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Adaptation of motor control to musculoskeletal pain: Theories for the sensorimotor interactions involved

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ABBREVIATIONS
RT High-recruitment-threshold

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BACKGROUND: There are reports in the literature showing that the pain alters motor control, whether in static or dynamic conditions.
VIEW OF THE PAST: Over the past decades theories have been proposed on how and in what conditions the pain affects motor control. To date, changes in movement control have been identified at both peripheral and central levels, which potentially leads to the emergence of compensatory lesions in the medium and long term.
CURRENT STATE: The current state of the art on the understanding of how pain alters movement control has enabled the emergence of preventive exercise protocols and treatment of movement disorders generated by the presence of pain.
FUTURE PERSPECTIVE: The application of new data acquisition and analysis technologies will allow the development of effective exercise protocols for pain management.

KEYWORDS: Pain theory | Movement disturbances | Pain adaptation

INTRODUCTION

The effects of acute and chronic musculoskeletal pain on motor control have been extensively investigated due to the pronounced socio-economic impact and potential deleterious effects on athletes' performance. Three theories have been proposed. Travell et al. [1] proposed a theory to explain the perpetuation of pain due to an acute episode. This is known as the "vicious cycle" model, in which pain is transmitted by group III and IV afferent fibers and then, via the excitation of motoneurons located in the anterior horn of the spinal cord, evokes muscle hyperactivity as a protective reaction, causing ischemia and metabolic acidosis, which generates more pain and perpetuates the cycle of pain-spasm-pain. Half a century later, Lund et al. [2] proposed the pain adaptation model. For the first time, it was considered that pain may cause disturbances in the neural control of muscles affected by pain and muscles that were remote relative to the location of the pain. According to the authors, acute and chronic muscle pain decreases agonistic muscle activity (in the painful muscle), and at the same time increases antagonistic muscle activity (in the non-painful muscle). The sum of these changes in muscle contraction impairs motor control, potentially decreasing range of motion, speed and precision of movement. Twenty years later, Hodges proposed a new perspective of motor adaptation to pain that is consistent with clinical and experimental observations [3]. The authors propose that musculoskeletal pain infers important changes in motor control at multiple levels of the motor system, leading to redistribution of activity within and between muscles, resulting in altered mechanical behavior, distribution of loads, and stiffness. This adaptation provides immediate potential benefits for the system and possible long-term deleterious consequences due to motor control changes associated with pain.

Interestingly, so far there is no clear, unequivocal and systematically determined causality when investigating the effects of pain on motor control. Due to the multidimensional characteristics of motor control, the effects of pain depend on the motor task to be performed, its speed, amplitude and execution time, the number of repetitions of the motor gesture, the number of joints and degrees of freedom involved, the location (whether proximal or distal to the part of the body performing the movement) and intensity of pain, among other variables. For example, it has been shown that mild and moderate acute muscle pain attenuates by more than 20% agonistic, antagonistic, and synergistic EMG activities with subsequent changes in movement kinematics, prolonged reaction times, and altered motor programming for high force demand tasks, coupled with significant changes in motor planning [4].

The understanding of the mechanisms of how pain affects motor control is incomplete. While pain does not seem to impair the ability to produce submaximal force [5], yet its effects on muscle activity can be inconsistent: it can increase [6] or decrease [7] by more than 25% from pain-free condition. Furthermore, to explain motor adaptations while under the influence of pain, a theory must consider changes at multiple levels of the motor system and determine how activity within and between muscles is redistributed and how these muscle activation patterns become integrated. In recent decades, advances in data processing methods have allowed muscle electrical signals to be decomposed to the point of identifying the contribution of individual motor units over several muscle contractions, including identifying the type of motor unit recruited. For instance, only recently it was shown that during acute muscle pain force output is held invariant compared to the pain-free condition by recruiting motor units with higher recruitment threshold and higher motor unit action potential amplitude [8].

Current views propose two theories of motor units' adaptation in response to pain. One indicates that the central nervous system will increase the synaptic input received by high-recruitment-threshold (RT) motor units to compensate for the inhibition of low-RT motor units [9]. Another theory suggests that the inhibition is non-uniform across a pool of motor units and shows an alternative way to compensate for the relative inhibition of agonist muscle's activity while producing the same amount of force [8]. There are also recent contributions of transcranial magnetic stimulation to the understanding of the central nervous system's role in these processes. In general, there is a pain-related reduction in motor cortical and spinal inhibition and a reorganization of motor maps [10].

Altogether, these data suggest that the interaction of pain and movement is not only a way to understand a localized interaction, but a complete paradigm to understand pain. However, studies involving the effects of musculoskeletal pain on motor skills have prioritized less complex motor gestures than those observed in sports or even in day-to-day tasks. This is mainly due to methodological difficulties. The challenge for this area of research is to investigate the influence of musculoskeletal pain on the control of highly complex human movements. Therefore, new tools for acquisition and processing of biological signals must be developed.

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