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Recognising neuroplasticity in musculoskeletal rehabilitation: A basis for greater collaboration between musculoskeletal and neurological physiotherapists

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ABSTRACT

Evidence is emerging for central nervous system (CNS) changes in the presence of musculoskeletal dysfunction and pain. Motor control exercises, and potentially manual therapy, can induce changes in the CNS, yet the focus in musculoskeletal physiotherapy practice is conventionally on movement impairments with less consideration of intervention-induced neuroplastic changes. Studies in healthy individuals and those with neurological dysfunction provide examples of strategies that may also be used to enhance neuroplasticity during the rehabilitation of individuals with musculoskeletal dysfunction, improving the effectiveness of interventions. In this paper, the evidence for neuroplastic changes in patients with musculoskeletal conditions is discussed. The authors compare and contrast neurological and musculoskeletal physiotherapy clinical paradigms in the context of the motor learning principles of experience-dependent plasticity: part and whole practice, repetition, task-specificity and feedback that induces an external focus of attention in the learner. It is proposed that increased collaboration between neurological and musculoskeletal physiotherapists and researchers will facilitate new discoveries on the neurophysiological mechanisms underpinning sensorimotor changes in patients with musculoskeletal dysfunction. This may lead to greater integration of strategies to enhance neuroplasticity in patients treated in musculoskeletal physiotherapy practice.

1. Introduction

Evidence is emerging that the central nervous system (CNS) reorganises in response to musculoskeletal dysfunction (Moseley and Flor, 2012). Coined 'neuroplasticity,' this reorganisation is an intrinsic property of the nervous system enabling it to adapt to environmental changes, physiologic modifications, and experiences (Pascual-Leone et al., 2005). Neuroplasticity can be adaptive or maladaptive in the presence of pain or dysfunction, and the same processes causing CNS reorganisation may potentially be harnessed to reverse central changes and lead to positive patient outcomes (Flor, 2002). Yet physiotherapists working with clients with musculoskeletal dysfunction conventionally evaluate region-specific movement performance or prescribe motor control exercises without considering the potential for plasticity of the CNS. In contrast, physiotherapists working with clients with neurological dysfunction commonly consider the effect of cortical dysfunction on patient performance as the brain is known to be the source of the problem. Recognising and addressing neuroplasticity as a component of motor control in patients with musculoskeletal dysfunction is important as (1) it may lead to greater understanding of neural mechanisms underpinning musculoskeletal dysfunction; and (2) addressing maladaptive neural organisation via neuroplasticity may improve the effectiveness of treatments that target motor behaviour, such as movement skill and muscle strength.

There is evidence that cortical processes influence aspects of musculoskeletal rehabilitation. However, the current approach musculoskeletal physiotherapists routinely use for exercise prescription is primarily influenced by exercise protocols investigated

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in clinical trials (Macedo et al., 2009; Bystrom et al., 2013), with little focus on central brain processes associated with neuroplasticity. One approach for improving motor performance through neuroplasticity is mental imagery, whereby actual movement is deliberately enhanced or substituted by mental rehearsal of a task (Guillot et al., 2008). Used widely within a sporting context and in some instances neurological rehabilitation and pain syndromes (Moseley, 2004, 2006), its use within musculoskeletal rehabilitation is relatively underdeveloped; for reviews, see (Mulder, 2007; Guillot and Collet, 2008). Task-specific training is another approach shown to be effective in improving strength and motor performance, accompanied by changes in brain areas involved in performing the tasks (Carey et al., 2002; Tsao et al., 2010). It is therefore surprising that strategies addressing neuroplasticity, such as mental imagery and task-specific training, have not been more widely adopted in musculoskeletal rehabilitation.

In this paper the authors discuss the evidence supporting the presence of CNS neuroplasticity in musculoskeletal conditions and present examples from the field of neurological rehabilitation that highlight the potential role of neuroplasticity in the management of musculoskeletal dysfunction. Furthermore, it is argued that greater collaboration between musculoskeletal and neurological physiotherapists and researchers will lead to greater use of strategies to enhance neuroplasticity during musculoskeletal rehabilitation, optimising patient outcomes.

2. Evidence for neuroplasticity in patients with musculoskeletal dysfunction

Neuroplasticity has been defined as “the ability of the nervous system to respond to intrinsic and extrinsic stimuli by reorganising its structure, function and connections” (Cramer, 2010). There is overwhelming evidence that the brain is continuously remodelled in response to new or novel experiences (Kleim and Jones, 2008). Therefore, an appreciation of the influence of the central nervous system on all forms of movement as well as pain should underpin all forms of rehabilitation.

Evidence is emerging for cortical changes in patients with chronic musculoskeletal pain; for reviews see (Apkarian et al., 2009; Davis and Moayedi, 2013). In the presence of pain, several brain regions (the “pain matrix”) are consistently activated: primary (S1) and secondary (S2) somatosensory cortex, insula, anterior cingulate cortex (ACC), amygdala, prefrontal cortex (PFC) and thalamus (Henry et al., 2011). However, patterns of brain activity are distinct for different pain conditions, indicating cortical responses are specific to pathologies. Functional magnetic resonance imaging (fMRI) demonstrates the medial PFC is activated in response to painful stimuli in chronic low back pain (LBP), whereas the insula is activated in knee osteoarthritis (Apkarian et al., 2009). Early work by Flor et al. (1997) using magnetoencephalography demonstrated activity in the somatosensory cortex representing the back increases and shifts medially in response to painful stimuli in patients with LBP, with the degree of shift associated with the chronicity of pain. With transcranial magnetic stimulation (TMS), patients with chronic LBP also show changes in the representation of specific muscles in the motor cortex (Tsao et al., 2011), with greater differences in cortical reorganisation from that observed in healthy individuals associated with reduced coordination of the trunk muscles (Tsao et al., 2008).

Recent advances in magnetic resonance imaging techniques provide new methods for examining cortical changes resulting from musculoskeletal pain. Proton magnetic resonance spectroscopy (Duarte et al., 2012) has shown changes in brain neurochemistry in patients with chronic LBP (Siddall et al., 2006) and following spinal cord injury (Stanwell et al., 2010). Neurochemical changes are specific to the side of pain, with patients with left sciatica demonstrating greater changes in the right thalamus (Yabuki et al., 2013). Grey matter volume is also decreased in patients with chronic LBP in the bilateral dorsolateral PFC and right thalamus, equivalent to grey matter loss in 10–20 years of aging (Apkarian et al., 2004). Resting-state fMRI shows the medial PFC (involved in emotional and self-referential processing) in LBP demonstrates increased connectivity with regions related to pain processing and receipt of pain information from the periphery (S2, insula, cingulate and S2 regions) (Baliki et al., 2011). In carpal tunnel syndrome, central morphometric changes demonstrated with diffusion tensor imaging correlate with median nerve conduction velocity (Maeda et al., 2013). These studies provide strong evidence that cortical changes occur in response to pain, and changes appear to be specific to the regional pathology, pain intensity and duration.

3. Interventions inducing neuroplasticity

Cortical changes due to chronic pain are reversible in response to pain reduction. Seminowicz et al. (2011) demonstrated that decreased cortical thickness and excessive activity during cognitive tasks in patients with chronic LBP normalised with reduced pain following treatment with either zygopophyseal joint block or spinal surgery. Maladaptive changes in the motor cortex can also be improved following specific exercise training. Deep abdominal muscle training using real-time ultrasound feedback results in an anteromedial shift of its representation in the motor cortex, towards that observed in healthy individuals (Tsao et al., 2010). This did not occur following general walking exercise, suggesting training must be specific to induce cortical changes. Further, feedforward activation of deep abdominal muscles improved following specific isolated contractions, but not following a sit up exercise activating all abdominal muscles in a non-specific manner (Tsao and Hodges, 2007). Therefore, mere repetition of muscle contractions without precision during training may not be sufficient to yield brain changes or changes in functional outcome. There is also some evidence that lumbar spine manipulation invokes a transient increase in central motor excitability (Dishman et al., 2008). These findings suggest cortical abnormalities in patients with musculoskeletal pain can be positively influenced with motor training, and the CNS may also be potentially affected by manual therapy.

Although the therapist is working with a non-lesioned brain in managing patients with musculoskeletal dysfunction, the neurobiological basis of neuroplasticity and potential for motor learning is the same as for the person with brain damage such as stroke. In stroke rehabilitation, the interventions with the best evidence for demonstrable positive effects on neuroplasticity and motor learning are intensive repetitive practice and task-specific training (van Vliet, 1993; French et al., 2007). A systematic review and meta-analysis of TMS and fMRI evidence concluded a large overall effect

Table 1
Principles of experience-dependent plasticity, as outlined by Kleim and Jones (2008).

Principle	Supporting references
Using part and whole practice exercises where specific parameters such as amplitude and speed resemble the real life desired task	van Vliet and Heneghan (2006) Kleim and Jones (2008)
Performing sufficient repetitions to induce neural change	Kleim and Jones (2008)
Task-specificity	French et al. (2007)
Providing feedback that induces an external focus of attention in the learner	Durham et al. (2009) Durham et al. (2013) Sturmberg et al. (2013)