

# Persistence of improvements in postural strategies following motor control training in people with recurrent low back pain

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## Abstract

This study investigated long-term effects of training on postural control using the model of deficits in activation of transversus abdominis (TrA) in people with recurrent low back pain (LBP). Nine volunteers with LBP attended four sessions for assessment and/or training (initial, two weeks, four weeks and six months). Training of repeated isolated voluntary TrA contractions were performed at the initial and two-week session with feedback from real-time ultrasound imaging. Home program involved training twice daily for four weeks. Electromyographic activity (EMG) of trunk and deltoid muscles was recorded with surface and fine-wire electrodes. Rapid arm movement and walking were performed at each session, and immediately after training on the first two sessions. Onset of trunk muscle activation relative to prime mover deltoid during arm movements, and the coefficient of variation (CV) of EMG during averaged gait cycle were calculated. Over four weeks of training, onset of TrA EMG was earlier during arm movements and CV of TrA EMG was reduced (consistent with more sustained EMG activity). Changes were retained at six months follow-up ( $p < 0.05$ ). These results show persistence of motor control changes following training and demonstrate that this training approach leads to motor learning of automatic postural control strategies.

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*Keywords:* Low back pain; Postural control; Feedforward postural adjustments; Motor training

## 1. Introduction

Feedforward or anticipatory postural adjustments are argued to counteract predictable challenges to the body from internal or external forces (Belen'kii et al., 1967; Bouisset and Zattara, 1981). Because these adjustments occur before feedback is available, they are considered to be preprogrammed by the central nervous system (CNS). Changes in feedforward postural adjustments have been demonstrated in a variety of musculoskeletal conditions including anterior knee pain (Cowan et al., 2001), low back pain (LBP (Hodges and Richardson, 1996)), shoulder impingement (Wadsworth and Bullock-Saxton, 1997) and idiopathic neck pain (Falla et al., 2004). Many of these

changes persist after the resolution of symptoms (Hodges and Richardson, 1996), and it has been hypothesised that they may contribute to recurrence and chronicity of pain episodes (Hodges and Moseley, 2003). Hence training interventions that aim to address these alterations in postural control have been suggested (Richardson et al., 1998).

Several authors have argued that feedforward postural adjustments can be trained. Schmitz and Assaiante (2002) showed that improvements in feedforward postural adjustments were possible in children following practice of a bimanual coordination task. Forrest (1997) found similar improvements in feedforward activation after 16 weeks of Tai Chi training, and Cowan et al. (2003) demonstrated reversal of delayed feedforward activation of the quadriceps muscle in people with anterior knee pain following a six weeks training program. In general, these studies have employed comprehensive programs and included practice of functional tasks that required feedforward postural

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adjustments. However, a common clinical approach that has been shown to be effective in the management of musculoskeletal conditions (O'Sullivan et al., 1997; Stuge et al., 2004) involves training the activation of the delayed muscle with repeated isolated voluntary contractions (Richardson et al., 1998). The basis for this approach is that repeated activation induces plastic changes in the nervous system and leads to modified automatic recruitment of the trained muscle during the performance of untrained functional tasks.

In a recent study, we investigated whether this training approach can induce immediate changes in feedforward activation by using the model of changes in activation of the deep abdominal muscle, transversus abdominis (TrA) in people with recurrent LBP (Tsao and Hodges, 2005). Although TrA is activated in a feedforward manner in healthy individuals (Hodges and Richardson, 1997), this activity is consistently delayed in people with recurrent LBP (Hodges and Richardson, 1996), and provides a marker of postural control dysfunction. The results of that study showed immediate improvements in feedforward postural adjustments of the TrA following a single session of training of isolated voluntary contractions of this muscle. Importantly, these improvements were not replicated by activation of TrA in a non-isolated manner during a functional manoeuvre in a separate randomly assigned group (Tsao and Hodges, 2005). However, whether these changes can be further improved with a longer duration of training of isolated voluntary contractions, and whether they persist after training is ceased (a requirement of motor learning) remains unknown and was the aim of the present study.

## 2. Methods

### 2.1. Subjects

Nine volunteers ( $26 \pm 7$  (means  $\pm$  SD) years, 2 males, 7 females) with unilateral or bilateral LBP lasting longer than three months ( $2.8 \pm 2$  years) were recruited. Subjects were excluded if they had any circulatory, neurological, respiratory or orthopaedic disorders, or if they had undertaken any form of abdominal training in the preceding 12 months. The study was approved by the Institutional Medical Research Ethics Committee and performed in accordance with the Declaration of Helsinki.

### 2.2. Electromyography

Intramuscular fine-wire bipolar electromyography (EMG) electrodes (Teflon-coated stainless steel wire, 75  $\mu$ m with 1 mm Teflon removed, and tips bent back  $\sim$ 1 and  $\sim$ 2 mm to form hooks) were threaded into a hypodermic needle and inserted into the TrA, obliquus internus abdominis (OI) and obliquus externus abdominis (OE) muscles with ultrasound guidance (De Troyer et al., 1990; Hodges and Richardson, 1997). Pairs of surface electrodes (Ag/AgCl discs, 10 mm diameter, and 20 mm inter-electrode distance, Grass Telefactor USA) were placed over the rectus abdominis (RA), erector spinae (ES) and the anterior (AD) and posterior (PD) deltoid muscles. EMG data were amplified 2000

times, band-pass filtered between 20 Hz and 1 kHz, and sampled at 2 kHz using a Power1401 Data Acquisition System with Signal2 and Spike2 software (Cambridge Electronic Design, UK).

## 3. Procedure

Fig. 1 illustrates subject screening and testing procedures. Subjects attended three test sessions distributed over four weeks with a further follow-up at six months. Trunk muscle activity during single rapid arm movements and self-paced walking was evaluated at all sessions. In sessions 1 (initial) and 2 (two weeks), recordings were made before and immediately after a session of training.

### 3.1. Single rapid arm movement

Subjects stood with their feet shoulder-width apart, and either flexed or extended the arm at the shoulder to  $\sim 45^\circ$  "as fast as possible" in response to an auditory tone (Hodges and Richardson, 1996). Distinct tones indicated movement direction, and the order and timing of the auditory tones were randomised to limit the predictability of the task. Ten repetitions of flexion and extension were completed as this number of trials has been shown to optimise repeatability of the data (Moseley and Hodges, unpublished data). A potentiometer was attached to the left arm to measure angular displacement and acceleration at the shoulder (sampling rate: 100 Hz).

### 3.2. Self-paced walking

Subjects walked at their normal pace over-ground for 2 min prior to data collection to allow for accommodation

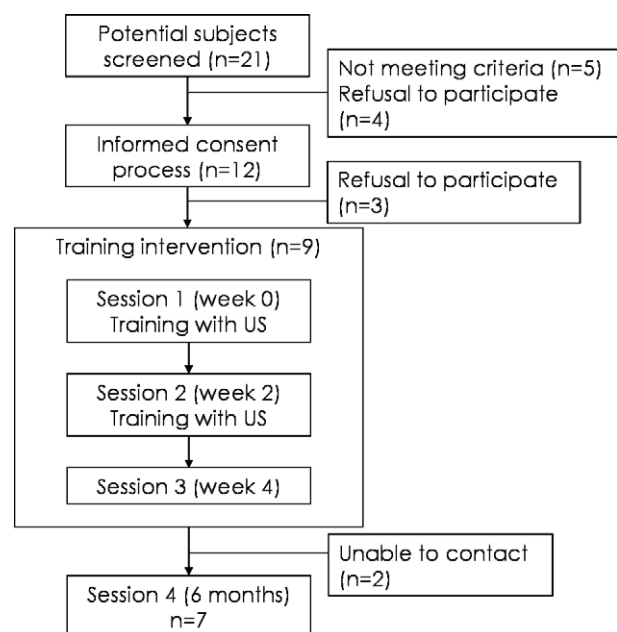


Fig. 1. Flow diagram of subject screening and experimental protocol (US – Ultrasound).

to the experimental setup, after which EMG data were recorded for 15 s. Temporal features of the gait cycle (foot strike) were identified using a foot switch under the posterior aspect of the right heel (sampling rate: 100 Hz). This task was selected as previous studies have reported phasic EMG activity of TrA activity during walking in people with LBP (Saunders et al., 2005a) compared to more constant activation pattern in healthy individuals (Saunders et al., 2004).

### 3.3. Pain and functional measures

Self-reported pain was measured using an 11-point visual analogue scale (VAS) anchored with “no pain” at 0 and “worst pain imaginable” at 10. In addition, a patient-specific functional scale (PSFS) was used to measure the functional capacity of each subject. This involved the nomination of three activities of daily living that were limited by symptoms and subjects rated each activity on an 11-point scale anchored with “unable to perform tasks” at 0 and “able to perform tasks at pre-injury status” at 10. Both the pain VAS and PSFS have been shown to be valid (Jensen et al., 1989) and reliable (VAS (Zusman, 1986); PSFS (Stratford et al., 1995)), and were completed at the beginning of each session.

### 3.4. Training intervention

The aim of training was to gently contract the TrA in isolation from the other abdominal muscles (Richardson et al., 1998). Training by an experienced musculoskeletal physiotherapist was conducted at the initial session and at the two week session. Consistent with clinical practice, feedback of contraction (thickening and shortening of TrA with or without substitution by OI) was provided using real-time ultrasound imaging (Henry and Westervelt, 2005; Hodges et al., 2003b; Richardson et al., 1998). All subjects contracted the TrA to 5%  $RMS_{max}$  with minimal activation of other abdominal muscles. This level was determined by performance of maximum voluntary contractions (MVC) of TrA (forced expiratory manoeuvre (Ninane et al., 1992)) at the beginning of each session at week 0 and week 2. Three repetitions were completed with verbal encouragement and the highest root-mean-square (RMS) EMG of the TrA was recorded ( $RMS_{max}$ ). As TrA is activated differentially from the other superficial abdominal muscles and at low intensities during function (Hodges, 2001; Hodges and Richardson, 1999; Saunders et al., 2005b), training of isolated low level recruitment of TrA can be considered to be consistent with its activation pattern during function.

Once the subject's performance was optimal (best activity of TrA with minimal activation of the other abdominal muscles), they were instructed to hold the muscle contraction while maintaining respiration for 10 s. Three sets of 10 repetitions were carried out with a 2 min rest between each set. Subjects were instructed to train twice per day for four weeks and compliance was evaluated with an exercise diary

(percentage of actual training performed over the expected training quantity). At the completion of four weeks of training, all subjects ceased training and no specific instructions were given with regards to activity or exercise.

To investigate whether subject's performance of the training task improved with practice, each contraction was given a rating out of 10 according to the degree of isolation from other superficial abdominal muscles. This score was determined through palpation (out of three), observation of ultrasound image (out of four) and EMG recordings (out of three), and has been shown to be associated with the objective measure of voluntary control of this muscle (Ferreira, 2005). As the rating was assigned prior to analysis of the EMG data, the researcher who rated the performance had no prior knowledge of the effect of the intervention on the individual and thus could not bias their interpretation of performance.

## 4. Data analysis

### 4.1. Rapid arm movement

EMG data were high-pass filtered at 50 Hz (4th order Butterworth) to remove movement artefact. Onset of EMG activity was identified visually without reference to the identity of the muscle, direction of movement, time of testing, or whether the data were from trials pre- or post-training. Visual identification has been shown to be reliable and is preferred to computer-based methods as it is less affected by factors such as amplitude of background EMG or the rate of increasing activity (Hodges and Bui, 1996). Onset of trunk muscle EMG was calculated relative to that of deltoid.

Peak angular acceleration of the shoulder for each trial was also calculated to evaluate whether subjects changed the way they moved the arm between sessions. Angular displacements of the shoulder were differentiated twice and peak acceleration was identified.

### 4.2. Walking

EMG data were high-pass filtered at 50 Hz (4th order Butterworth) to remove movement artifact, full-wave rectified, low-pass filtered at 30 Hz (6th order Butterworth; (Hodges and Gandevia, 2000)), and baseline EMG activity at rest was subtracted. EMG averages were triggered from right foot strike. Prior to averaging, trunk muscle EMG data were resampled to 100 samples per cycle. The mean and SD of the averaged EMG cycle were assessed. The coefficient of variation (CV;  $SD/mean$ ) was calculated for each muscle to provide an indication of the variability of EMG signals from the mean. Greater amplitude of phasic modulation of EMG would yield higher CV.

As changes in the speed of walking may affect activation of the trunk muscles (Saunders et al., 2004), cadence was determined, averaged across step cycles and compared between trials.

5. Statistical analysis

Statistical analysis was performed using Statistica 7 (Statsoft, USA) with the significance level set at 0.05. The onsets of trunk muscle EMG during rapid arm movement and the mean, SD and CV during walking were compared between sessions with repeated-measure analysis of variance (ANOVA) with one repeated measure (Session: pre/post initial, pre/post two weeks, four weeks and six months) and one independent factor (Muscle). Post-hoc testing was performed using Duncan’s multiple range test. Peak arm acceleration and cadence were compared between sessions with repeated-measures ANOVA.

Quality of performance of voluntary activation was compared between the first and second session using a *t*-test for dependent samples, and the relationship between performance scores and changes in the EMG onset and CV of TrA EMG immediately after training at week 0 and week 2 were determined using Pearson’s correlation. Pain VAS and PSFS scores were compared between sessions with repeated-measures ANOVA. The relationship between overall changes in pain VAS and PSFS scores and changes in postural control (onset of TrA EMG or CV) at the end of four weeks of training were also examined using Pearson’s correlation.

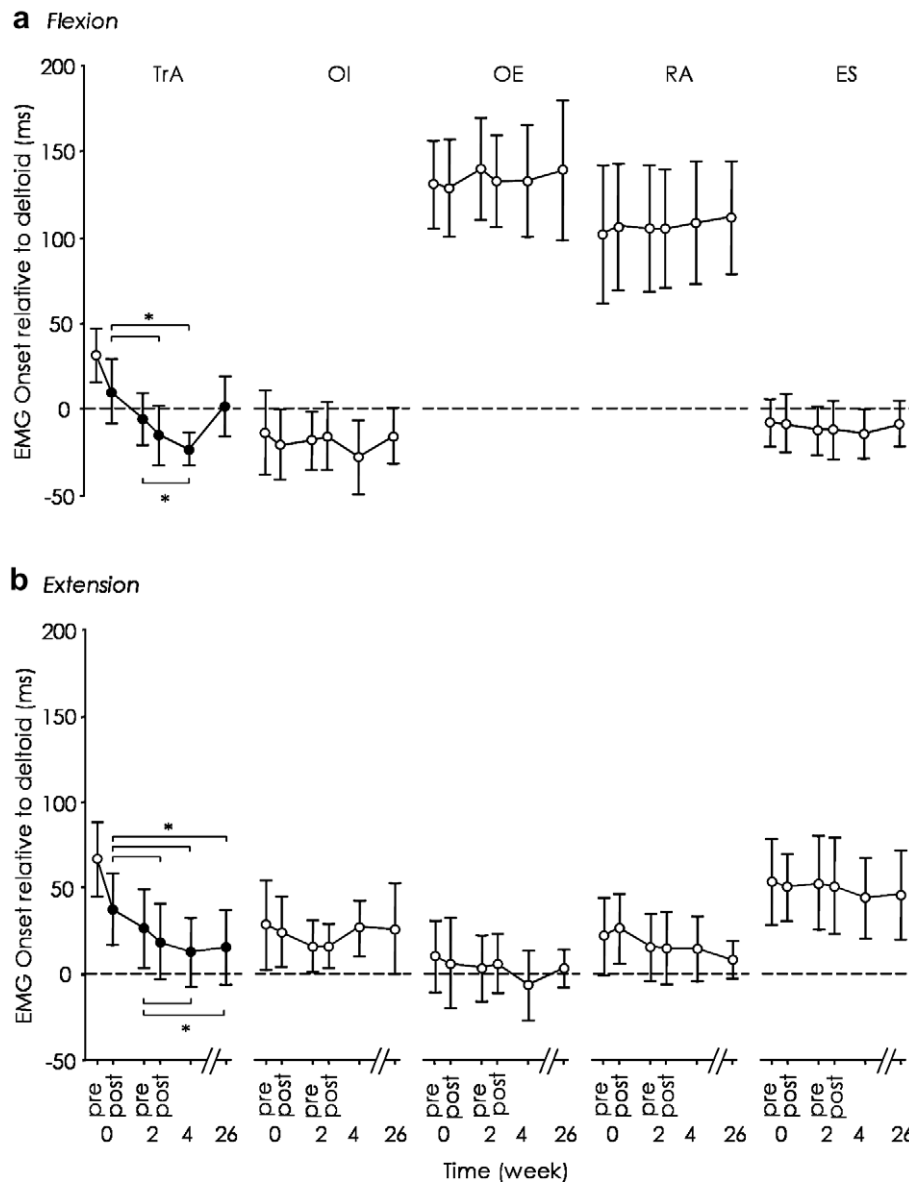


Fig. 2. Group data of onset of trunk muscle EMG for trials of arm flexion (a) and extension (b). Dotted line denotes onset of prime mover; deltoid. Negative values indicate onset of trunk muscle EMG prior to deltoid. Data are shown before and after training at weeks 0 and 2, and at 4 weeks and six months follow-up. Onset of EMG and 95% confidence intervals are shown. Black circle indicate significant difference ( $p < 0.05$ ) when compared with pre-training data at week 0. Consistent earlier activation of the transversus abdominis (TrA) in both arm directions can be observed. \* $p < 0.05$  (OI – obliquus internus abdominis; OE – obliquus externus abdominis; RA – rectus abdominis; ES – erector spinae).

**6. Results**

All nine subjects attended sessions 1–3 and seven subjects attended the follow-up session at six months (Fig. 1). Compliance of the training regime was measured at 81 (10) %.

*6.1. Rapid arm movement*

Fig. 2 illustrates onset of trunk muscle EMG relative to that of the deltoid during arm movements. As expected for people with LBP, activation of TrA EMG prior to training occurred after that of the deltoid during both arm flexion and extension (Hodges and Richardson, 1996).

Analysis of the EMG onset data revealed a significant main effect for Muscle ( $F = 30.47, p < 0.001$ ) and Session

( $F = 11.05, p < 0.001$ ), and a significant interaction between Muscle and Session ( $F = 4.81, p < 0.001$ ). Post-hoc analysis revealed that the onset of TrA EMG was earlier for both flexion and extension tasks following a single session of training (week 0,  $p = 0.0012$ ). Improvement in the timing of TrA activation continued over the four weeks training period with improvements retained at six months follow-up ( $p < 0.001$ ). No changes were found for other trunk muscles between sessions (OI and OE  $p > 0.10$ , all other trunk muscle  $p > 0.21$ ). All subjects displayed a similar temporal shift in onset of TrA EMG over four weeks of training (Fig. 3). Changes were more variable at six months with regression of training effect in some subjects. Peak arm acceleration was not different between test sessions ( $F = 1.12, p = 0.37$ ; Fig. 6a).

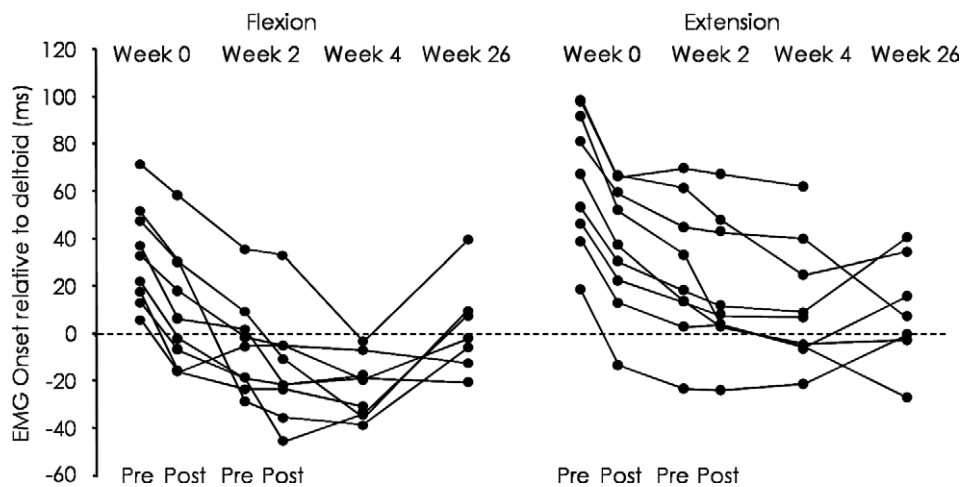


Fig. 3. Individual subject data for onset of transversus abdominis (TrA) EMG for flexion (left) and extension (right). The dotted line represents the onset of the prime mover deltoid. Data are not available for two subjects at six months. Note consistent earlier activation of TrA EMG observed in all subjects, with variable changes at six months follow-up.

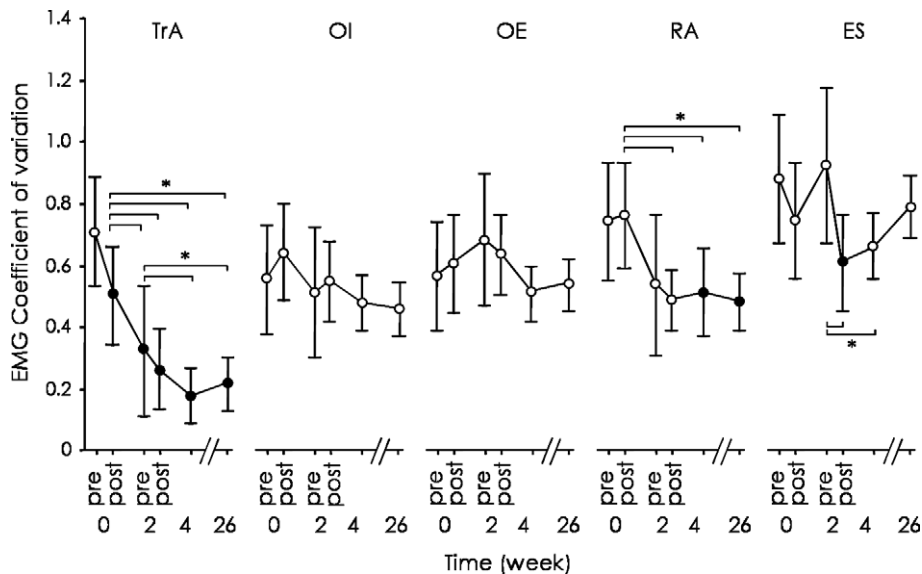


Fig. 4. Group data for coefficient of variation (CV) during self-paced walking. Black circle indicate significant difference ( $p < 0.05$ ) when compared with pre-training data at week 0. Note consistent reductions in CV in the transversus abdominis (TrA) over the training sessions with retention of effects at six months follow-up. \* $p < 0.05$  (OI – obliquus internus abdominis; OE – obliquus externus abdominis; RA – rectus abdominis; ES – erector spinae).



6.2. Walking

Fig. 4 shows changes in the CV for self-paced walking. There was a main effect for Muscle ( $F = 14.20, p < 0.001$ ) and Sessions ( $F = 7.73, p < 0.001$ ), and a significant interaction between these two factors ( $F = 1.89, p = 0.018$ ). Post-hoc analysis demonstrated that the CV for TrA EMG was consistently decreased after training and changes were retained at six months follow-up ( $p < 0.0015$  between pre-training and all sessions, with the exception of pre- and post-training in session 1  $p = 0.11$ ). The CV also reduced for RA ( $p < 0.03$  pre-training compared with sessions 3 and 4, post-training at session 1 compared with sessions 2, 3 and 4) and ES ( $p < 0.031$  between pre-training at sessions 1 and 2 compared with post-training data at sessions 2 and 3). There were no significant changes for other trunk muscles between sessions ( $p > 0.24$ ). For both mean and SD, there was a main effect for Session which showed increases in mean and SD (mean:  $F = 5.67, p < 0.001$ ; SD:  $F = 2.67, p < 0.035$ ). However, no interaction was found between Muscle and Sessions ( $F < 0.58, p > 0.90$ ). As the mean EMG activity was not reduced over the sessions, a decrease in CV is reflective of less variability in the EMG rather than inactivity in the muscle. Cadence did not vary between sessions (Fig. 6b,  $p = 0.62$ ).

6.3. Performance of training

Performance of the training task was improved at session 2 (week 0:  $6.6 \pm 1.3$ , week 2:  $8.1 \pm 1.3, p = 0.025$ ).

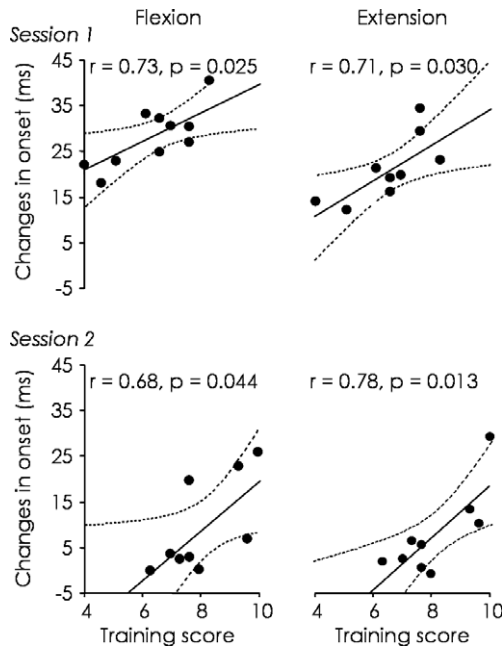


Fig. 5. Linear relationship between quality of training and changes in timing of onset of transversus abdominis (TrA) activity. Linear regressions (and 95% confidence intervals) are shown for session 1 (upper panel) and session 2 (lower panel), for arm flexion (left panel) and extension (right panel). Positive values for timing data indicate earlier onset of activity. Note the positive correlation between quality of training and earlier changes in TrA activation.

Furthermore, there was a positive linear relationship between changes in onset of TrA EMG immediately after training and performance scores at week 0 and week 2 (Fig. 5).

6.4. Pain and functional measures

Fig. 6c illustrates a reduction in self-reported pain at six months follow-up ( $p = 0.0047$ ), and improvements in PSFS scores at four week and six months ( $p < 0.02$ ). There was only a weak and non-significant relationship between changes in pain VAS scores and changes in TrA onsets (flexion  $r = -0.10, p = 0.80$ ; extension  $r = 0.10, p = 0.80$ ) or CV ( $r = -0.17, p > 0.67$ ), and between PSFS scores

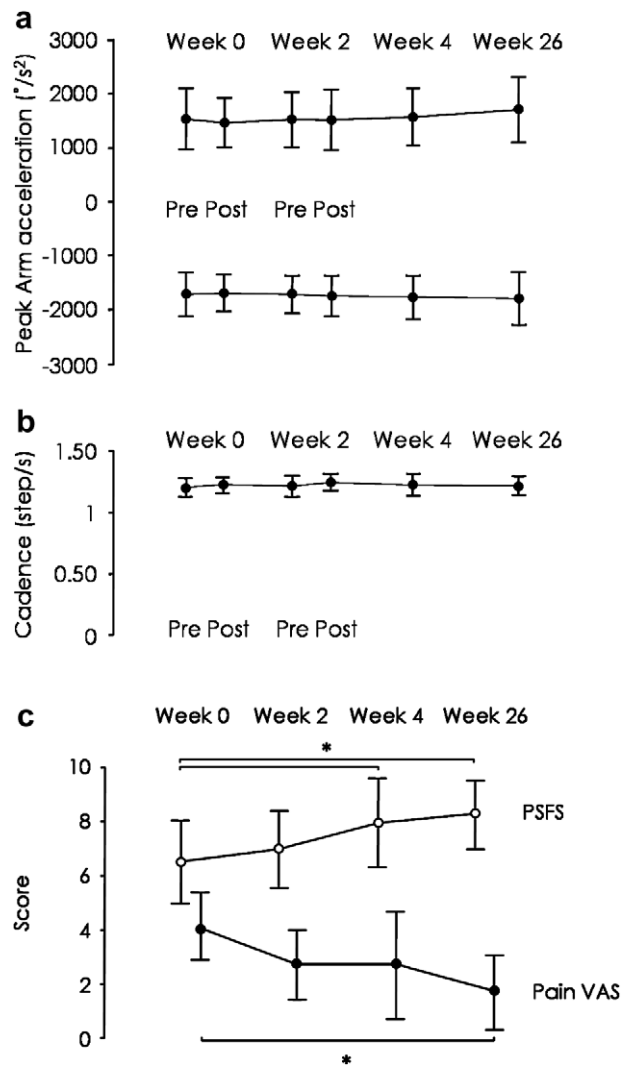


Fig. 6. (a) Peak arm acceleration during arm flexion (positive values) and extension (negative values) movements, (b) Cadence during self-paced walking and (c) Pain and functional outcome measures. Note no significant changes were found for peak arm acceleration and cadence between all sessions. A significant reduction in pain scores (visual analogue scale (VAS)) and an improvement in functional scores (patient-specific functional scale (PSFS)) were found at week 4 and 6 months follow-up. \* $p < 0.05$ .

and changes in TrA onsets (flexion  $r = -0.1$ ,  $p = 0.68$ ; extension  $r = 0.18$ ,  $p = 0.64$ ) or CV ( $r = -0.071$ ,  $p > 0.86$ ).

## 7. Discussion

This study demonstrates for the first time that persistent improvements in feedforward activation can be achieved with training of isolated voluntary contractions. Specifically, four weeks of this type of training of the TrA in people with recurrent LBP is associated with long-term improvements in feedforward postural adjustments and reduced modulation of the trained muscle during untrained functional tasks. The results also suggest that these changes can be retained for six months despite the cessation of training. Together with existing clinical trials that support the efficacy of training of isolated voluntary contractions (O'Sullivan et al., 1997; Stuge et al., 2004), the present findings suggest that improvements in motor control may be a possible mechanism underlying the clinical improvements in individuals with LBP, but future randomised controlled trials are needed to confirm these findings.

### 7.1. Changes in feedforward postural adjustments and gait-related EMG are maintained following training

Our previous study established that changes in feedforward postural adjustments were possible following a single session of training of isolated voluntary contractions (Tsao and Hodges, 2005). This is supported by the results of the present study which involved a different group of subjects. Longer duration of training led to further changes in timing of TrA EMG onset towards values that are observed in healthy individuals during arm movement tasks (flexion  $-32$  ms, extension  $-19$  ms (Hodges and Richardson, 1997)). These findings are consistent with existing literature that report long-term changes in feedforward activation (Cowan et al., 2003; Forrest, 1997; Schmitz and Assaiante, 2002). However, those studies trained functional tasks that required feedforward activation, whereas the present study trained voluntary activation in a novel task and showed that this was sufficient to induce long-term changes. Only one previous preliminary report of a case study of two individuals has demonstrated long-term improvements in feedforward activation associated with ten weeks of this type of training (Jull et al., 1998). In addition, the present data indicates that this type of training is associated with reduced CV of the trained muscle during self-paced walking. Decreased variability across the gait cycle during and after training suggests a more constant activation which approximates the responses identified in healthy individuals (Saunders et al., 2004). The effects of training on muscle activation during rapid arm movement and walking may imply that this intervention approach has the potential to change motor control across a variety of functional tasks.

An important finding was that changes in postural control could be retained at six months despite the cessation of training. Although the effect for the group was significant,

there were variations between individuals. It is not possible to determine whether this variability is related to cessation of training or changes in other factors such as alterations in regular activity. Nevertheless, maintenance of training effects in the majority of subjects is consistent with previous studies that have shown long-term retention of training-related changes in voluntary movements (Newell, 1991) and postural tasks (Bhatt and Pai, 2005). As motor learning necessitates permanent changes in muscle activation (Magill, 2001), the present findings suggest that learning has occurred with the training intervention and changed the way the CNS controls the trained muscle during functional tasks.

Improvements in control of the TrA during functional tasks may be beneficial for people with recurrent LBP. Data from human and animal experiments suggest that these muscles have an important contribution to spinal control through the generation of intra-abdominal pressure and fascial tension (Cresswell et al., 1992; Hodges et al., 2001, 2003a; Tesh et al., 1987). Importantly, studies have shown that interventions that include training of repeated voluntary contractions of TrA are associated with reduced pain and disability in people with recurrent LBP (O'Sullivan et al., 1997; Stuge et al., 2004). Although the relationship between improvement in symptoms and changes in control has not been tested, the present data suggest that enhanced motor control during functional tasks may contribute to or underlie the clinical change.

As our previous study confirmed that changes in temporal activation following training are specific to training of isolated voluntary contractions and not induced by repetition of tasks that require minimal skills and attention (sit-up (Tsao and Hodges, 2005)), the results suggest that changes observed in this study are likely to be related to the intervention and not due to other factors. Nevertheless, further work should include a control group to confirm this. As previous studies have demonstrated no significant changes in timing with repeated measurements (Moseley and Hodges, unpublished data; Hodges, 1996) or other interventions (Tsao and Hodges, 2005), changes in EMG onset observed in the present study are unlikely to be due to the effect of repeated testing.

### 7.2. Changes in feedforward postural adjustments are related to the quality of training and are associated with improvements in self-reported pain and function

There was a positive association between changes in timing of TrA activation and the quality of training performance. This is consistent with our previous data that demonstrated more skilled activation of the TrA (i.e., greater degree of isolation) was associated with greater change in timing of EMG onset (Tsao and Hodges, 2005). Kleim et al. (1998) have reported that practice of a skilled task induces greater plastic changes in the motor system compared to unskilled training. As isolated voluntary contractions require skilled activation of muscles,

training that involves mere repetition of muscle contractions without precision (that is, unskilled training) may not induce similar improvements in feedforward activation. This could explain our previous findings of no change with simple repetition of a sit-up (Tsao and Hodges, 2005) and is consistent with the relationship between quality of control and changes in timing of EMG onset.

Improvements in self-reported pain and functional measures were observed following four weeks of training of isolated voluntary contractions, and were consistent with findings from previous clinical trials of people with LBP (O'Sullivan et al., 1997; Stuge et al., 2004). However, this study was not designed to test this effect and the results must be interpreted with caution. Changes in pain and functional scores had a weak and non-significant correlation with changes in feedforward postural adjustments or CV. This weak association between impairment and function is not unexpected. According to the International Classification of Functioning, Disability and Health (WHO, 2001), association is expected to be low between different domains of testing. Notably, self-assessment of pain and function are consequences of complex interactions between many multi-dimensional factors including sensory afferents, motivation, catastrophisation and fear (Turk, 1996; Vlaeyen et al., 1995). Thus the lack of direct correlation may simply mirror this underlying complex interaction between multiple factors.

It is important to emphasise that this study does not advocate that repeated isolated voluntary contractions is sufficient to treat individuals with LBP. Rather, the study indicates that one impairment often identified in LBP (i.e., delayed activity of TrA) can be changed with training. Existing studies support the implementation of management strategies which involve multi-modal and multi-disciplinary approaches (Guzman et al., 2002; Hayden et al., 2005a,b; Waddell and Burton, 2005). Nevertheless, the data has highlighted a possible contribution of this type of training in the rehabilitation of common musculoskeletal pain conditions.

### 7.3. Future directions

This study was designed to determine whether long-term changes in motor control could be induced by training of isolated voluntary contractions. Consequently a control group or randomisation process was not included. Although previous data which included a control group has confirmed that changes are dependent on the training type and cannot be replicated by simple repetition of activation in a functional task, a larger study is required to evaluate association with clinical changes. Furthermore, the present study did not include an asymptomatic control group. However, we argue that whether timing of trunk muscles could or could not be changed in a healthy population would not affect the current findings in people with LBP. Therefore, the results suggest that changes with train-

ing can be maintained and provide a guide to the dosage of training as well as the expected size of postural control changes. These findings form a basis for a larger randomised clinical trial that aims to investigate both the efficacy and underlying mechanisms of interventions that include this training approach.

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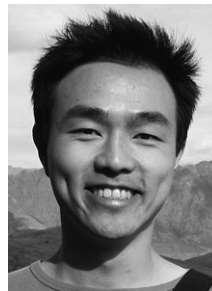
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