

Widespread brain activity during an abdominal task markedly reduced after pain physiology education: fMRI evaluation of a single patient with chronic low back pain

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The way people with chronic low back pain think about pain can affect the way they move. This case report concerns a patient with chronic disabling low back pain who underwent functional magnetic resonance imaging scans during performance of a voluntary trunk muscle task under three conditions: directly after training in the task and, after one week of practice, before and after a 2.5 hour pain physiology education session. Before education there was widespread brain activity during performance of the task, including activity in cortical regions known to be involved in pain, although the task was not painful. After education widespread activity was absent so that there was no brain activation outside of the primary somatosensory cortex. The results suggest that pain physiology education markedly altered brain activity during performance of the task. The data offer a possible mechanism for difficulty in acquisition of trunk muscle training in people with pain and suggest that the change in activity associated with education may reflect reduced threat value of the task. [Moseley GL (2004): Widespread brain activity during an abdominal task markedly reduced after pain physiology education: fMRI evaluation of a single patient with chronic low back pain. *Australian Journal of Physiotherapy* 51: 49–52]

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Introduction

Pain physiology education for patients with pain is aimed at altering the patients' knowledge about their pain states — 'reconceptualisation of the problem'. Education of this type may involve 2–3 hours of teaching, either individually or in a small group, and can involve provision of information about the physiology of the nervous system in general and pain mechanisms in particular. The information can be presented in detail which, contrary to the perceptions of health professionals, can be understood by relatively uneducated patients (Moseley 2003b). Pictures, examples, and metaphors are normally used. The material has been discussed within the context of clinical trials and is presented in detail elsewhere (Butler and Moseley 2003).

In chronic back pain, pain physiology education alters pain beliefs and attitudes (Moseley et al 2004) and in conjunction with physiotherapy improves functional and symptomatic outcomes (Moseley 2002, Moseley 2003a). One possible explanation for the improvement in function is that reconceptualisation of the problem leads to increased confidence which in turn leads to increased activity levels. However, we have also shown that altered pain beliefs are directly associated with altered movement performance even if there is no opportunity to be physically active (Moseley 2004). That finding implies that motor performance may be directly limited by pain beliefs, which would be consistent with clinical observation.

One motor task that is particularly relevant in this regard is

voluntary activation of the deepest abdominal muscle, transversus abdominis (TrA). Based on extensive biomechanical and physiological data, this muscle is thought to play a unique role in maintaining spinal control (Hodges 1999), but is dysfunctional in patients with chronic recurrent back pain (Hodges and Richardson 1996, Hodges and Richardson 1998). Voluntary activation of this muscle without activating superficial abdominal muscles is considered by many clinicians to be a critical first step in regaining trunk muscle control (Richardson et al 1999). However, anecdotally at least, patients with chronic back pain sometimes find this task very difficult despite training and practice.

Using a single case design, we were interested in whether pain physiology education had an effect on the pattern of brain activity during performance of this abdominal task. Changes in cortical activation should provide insight into the nature of the effect of pain physiology education on motor tasks.

Method

Patient A thirty-six year old female with a history of chronic disabling (18-item Roland Morris Disability Questionnaire = 12) low back pain (~ 4.5 years since onset with a fall at work) and with no neural signs, agreed to undergo three functional magnetic resonance imaging (fMRI) scans. She had been off work since the onset of pain and had presented for physiotherapy after referral from her general practitioner. She had not previously participated in pain management but had received twice-weekly chiropractic manipulations for three

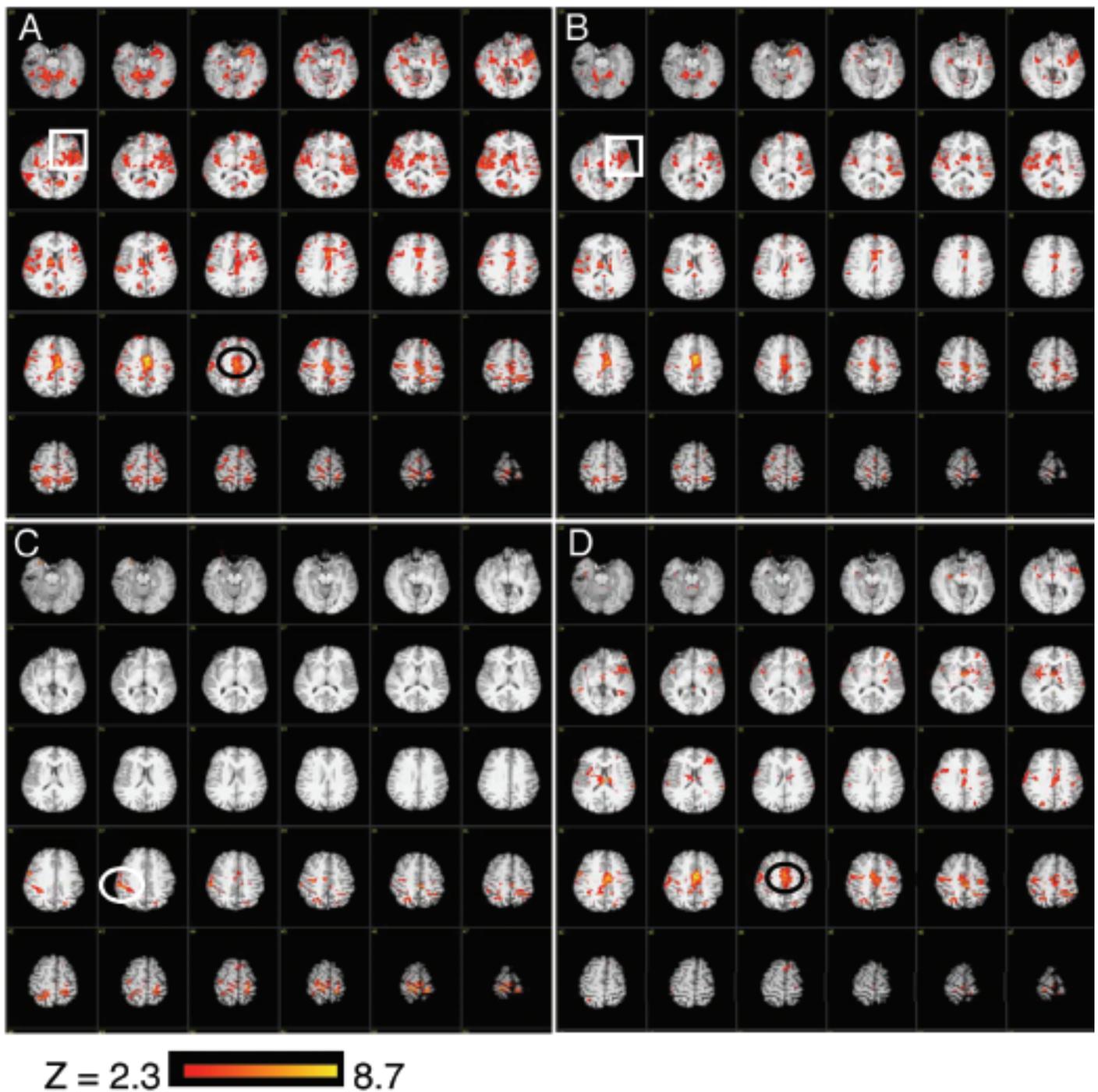


Figure 1. MRI images colour coded according to Z-values, taken from a single subject with chronic low back pain during a voluntary abdominal muscle task. Areas of the brain in which more activity occurred during performance of the task than during the rest period are shown (threshold = 2.3, $p < 0.01$). Images are shown in axial slices from base (slice 1, top left) to top of brain. Images shown were acquired directly after training in the abdominal drawing-in task (A), after one week of hourly practice of the task (B), and then directly after a 2.5 hour one-to-one education session about the physiology of pain (C). Note marked reduction in activation, excepting primary somatosensory areas, after education. Panel (D) shows statistical comparison between scans two and three. Frontal cortex (box, panel A & B), anterior cingulate cortex (small black circle, panel A & D) and primary sensory/motor cortex (small white circle, panel C) are shown.

years. She was using intermittent oral morphine and nonsteroidal anti-inflammatory medications for pain relief, but reported that they had limited effect.

Abdominal task and self-report tests The abdominal drawing-in task, which involves a gentle drawing-in of the

lower abdomen, was used for the study. Accurate performance can be verified by a trained physiotherapist and confirmed using real-time ultrasound (Richardson et al 1999). The following self-report measures were also used: McGill Pain Questionnaire (Melzack 1975), Roland Morris Disability Questionnaire (Roland and Morris 1983), Fear

Table 1. Psychometric self-report measures taken before the first fMRI scan and before the third fMRI scan (following education).

	Before scan 1	Before scan 3
McGill Pain Questionnaire	40	38
Roland Morris Disability Questionnaire	12	11
Fear Avoidance Beliefs Questionnaire (physical activity)	19	17
Pain Self-Efficacy Questionnaire	20	22

Avoidance Beliefs Questionnaire (Waddell et al 1993), physical activity items, Pain Self-Efficacy Questionnaire (Nicholas et al 1991).

fMRI For each session, images were acquired using a 1.5 T Siemens^a fMRI system. An anatomical scan was acquired prior to the first session. The supine subject was made comfortable with a pillow under the knees and the head stabilised by a strap and foam padding. A block design was used such that the patient would rest for 10 seconds and then perform the task for 6 seconds (indicated by 'off' and 'on' visual cues, respectively). This cycle was performed 10 times. Image processing, registration of the rendered threshold images to the high resolution anatomical image, and statistical analysis were performed using statistical parametric mapping software^b. Scanning parameters are detailed in the Addendum. This experimental approach provides a statistical comparison of activity of the brain during the 'on' (performing the task) condition, to that during the 'off' (rest) condition (a 'fixed effects analysis'). Thus, any variable constant during both conditions (e.g. pain) will not affect results.

Pain physiology education and scanning schedule The initial physiotherapy session involved teaching the patient how to perform the abdominal drawing-in task according to the accepted protocol (Jull and Richardson 2000). The first scanning session was undertaken directly after training. The physiotherapist evaluated performance at the task during scanning and the patient was questioned about whether contraction was painful or if she felt anxious in any way during performance of the task. After scanning, the patient was advised to practise the task for five minutes each waking hour for one week and to keep a practice diary during the week. A second scan was conducted after one week. Pain physiology education was undertaken directly following the second scan.

Pain physiology education involved 2.5 hours of one-to-one teaching and covered the physiology of the nervous system in general and of the pain system in particular. The information was presented in detail. Pictures, examples, and metaphors were used.

A third and final scan was conducted immediately after the pain physiology education. The following psychometric self-report tests were completed prior to the first and third scan: McGill Pain Questionnaire (Melzack 1975), Roland Morris Disability Questionnaire, (Roland and Morris 1983), physical activity items of the Fear Avoidance Beliefs Questionnaire, (Waddell et al 1993) and the Pain Self-Efficacy Questionnaire (Nicholas et al 1991).

Fixed effects analyses were conducted on the fMRI data for each scan and to compare brain activity during performance of the task between the second and third scanning sessions.

Results

The patient reported no pain during performance of the abdominal task. Compliance with the home practice schedule was high (~ 80%); however there was no marked improvement in performance of the task, as judged by the physiotherapist, between the first and second scanning sessions. The physiotherapist judged performance of the task as poor, poor, and satisfactory during the three scanning sessions, respectively.

Each of the psychometric self-report tests showed a slight change toward the desired treatment effect between the first and third scans, however, no large changes were observed (Table 1).

Figure 1A shows axial slices obtained in the initial fMRI scan registered to the high-resolution anatomical image. There was widespread cortical activity associated with performance of the abdominal drawing-in task, including activity in primary somatosensory cortex, anterior cingulate cortex, association areas (parietal cortex) and frontal cortex. The second scan (Fig.1B) also shows widespread activity across several cortical areas, although there is a general reduction in brain activation. The final scan (Fig. 1C), conducted following pain physiology education, shows a marked reduction in cortical activation in all but the primary somatosensory cortex. In particular, the final scan shows that performance of the task did not involve activation of the cingulate, frontal, or insular cortices, components of the so-called 'pain matrix'. Figure 1D shows differences in brain activity during performance of the task between the second and third scans (i.e. activity during task performance in scan two minus activity during task performance during scan three).

Preprocessing protocols, motion correction data, and time series plots for significant voxels between scans two and three are provided in the Addendum.

Discussion

These data from a single patient with chronic disabling low back pain suggest that pain physiology education leads to a marked reduction in cortical activation, as measured by fMRI, during performance of the abdominal drawing-in task. Although care should be taken when interpreting fMRI data from a single subject, the current finding is important because it suggests that in this patient the provision of information about pain physiology was sufficient to alter brain activation during a motor task, even when there was no opportunity to practise the task.

In this sense, the fMRI data are compatible with the psychometric data and consistent with earlier work that demonstrated, in 121 chronic low back pain patients, that cognitive changes imparted by pain physiology education are associated with changes in physical performance, even when physical exposure is not possible (Moseley 2004). Although the mechanism of the effect is not clear, the altered cortical activation observed in this single case suggests some possibilities.

In this patient, before pain physiology education, performance of the abdominal drawing-in task involved

activation of several components of the so-called 'pain matrix'—those cortical regions most often activated during pain, including the cingulate cortex, the insular cortex, and the frontal cortex (Fig. 1A & B). The third scan (Fig. 1C) demonstrated that activation of these areas is not *required* for the task but reflects brain processes that are *associated* with the task prior to pain physiology education. Direct comparison between scans two and three corroborates that finding by demonstrating significantly more activity in these areas during performance of the abdominal task before pain physiology education than during performance of the same task after pain physiology education (Fig. 1D).

Considering that pain physiology education can lead to changes in pain beliefs, such as a reduction in the conviction that pain is associated with harm and that pain is necessarily associated with disability (Moseley et al 2004), it seems most likely that the changes in brain activation reflect reduced threat associated with the task. That is, perhaps even a benign activity involving the low back, such as the abdominal drawing-in task, was threatening for this patient, although she did not report that to be the case. Nonetheless, this possibility would support clinical observations of guarding and protective muscle activation patterns in this group (Main and Watson 1996, Watson et al 1997) and offers a possible explanation for the difficulty that such patients have in performing this relatively easy motor task using conventional training approaches. Finally, the current results suggest that pain physiology education may offer an effective strategy for overcoming barriers to regaining normal control of the trunk muscles in some patients with chronic low back pain. Further research should clarify this issue.

The current results need to be verified in a clinical trial. Nonetheless, the current data from a single patient with chronic disabling low back pain show that pain physiology education leads to a marked reduction in cortical activation during performance of a voluntary abdominal muscle task. Most notable is the reduction in activity of those cortical areas normally involved in pain. Pain physiology education may be an effective strategy for overcoming barriers to acquisition of normal trunk muscle control in patients with low back pain.

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Addendum Scanning details are available on the eAJP web site at <www.physiotherapy.asn.au/AJP>

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