WFC 2013 Award Winning Paper

Neural Responses of Posterior to Anterior Movement on Lumbar Vertebrae: A Functional Magnetic Resonance Imaging Study

Michael L. Meier, PhD,[a] Sabina Hotz-Boendermaker, PhD, PT,[a] Bart Boendermaker, MSc, MAS,[b] Roger Luechinger, PhD,[c] and Barry Kim Humphreys, DC, PhD[d]

Abstract

Objective: The purpose of this study was to develop and test a clinically relevant method to mechanically stimulate lumbar functional spinal units while recording brain activity by means of functional magnetic resonance imaging (MRI).

Methods: Subjects were investigated in the prone position with their face lying on a modified stabilization pillow. To minimize head motion, the pillow was fixed to the MRI headrest, and supporting straps were attached around the shoulders. An experienced manual therapist applied controlled, nonpainful pressure stimuli to 10 healthy subjects at 3 different lumbar vertebrae (L1, L3, and L5). Pressure applied to the thumb was used as a control. The stimulation consisted of posterior to anterior (PA) pressure movement. The therapist followed a randomized stimulation protocol projected onto a screen in the MRI room. Blood oxygenation level–dependent responses were analyzed in relation to the lumbar and the thumb stimulations. The study was conducted by the Chiropractic Department, Faculty of Medicine, University of Zürich, Switzerland.

Results: No participant reported any discomfort due to the prone-lying position or use of the pillow. Importantly, PA-induced pressure produced only minimal head movements. Stimulation of the lumbar spinous processes revealed bilateral neural responses in medial parts of the postcentral gyrus (S1). Additional activity was observed in the secondary somatosensory cortex (S2), posterior parts of the insular cortex, different parts of the cingulate cortex, and the cerebellum. Thumb stimulations revealed activation only in lateral parts of the contralateral S1.

Conclusion: The current study demonstrates the feasibility of the application of PA pressure on lumbar spinous processes in an MRI environment. This approach may serve as a promising tool for further investigations regarding neuroplastic changes in chronic low back pain subjects. (J Manipulative Physiol Ther 2014;37:32-41)

Key Indexing Terms: *Magnetic Resonance Imaging Functional; Low Back Pain; Chronic Pain; Manual Therapies; Chiropractic*

Chronic low back pain (CLBP) represents the most common musculoskeletal problem in society today and leads to enormous health care costs.[1-11] Current CLBP treatments attempt to mediate functional and structural abnormalities in the musculoskeletal system. However, these treatments are frequently unsuccessful suggesting that other mechanisms are involved beside end-organ dysfunction. A plethora of research focused on revealing the process of chronicity of low back pain in the fields of methodology, psychology, anatomy, and neurophysiology have thus far been disappointing. The advent of human brain imaging such as functional magnetic resonance imaging (fMRI) provides an important new avenue for the investigation of cortical pain processing in acute low back pain and CLBP. Recent neuroscientific studies have revealed neuroplastic changes in the brain of CLBP subjects, which are strongly related to the chronicity of

[a] Research Associate, Chiropractic Department, Faculty of Medicine, University of Zürich, Zürich, Switzerland.
[b] Manual Therapist, Faculty of Medicine and Pharmacy, Vrije Universiteit Brussel, Brussel, Belgium.
[c] Physicist, Institute of Biomedical Engineering, Swiss Federal Institute of Technology and the University of Zurich, Zürich, Switzerland.
[d] Professor, Chiropractic Department, Faculty of Medicine, University of Zürich, Zürich, Switzerland.
Submit requests for reprints to: Michael L. Meier, PhD, Professor, Ziegelfeldstrasse 109, 4600 Olten, Switzerland (e-mail: *Michael.meier@uzh.ch*).
Paper submitted April 27, 2013; in revised form September 5, 2013; accepted September 22, 2013.
0161-4754/$36.00

http://dx.doi.org/10.1016/j.jmpt.2013.09.004

low back pain.[12,13] Although some neuroplastic mechanisms at the spinal level and with spinal manipulation have been reported,[14-17] only sparse evidence exists that describes cortical reorganization of CLBP subjects. A recent study suggests that alterations in cortico-limbic connections may be able to predict the transition from subacute to chronic back pain.[12] In this study, painful intracutaneous electric stimulation showed enhanced cortical reactivity and extensive reorganization in the primary somatosensory cortex (S1) in CLBP subjects compared with a control group.[18] Moreover, the application of mechanical compression to paravertebral musculoskeletal tissue of the lumbar spine in CLBP subjects revealed augmented activation in cortical areas associated with pain processing, although S1 activity could not be observed.[19] Finally, nonpainful stimulation by mechanical plate vibration on the lower back of CLBP subjects showed decreased activation in cortical regions, which are crucial for cognitive and affective top-down modulation of afferent signals from the lower back.[20]

The limited amount of evidence regarding the neural underpinnings of CLBP subjects is reflective of the methodological problems and technical challenges when using fMRI. Some of these difficulties include:

1. Technical challenges that arise when investigating the lower back, such as the unconventional prone position of the subjects and associated higher risk for unwanted head motion, enabling normal breathing with a more confined head position, which, in turn, makes it more difficult to apply a controlled experimental stimulus. In addition to the increased task-free head motion in the prone position, mechanical stimulation of the lower back can lead to additional extensive head movements. These movement provoked changes in the fMRI signal can be confused with signal changes due to brain activity as the movement may be correlated with the task.[21]
2. When comparing healthy and CLBP subjects, most neuroimaging studies applied electrical and thermal stimuli[18,22] or stimulated extremities such as the forearm[22] to reveal reorganization in the somatosensory system. However, low back pain is thought to be a mechanical disorder,[23] and therefore, a mechanical stimulus to the lumbar spine would be a more logical and appropriate choice.[19]
3. Cortical reorganization as depicted by a shift of the locus in S1 activation has been demonstrated in CLBP subjects[18,20] and in complex regional pain syndrome patients,[24] suggesting cortical somatosensory changes by long-term nociceptive input. However, S1 activity is difficult to verify as it is frequently not present or subtle and often only survives significance thresholds when small volume corrections are applied to the fMRI data or when significance thresholds are strongly reduced.[19,20,25]

Applying manual pressure over bony and soft tissues of the lower back is a common and widespread procedure used in manual therapy to provoke the patient's pain complaint.[26] Therefore, we aimed to experimentally mimic common shear loading mechanisms as used by manual therapists by directly stimulating distinct functional spinal units of healthy subjects (FSU, ie, functional entity of 2 adjacent vertebrae including disk, ligaments, and zygapophyseal joints)[27] while simultaneously observing corresponding brain activity.

The current investigation is a proof-of-concept study. The overall aim was to overcome the aforementioned methodological limitations by using a manual pressure posterior to anterior (PA) stimulus on the lumbar spinous processes of prone-lying stabilized subjects during fMRI scanning. Regarding neural activity, we hypothesized that somatosensory areas including the primary and secondary somatosensory cortex (S1 and S2) would show enhanced activation, as both areas have previously demonstrated somatotopic organization of the human body.[28-31] It is envisaged that the results of this study will provide a useful methodology to examine neural responses to disentangle the cortical representation of the lower back and possibly reveal neuroplastic changes, which occur in CLBP subjects. In summary, the purpose of this study was to develop and test a clinically relevant method to mechanically stimulate lumbar functional spinal units while recording brain activity by means of fMRI.

Methods

Subjects

Ten subjects (7 females) with a mean age of 35.3 years (SD, ±15.0) participated. The subjects were recruited from an online advertisement platform at the University of Zurich (www.marktplatz.uzh.ch), between September 2012 and December 2012. Exclusion criteria were low back pain within the last 3 months; any history of neurologic, psychiatric, or a major medical disorder; and the presence of an indwelling metal or medical device incompatible with magnetic resonance imaging (MRI). The study protocol, procedures, and consent forms were approved by the local cantonal ethics committee (Zurich, Switzerland). Subjects received 35 Swiss Francs per hour for their participation.

Experimental Procedure

The participants were scanned in the prone position with the face lying on a modified stabilization pillow (Posifix Prone Headrest; CIVCO medical solutions, Kalona, IA). The pillow was fixed to the magnetic resonance headrest by means of double-faced adhesive tape (Fig 1). For maximal comfort, additional pads were placed individually under the chest. To further minimize head motion, straps were