic trunk flexion tasks (Esola et al., 1996; McClure et al., 1997), as well as delayed feedforward postural responses of deep lumbar and abdominal muscles (Hodges, 2001; MacDonald et al., 2009) have all been described in patients with chronic LBP. Among these adaptations, increased EMG activity of trunk muscles during trunk flexion has been associated with increased pain-related fear exhibited by patients with LBP (Geisser et al., 2004). Increased EMG activity of lumbar erector spinae muscles during full trunk flexion has also been associated with increased functional disability in patients with chronic or recurrent LBP (Triano and Schultz, 1987). Moreover, EMG activity during a flexion–extension task was found to fluctuate concomitantly with the psychological profile of patients with chronic LBP during an exercise rehabilitation program (Marshall and Murphy, 2006). Recent data also indicate that the severity of functional disability in patients with chronic LBP is associated with decreased changes in EMG activity of superficial trunk muscles during experimentally induced LBP (Dubois et al., 2011), suggesting that these patients may present with decreased adaptive capabilities when exposed to an acute perturbation such as a painful stimulation. Studies about decreased motor variability in patients with chronic musculoskeletal pain support this idea (Jacobs et al., 2009; Madeleine, 2010).

Owing to these past studies, it appears that increased disability in patients with chronic LBP is associated with a reorganization of muscle activation patterns and not necessarily with decreased aerobic or muscular endurance. It has often been hypothesized that the redistribution in muscular activity allows short-term benefits but represents a maladaptive strategy to the original threat to low back structures, contributing to the chronification of low back pain (Hodges, 2011) and thus, chronic disability.

Following the proposed fear-avoidance model of musculoskeletal pain, and since clinical pain, psychological factors and neuromuscular adaptations have all been associated with functional disability, it appears relevant to determine whether neuromuscular adaptations are a maladaptive process contributing to functional disability in patients with chronic LBP exhibiting elevated pain-related fear, anxiety or catastrophizing. Therefore, the main objective of this study is first to determine the independent contribution of clinical pain, psychological factors and neuromuscular adaptations, to functional disability in patients with chronic non-specific LBP. The second objective is to assess whether neuromuscular adaptations mediate the relation that is often observed between psychological factors and functional disability in these patients.

2. Methods

2.1. Participants

Fifty-two patients with chronic or recurrent non-specific LBP, between 18 and 55 years of age (34 men, 18 women; mean age ± SD: 40.1 ± 11.4 for men and 39.3 ± 12.1 for women) were included in the study. Patients were recruited through advertisements in the local newspaper. These patients were selected according to previously established criteria for chronic and recurrent LBP (chronic LBP: present at least half the days over a 12-month period; recurrent LBP: present for less than half the days over a 12-month period) (Von Korff, 1994). Patients presenting any other active condition or other non-mechanical spinal condition, neurological deficits or other chronic pain syndromes were excluded from the study. All experimental procedures conformed to the standards set by the latest revision of the Declaration of Helsinki and were approved by the Research Ethics Board of "Université du Québec à Trois-Rivières". All participants gave written informed consent, acknowledging their right to withdraw from the experiment without prejudice and received compensation of $50 for their travel expenses, time and commitment.

2.2. Experimental protocol

The experimental session lasted approximately 150 min and was conducted at the neuromechanics and motor control laboratory. Upon arrival of the participant, a physical examination was carried out in order to rule out possible non-mechanical spinal conditions and determine the participant's eligibility to the study. The experimental session included questionnaires to measure psychological factors and disability as well as the assessment of neuromechanical responses with and without lumbar noxious heat stimulations during a flexion–extension task.

2.3. Questionnaires

Disability, fear-avoidance beliefs (about work and physical activity), state and trait anxiety as well as pain catastrophizing were assessed using the modified Oswestry Low Back Pain Disability Questionnaire (ODQ) (Fairbank, 2000), the Fear-Avoidance Beliefs Questionnaire (FABQ) (Waddell et al., 1993), the State-Trait Anxiety Inventory (STAI-Y) (Spielberger et al., 1980), and the Pain Catastrophizing Scale (PCS) (Sullivan et al., 1995) in their French, validated version respectively (Chaory et al., 2004; French et al., 2005; Gauthier and Bouchard, 1993; Vogler et al., 2008).

2.4. Thermal cutaneous stimulation

Cutaneous heat stimulation was administered using a 9 cm^2 contact thermode (MEDOC TSA-2001, Ramat Vishay, Israel). Stimuli were either applied over the L5 spinous process (homosegmentally to EMG recordings) or over the T7 spinous process (heterosegmentally to