CHANGES IN MUSCLE ACTIVITY AND STATURE RECOVERY AFTER ACTIVE REHABILITATION FOR CHRONIC LOW BACK PAIN

Abstract

Patients with low back pain often demonstrate elevated paraspinal muscle activity compared to asymptomatic controls. This hyperactivity has been associated with a delayed rate of stature recovery following spinal loading tasks. The aim of this study was to investigate the changes in muscle activity and stature recovery in patients with chronic low back pain following an active rehabilitation programme. The body height recovery over a 40-minute unloading period was assessed via stadiometry and surface electromyograms were recorded from the paraspinal muscles during standing. The measurements were repeated after patients had attended a rehabilitation programme and again at a six-month follow-up. Analysis was based on 17 patients who completed the post-treatment analysis and 12 of these who also participated in the follow-up. By the end of the six months, patients recovered significantly more height during the unloading session than at their initial visit ($ES = 1.18$; $P < 0.01$). Greater stature recovery immediately following the programme was associated with decreased pain ($r = -0.55$; $P = 0.01$). The increased height gain after six months suggests that delayed rates of recovery are not primarily caused by disc degeneration. Muscle activity did not decrease after treatment, perhaps reflecting a period of adaptation or altered patterns of motor control.

Key Words

Low back pain; electromyography; stature change

Introduction

Intervertebral discs lose height in response to compressive forces, due to a combination of fluid outflow and elastic deformation of both the disc and the vertebral endplates. When the spine is subsequently unloaded, these processes are reversed, leading to elastic return, fluid inflow and disc height recovery (Adams et al., 1990). Changes in disc height lead to changes in overall body length (or stature). Therefore precision stadiometry, which measures changes in body height, is often used as an indirect and non-invasive method for assessing changes in disc height and comparing the relative spinal loading resulting from different activities. It has been observed that people with chronic low back pain (CLBP) appear to lose stature at a similar rate to healthy controls in response to loading, but are significantly slower to recover this height when the spine is unloaded (Rodacki et al., 2003; Healey et al., 2005). Possible causes of this may be an altered response due to disc degeneration (Urban & Roberts, 2003), or elevated muscle activity increasing the compressive forces acting on the spine (Healey et al., 2005).

Increased activity of the superficial paraspinal muscles during static postures such as standing (Ambroz et al., 2000) or full flexion (Watson et al., 1997b) is often reported in patients with CLBP. It is unknown why this hyperactivity occurs, although it may reflect a compensatory mechanism in the presence of spinal instability (possibly caused by injury, disease or degeneration) (Panjabi, 1992), and may persist after the original injury or cause has disappeared (van Dieën et al., 2003).

Healey et al. (2005) found a significant negative correlation between paraspinal muscle activity and stature recovery in people with mild CLBP, suggesting that the increased muscle activity may increase the loading on the intervertebral discs and delay their regain of height. This is of clinical consequence because intervertebral disc height loss may compromise spinal stability (Zhao et al., 2005), increase loading on other spinal structures, such as the facet joints, and lead to concentrations of compressive stress (Adams et al., 2002). Significant correlations have been observed between delayed stature recovery and higher levels of both pain and disability (Healey et al., 2005), supporting the relevance of this research area.

Treatment programmes can affect both the activity of the superficial back muscles and stature recovery in patients with low back pain (LBP). For example, reduced muscle activity at full flexion has been observed following a pain management programme (Watson et al., 1997a) and an intense physical exercise rehabilitation programme has been shown to significantly increase the morning height of patients compared to those who received no treatment (Hupli et al., 1997). Reduced muscle contraction was suggested as a possible explanation in this case.

The aim of this study was to investigate the changes in muscle activity and stature recovery following an active rehabilitation programme and to establish if there was any relationship with clinical outcome. It was hypothesized that muscle activity would be reduced following the programme and that this would be associated with increases in stature recovery and also with improvements in pain and disability.

Methods

Participants

Patients with CLBP (LBP lasting more than three months) were recruited from the waiting lists for both the Back Exercise Group (BEG) and the Work Back to Life Group

(WBTL), both of which are run in [*removed to maintain anonymity*]. Patients on these waiting lists were sent information about the study in the post and asked to return a reply slip if they were willing to take part. All testing of NHS patients took place at [*removed to maintain anonymity*].

Exclusion criteria were; nerve root compression, central nervous system impairment, progressive motor deficit, sphincter impairment from neurologic cause and presence of "red flags" (e.g. unexplained weight loss, recent urinary tract infection, history of intravenous drug use). Many of the patients were taking analgesics for their back pain; it was not considered practical, or ecologically valid, to exclude those on medication. Participants were offered £12.50 for each session they attended to cover travel and parking expenses. Ethical approval was granted by the [*removed to maintain anonymity*] NHS ethics committee and local NHS permission was granted by [*removed to maintain anonymity*] NHS Trust. All participants provided written informed consent.

Muscle Activity Measurement

Raw electromyographic (EMG) signals were recorded using a DELSYS system (Delsys Inc. Boston, MA, USA). Single differential surface electrodes consisting of two silver bars with an inter-electrode spacing of 10mm were used. Signals were band-pass filtered between 20 and 450 Hz with a sampling frequency of 1000Hz. Electrodes were placed over the erector spinae muscle at the level of the L1-2 and L4-5 interspaces, approximately 3cm from the midline on either side and a reference electrode placed on the right iliac crest. Participants assumed a standing posture for ten seconds while a recording was taken. EMG data were normalised relative to a reference voluntary contraction (RVC). A sub-maximal RVC was used as this has been shown to increase between-day reliability within CLBP patients (Dankaerts et al., 2000). The reference task required each participant to stand while holding up a 0.5kg mass in each hand with arms bent (upper arms horizontal, lower arms vertical) for ten seconds. The signal mean value was removed from the raw EMGs, before rectifying and integrating over a period of five seconds. An analysis of variance showed no significant difference between the EMG data at the different electrode sites and hence an average of the four sites was used in the analysis. The EMG reading and the RVC were both taken to be the average of the three readings recorded during the session. The non-normalised values were also analysed but, unless specified, muscle activity refers to values normalised to the RVC.

The stadiometer

Changes in stature were measured with a standing stadiometer, which consisted of a rigid frame, mounted at a right angle to a base plate and inclined backward 15° from the vertical (Figure 1). Four anatomical points were identified (Lewis & Fowler, 2009) and then supported by the frame to maintain the natural contours of the head and spine. The position of the feet was marked and head position was controlled by the use of spectacle frames with attached lasers, aligned with two movable targets above the participant's head. A high-resolution linear variable displacement transducer (Solartron Metrology, DC50) was used to detect changes in stature by measuring vertical displacement with an accuracy of approximately 0.01mm. The information was observed graphically on a laptop computer at the time of collection and stored digitally, at a sampling rate of 100Hz, for later analysis.

All participants initially undertook a brief familiarisation session on the stadiometer to enable them to practice the adoption of a repeatable and comfortable posture. This consisted of five recordings, between which the participant was asked to lean forward and break contact with the postural controls before resuming their position for the next measurement. A pilot study demonstrated that this approach was sufficient to produce reliable stadiometer readings (average standard deviation (SD) 1.0mm, standard error of measurement 0.8mm). Participants remained in position for a period of 20 seconds and the stature value used was the mean reading over the final 10 seconds.

Pain intensity

A numerical rating scale (NRS) was employed to assess pain intensity. Participants were asked to rate their pain during the past 24 hours on a scale ranging from (0) ‘no pain’ to (10) ‘worst possible pain. Research supports the reliability and validity of numerical rating scales of pain intensity (Jensen, 2003).

Disability

The Roland Disability Questionnaire (Roland and Morris, 1983) (RDQ) is a 24-item self-report measure that assesses disability due to back pain. Patients are asked to select which statements, related to perceived limitations in typical daily activities, apply to them. The RDQ has excellent reliability, validity and responsiveness (Roland and Fairbank, 2000; Turner et al., 2003).

Psychological factors

A number of additional questionnaires were included to assess psychological factors. The questionnaires used were the Hospital Anxiety and Depression Scale (HADS) (Zigmond and Snaith, 1983), the functional subscale of the Chronic Pain Self-Efficacy Scale (CPSS-PF) (Anderson et al., 1995), the Tampa Scale of Kinesiophobia (TSK) (Kori et al., 1990), the Pain Catastrophising Scale (PCS) (Sullivan et al., 1995) and the Pain Anxiety Symptoms Scale-20 (PASS-20) (Coons et al., 2004).

Procedure

Patients attended their first testing session (Session 1) before starting the rehabilitation programme (except for five patients who attended in the week after the programme commenced). Patients then returned for another testing session (Session 2) as soon as practical (usually within the following week and always within the following fortnight) after completing the rehabilitation group and then again six months later (Session 3), where possible. Patients were requested to try to maintain the same daily routine prior to attending each testing session in order to reduce fluctuations in physical activity levels. Although it was not possible for all patients to be tested at the same time of day, each patient attended at the same time for each of their visits (or within one hour of their previous time), apart from one exception when, due to work commitments, the patient attended in the morning for Session 1 and in the afternoon for Sessions 2 and 3.

For each session, a baseline stature measurement and initial EMG readings (at rest and during the RVC) were taken before participants assumed an unloading position on a physiotherapy bed for 20 minutes (either a side-lying or prone position). After 20 minutes, the participants stood up and performed the same EMG and stadiometer measurements, before again assuming an unloading position for a further 20 minutes.

The measurements were then taken for a final time. Stature change was calculated as the difference between the final and the initial stadiometer readings. At the end of the testing session patients were asked about their pain intensity during the past 24 hours. They were then given a questionnaire booklet containing the self-report measures. Although some patients completed the booklet immediately, the majority completed it at home and returned it at a later date.

Study population

Twenty-three patients attended both Sessions 1 and 2 (Table 1). Some patients found it difficult to maintain a consistent posture in the stadiometer and four patients were excluded from the stature recovery data as the SD of the five familiarisation readings was considered too high. For this purpose, a SD of 1.7mm was taken as the cut-off point (Lewis et al., 2012). The remaining 19 patients had an average SD of 1.1mm over the five familiarisation readings. The stature recovery data of one patient was excluded as he was considered to be an outlier and one further patient had incomplete EMG data resulting from technical problems. The analysis was therefore based on 17 patients (Table 1). Three patients did not complete the questionnaire booklet on both visits and so the data for disability and psychological factors are based on 14 patients.

Thirteen patients participated in all three sessions. After excluding one outlier (as above), the follow-up analysis was based on 12 patients (Table 1). Two patients did not complete the questionnaire booklet on both visits and hence the analysis for disability and psychological factors is based on 10 patients. Lewis (2011) provides further details and analysis regarding the drop-outs from this study.

Intervention

Two active, physiotherapy based interventions were utilised for the purposes of this study. The Back Exercise Group (BEG) involved four sessions (one a week). The first and last sessions were two hours in duration and consisted of exercise and education. The middle two sessions were one hour of exercise only. The exercise facet of the programme consisted of specific stretching and strengthening exercises and became progressively more difficult over the four weeks. Patients were also encouraged to exercise daily at home. The Work Back to Life (WBTL) group included five sessions (one a week), each of three and a quarter hours in duration. This programme included the exercise and education components that were in the BEG, but was based more on cognitive-behavioural principles. In particular, the WBTL group included individual goal setting aimed at returning patients to activities and tasks that they had stopped doing because of their back pain. Patients were allocated to either the BEG or the WBTL based on the results of TSK and RDQ questionnaires, with the WBTL group intended for those patients who were more severely disabled and demonstrated psychosocial risk factors for prolonged disability. Further details on the WBTL programme are given in the study by Woby et al. (2008). As the current study was not aiming to investigate the efficacy of specific interventions, the analysis was carried out on the BEG (n = 16) and WBTL (n = 7) groups combined.

Analysis

Parametric tests were used based on the results of Kolmogorov-Smirnov and Shapiro-Wilk tests of normality. One-tailed paired t-tests were performed to identify any pre- to post- treatment changes and Pearson's correlation coefficient was implemented to determine the inter-relations that existed between the changes in the outcome measures. Effect sizes (difference in means divided by initial SD) were also calculated to provide an indication of the meaningfulness of any changes that occurred. Finally, two-tailed correlation coefficients were employed to investigate the extent to which any of the measures at baseline were linked to changes in muscle activity and stature recovery.

Results

Immediately following treatment

A summary of the main outcome measures before (Session 1) and immediately following (Session 2) treatment are given in Table 2. Overall, there were significant improvements in both pain and disability immediately after the programmes. There was also a trend for greater stature recovery, but this did not reach significance ($P = 0.08$). Changes in stature recovery between Sessions 1 and 2 were correlated with changes in pain ($r = -0.55$, $P = 0.01$) and catastrophising ($r = -0.65$, $P < 0.01$), with a trend for a correlation with changes in disability ($r = -0.40$, $P = 0.08$). Two-tailed analysis showed a trend for patients with higher EMG levels after the programme to be those with higher baseline self-efficacy ($r = 0.52$, $P = 0.06$).

Follow-up analysis

The results for the patients who completed the six-month follow-up (Session 3) are given in Table 3. Stature recovery was significantly greater at Session 3 than at Session 1 ($ES = 1.18$, $P < 0.01$) and disability was significantly reduced ($ES = -0.59$, $P < 0.05$). There were significant correlations between changes in muscle activity levels between

Sessions 1 and 3 and changes in each of disability ($r = 0.61$, $P = 0.03$), catastrophising ($r = 0.85$, $P < 0.01$), pain-related anxiety ($r = 0.69$, $P = 0.01$), depression ($r = 0.59$, $P = 0.04$) and self-efficacy ($r = -0.57$, $P = 0.04$), although it should be remembered that these analyses were based on 10 patients only. No association was found between changes in muscle activity and changes in stature recovery. A reduction in EMG by the end of the six-month follow-up period was correlated with high initial levels of muscle activity ($r = -0.60$, $P = 0.04$).

Discussion

Stature recovery was significantly increased at the follow-up session (to levels comparable with asymptomatic individuals (Lewis, 2011)), suggesting that the reduced stature recovery previously observed in patients with CLBP (Healey et al., 2005) is not primarily the result of disc degeneration. This is consistent with a study carried out by Hupli et al. (1997), in which the morning height of patients increased after an intense physical exercise programme, with no observed changes in markers of disc degeneration. In the current study, on average, patients gained an additional 1.9mm in height during the unloading period at the follow-up compared to their initial visit, representing an increase of 73%. The increase in recovery also exceeds the standard error of measurement of 1.4mm assessed via an earlier repeatability study (Lewis, 2011). This involved ten participants from the same patient population as the current study, with stature recovery measurements taken on two separate days, both before the patient commenced the rehabilitation programme. Research into the occurrence and consequences of delayed stature recovery rates within patient groups is limited (providing the motivation for this study). The clinical significance of this change is therefore unclear, but it seems reasonable to suggest that such enhanced recovery of intervertebral disc height would reduce the loading on other spinal structures and so may facilitate a reduction in symptoms.

Immediately following the programme, changes in stature recovery were negatively correlated with changes in pain, with a trend for a link with changes in disability. This suggests that, over periods of up to six weeks, stature recovery measurements could potentially be used as a proxy indicator of changes in clinical outcome and could therefore provide an objective means of assessing progress in patients with back pain.

Overall, there was no change in resting EMG immediately following the programme and some patients surprisingly exhibited an increase in muscle activity levels. This pattern existed in both absolute and normalised EMG levels and therefore was not simply due to a reduction in RVC values. This may indicate an adaptation period immediately following a programme of increased activity and exercise, as the muscles compensate for increased demands, possibly in the context of pre-existing instability. There was a trend for increased EMG levels to be associated with higher initial self-efficacy, which may suggest greater participation in the daily exercise and stretching recommended in the programmes. This is not the first study to find that EMG levels do not make an immediate return to more "healthy" patterns of activity. For example, Mannion et al. (2001) reported that a reduction in pain after treatment was not accompanied by increased relaxation of the back muscles during full flexion. Furthermore, lumbar muscle activation during isometric testing and at the start of the dynamic fatigue test was unexpectedly increased and patients surprisingly demonstrated greater muscle fatigability (assessed via the rate of median frequency decline) post-therapy. The authors suggested that patients might be employing different motor control/recruitment patterns after treatment, perhaps as a result of less utilisation of guarding mechanisms. This may help to explain the findings in the current study. Following the programme, patients may have been using painful lumbar muscles to maintain upright posture to a greater extent than previously, or adopting an altered posture, such as a more neutral spine, leading to changes in muscle activation patterns. This suggests that elevated muscle activity may not necessarily be problematic in the short-term and may sometimes reflect a positive adjustment. This should be borne in mind when considering the use of techniques such as EMG biofeedback that aim to encourage decreased EMG levels.

Although both absolute and normalised EMG levels were reduced by the follow-up session, in neither case was this significant (possibly due to the small sample size). Over this six-month period, changes in muscle activity were associated with changes in each of disability, catastrophising, pain-related anxiety, depression and self-efficacy. Although based on limited numbers, these results are consistent with the findings of a cross-sectional study which found significant correlations between muscle activity and each of these variables (Lewis et al., 2012). This earlier study also found muscle activity to be a mediating factor between psychological factors and pain. Together, the results of both studies confirm the link between biomechanical and psychological factors in CLBP and add support to the importance of muscle activity within CLBP, although more research is required to fully understand the mechanisms and relationships involved.

Contrary to our hypothesis, the results did not support a correlation between changes in stature recovery and muscle activity following the rehabilitation programme. This study had the advantage of deriving data from a clinical sample with moderate levels of pain and disability and the results suggest that the relationship between muscle activity and stature recovery within this patient population may be more complex than originally thought. For example, there may have been changes in the patterns of paraspinal EMG that were more complicated or occurring at a deeper level than could be detected with only four sites of superficial EMG. Alternatively, there may simply have been too many confounding factors when comparing these measurements over several weeks or months in a fluctuating condition such as CLBP, particularly with the added complication of varied treatment responses.

The assessment of muscle activity was carried out while the patients were in a static standing posture as it is commonly reported that patients with CLBP have elevated paraspinal muscle activity in this position (Geisser et al., 2005). Although studies, such as Mannion et al. (2001), have assessed muscle activity during movement or strength and endurance tasks, it was decided not to include a dynamic assessment in the current study due to the severity of the condition of some of the patients. The average disability of participants in the current study was higher than the group assessed by Mannion et al. (initial RDQ of 12.0 (SD 4.9) compared to 7.8 (SD 4.6) respectively) and included some patients with severe back pain who would have been unable or unwilling to perform dynamic tasks, particularly at the initial visit.

Limitations

There were some limitations to our study. Many of the patients were taking analgesics and some patients changed their medication use during the course of the study, possibly as a result of advice given within the rehabilitation programs, which may have affected the pain scores in particular. It was also not possible to control the spinal loading that occurred prior to the participants attending each testing session and this may therefore have varied between both participants and visits; however the impact of this may have been mitigated by the EMG preparation and baseline measurements which formed a standardised activity at the start of each session. Finally, the sample size for the follow-up session in particular was smaller than we would have wished, which limited the statistical power of the analysis. Nevertheless, the results still showed a number of interesting findings, including a highly significant increase in stature recovery over this six-month period. We recommend that these findings are confirmed with a larger sample size. It would additionally be interesting to see if patients with acute or sub-acute LBP demonstrate the same pattern of results as the CLBP population considered in the current study.

Conclusions

In conclusion, the increased rate of stature recovery by the six-month follow-up suggests that the delayed recovery seen in patients with CLBP is not primarily the result of disc degeneration. Furthermore, an immediate decrease in EMG levels following active treatment may not always be the optimal response for long-term improvements in clinical outcome and a period of adaptation might be expected.

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Captions to illustrations

Figure 1. Participant in position in the stadiometer