# EFFECTS OF REHABILITATION ON BACK MUSCLE CONTRACTION PATTERNS OF LOW BACK PAIN PATIENTS

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The aims of this study were to conduct a comparative investigation of muscle function between low back pain (LBP) patients and normal subjects, as well as to explore whether intensive rehabilitation can change back muscle contraction synergy. 20 normal subjects and 20 patients with chronic LBP were asked to perform symmetrical and asymmetrical tasks. LBP patients were tested in the weeks immediately before and after 12-week LBP rehabilitation treatment. Tasks include "carrying" weights up and down with a 45° left rotation. Eight channel surface EMG electrodes were placed on the surface of paraspinal muscles. correlation between right and left corresponding muscles as well as between pre- and post-treatment were calculated. Lifting capacity for LBP patients were also measured before and after treatment. EMG profiles showed that the muscle activity strategies varied between normal subjects and LBP patients. The correlation coefficients for spinal muscles have shown very reproducible intra-subject muscle contraction synergies. Unbalanced EMG patterns found in LBP patients under symmetrical tasks were not affected by rehabilitation treatment.

**KEY WORDS:** electromyography (EMG), low back pain (LBP), paraspinal muscles

**INTRODUCTION:** Low back pain (LBP) is a major health problem in both developed and developing countries. Various therapeutic interventions are available to LBP patients. Unfortunately, most of these applied interventions lack scientific evidence with respect to their effectiveness. Back exercises are among the most commonly prescribed procedure for LBP treatment (McGill, 1992). Management of LBP commonly includes treatment to restore paraspinal muscle function (Keller, Johansen, Hellesnes, & Brox, 1992). Recently, several studies have dealt with the role of muscles in LBP and attempted to understand the use of aggressive spine rehabilitation as a tool in reducing the likelihood of LBP. Various authors found unbalanced contractions in different parts of the body during exercise and/or under load (De Luca, Sabbahi, & Roy, 1986; Roy, De Luca, Emley, Oddsson, Buijs, Levins, Newcombe, & Jabre, 1997). However, few studies have documented whether aggressive rehabilitation treatments aid in modifying the contraction strategies of low back muscles. Moreover, it has not been verified whether these treatments affect the likelihood of recurrent post-treatment pain. The purposes of this study are to compare muscle contraction patterns between normal subjects and patients with chronic LBP syndromes, and to observe whether these contraction patterns alter following an intensive rehabilitation treatment. This study was intended to answer or partially answer whether there are any synergies associated with muscle contraction strategies and low back pain and moreover, whether current rehabilitation treatments can change these synergies.

**METHODS:** 20 normal male subjects (mean age = 38 $\pm$ 7.8 years, mean weight = 70.3 $\pm$ 9.2 kg, mean height = 1.70 $\pm$ 0.07 m) and 20 male LBP patients with a minimum of 6 months' work loss due to LBP (mean age = 39.90 $\pm$ 8.6 years, mean weight = 66.87 $\pm$ 20.07 kg, mean height = 1.67 $\pm$ 0.08 m) were used. Maximum voluntary contraction (MVC) of spinal muscles was measured prior to testing by asking subjects to produce maximum muscular contraction. A postural restraint apparatus was built in the laboratory to stabilise the pelvis and lower limbs of the subject during testing. This apparatus was designed to ensure that sustained, maximum isometric contractions of the back muscles were accurately monitored. Subjects performed MVC at voluntary rates and 3-5 minutes rest periods were allowed between contractions based on each subject's ability in order to eliminate the effect of fatigue. Two trials of MVC were performed and the average peak values of the two trials were recorded as MVC.

Subjects were then asked to slowly perform symmetrical and asymmetrical tasks. In order to minimise effect of muscle fatigue, back muscles were contracted under 30% MVC. Duration of the tasks was about 10 seconds, with 2-3 minute rest periods between trials. Because the study found that subjects with chronic LBP had weaker back muscles than the pain-free control group, patients determined resting time for themselves with a minimum of two minutes given. The symmetrical task (Figure 1a) consisted of lifting a 5kg-weight slowly up/down, while the asymmetrical task (Figure 1b) consisted of the same task with a 45° left rotation.

In this study, trunk muscle strength was evaluated by measuring peak lifting torques in different postures. A Lido Workset™ stimulator (West Sacramento, CA, USA) was used to measure isokinetic and isometric arm lift capacities at three different work levels that were determined according to the arthopometric dimensions of each patient. A standard testing protocol provided by the Lido Workset™ Stimulator was followed and a total of 4 sets of lifting capacities, namely knee level, waist level, shoulder level, isokinetic peak torque and peak isometric torque, were measured for analysis.

Eight channels of surface EMG electrodes (bipolar Ag-AgCL Disc electrodes, $\phi$=2cm) were applied to alcohol cleaned skin, with impedance always controlled at less than 10 k$\Omega$, on the muscles over the lumbar region including the trapezius(Channel 1 and 5), longissimus dorsi(Channel 2 and 6), erector spinae (Channel 3 and 7), and external oblique (Channel 4 and 8). The interelectrode distance was 3cm. The detailed methodology in the EMG recording has been ascertained in earlier studies (4,5). EMG signals were differentially amplified and pre-filtered using a band-width of 10 to 1000 Hz to produce signals of approximately $\pm$ 5 V. The raw EMG signals were analogue to digitized at a sampling rate of 1000 Hz using BTS EMG system (BTS Inc, Milan, Italy). Signals were then low-pass filtered at 4 Hz and full-wave rectified to produce a linear envelope EMG (LE-EMG), and further normalized to the corresponding MVC percentage.

In order to identify the relationship or interdependence of EMG profiles, the correlation coefficients for Linear Envelope (LE) of left side EMG (channels 1-4) corresponding to the right side EMG (channels 5-8) were calculated. The correlation coefficients of EMG profiles for pre and post treatments within the subject were also compared. Data processing was performed on Matlab for Windows. Comparison between the two groups (normal and LBP patients) was carried out using pooled Student's t-test. Paired Student's test was used to compare pre- and post-treatment values. A statistical significance of $p < 0.05$ was used.

20 chronic LBP patients were treated at a spinal centre. The treatment program is ongoing, intensive, in-patient rehabilitation that lasts for 12 weeks (5.5 days per week). The program is divided into 3 phases: physical conditioning (5 weeks), work conditioning (4 weeks) and work readiness (3 weeks). EMG testing and muscle assessment of the patient group was performed during the week before and after the 12-week treatment program, and data was collected under the same lab set-up on both occasions.

**RESULTS:** Balanced muscle EMG activities were found in most of the normal subjects during symmetrical tasks. The mean correlation values between the left and right side LE-EMG were from 0.8 to 0.84 (Table 1). Maximum EMG ranged from 7.5-25% MVC, suggesting that the load used (5 kg) in this study was within the light or medium weight level for all normal subjects. In comparison, the peak LE-EMG profiles showed significant differences between LBP patients (range from 24 to 41 % MVC). More than 50% of the patients showed unbalanced EMG activities between the left and right side spinal muscles, with the mean correlation coefficients from 0.5 to 0.6 (Table 1). Differences of correlation values between normal subjects and patients were statistically significant ($P < 0.01$).

Unbalanced EMG profiles after treatment were not modifiable and the mean correlation values were from 0.54 to 0.62 (Table 1). No significant differences were found in pre- and post-treatment ($p > 0.2$).

Over all view, the results from asymmetrical testing shown the large variations for both patients and normal subjects, therefore it was difficult to summarise significant information.

Examination of LE-EMG profiles for the asymmetrical tasks demonstrated that EMG patterns on the right side were noticeably higher than the left side.
Pre- and post-treatment EMG patterns for LBP patients were similar for both symmetric and asymmetric tasks. Higher correlation coefficients were found in symmetrical tasks (range from 0.58 to 0.93, Table 2), suggesting the muscle contraction patterns did not change after the intensive rehabilitation program for most patients. The correlation values between pre- and post-treatment reduced for asymmetrical tasks (Table 2).
Lifting capacity in LBP patients increased significantly after treatment (Table 3). Within 4 sets of lifting tasks, peak isometric torque increased by 24.3% for isometric lifting, followed by 11.1% for shoulder level lifting, 9.8% for waist level and 9.4% for knee level lifting, suggesting that the intensive rehabilitation treatment enhanced the strength of trunk muscles.

**DISCUSSION AND CONCLUSION:** Patients with LBP express high recurrent rate of pain after different rehabilitation treatment plans (Roy et al. 1997). Current treatment programs for LBP are therefore not proven to be effective in the long term. No study has managed to provide explanation for this finding. This study's main finding showed a significant increase in muscle strength after an intensive LBP rehabilitation program lasting for approximately 3-4 months, however, no change was found in back muscle contraction synergy. This observation is presumed to be a possible factor in the recurrence of LBP, but requires further verification.
Different synergies were found between normal subjects and LBP patients in this study. However, differentiation of whether this arises as a cause or an effect of LBP was not investigated, as this study was focused on the effects of rehabilitation on muscle contraction synergy. Previous muscle EMG and related modelling research has found muscle contraction patterns to be closely associated with loading of the lumbar spine (McGill, 1992). A recent study (Kiefer, Shirazi-Adl & Parnianpour, 1998) of a synergetic model aimed to further clarify this association and its under-lying mechanisms. It presented an *in vitro* outline of muscular activity that occurs during susceptible spinal stiffness and geometric configurations. Results from this modelling study suggest that a synergetic system in some form is present. Another recent study (Solomonow, Zhou, Harris, Lu, & Baratta, 1998) using electric mechanical stimulation reported that abnormal muscle contraction patterns can lead to spinal injury. Other biomechanical studies have also shown that inadequate muscle control, such as disorder, unbalance, or loss of control will cause excessive load sharing of the passive spinal system. This can cause abnormal motion and higher strains of highly innervated structures, potentially resulting in pain or discomfort (Merletti, De Luca & Sathyan, 1994). Therefore, it is assumed that muscular contraction patterns are a potential cause of LBP, although this requires further investigation. A long term prospective study would be required to thoroughly test this hypothesis.
In summary, muscle activity patterns varied between normal subjects and LBP patients. LE-EMG profiles and the correlation coefficients for spinal muscle contraction patterns have been shown to be highly reproducible, and intra-subject muscle contraction synergies were further demonstrated to be insensitive to an intensive rehabilitation program.

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**Table 1 Average Correlation Coefficient For LBP and Normal Subjects Performing Symmetrical Tasks**

| Channel | 1x5 | 2x6 | 3x7 | 4x8 |
|---|---|---|---|---|
| Patient-pre | 0.518 | 0.500 | 0.602 | 0.585 |
| SD | 0.252 | 0.217 | 0.239 | 0.231 |
| Patient-post | 0.536 | 0.547 | 0.618 | 0.602 |
| SD | 0.264 | 0.241 | 0.213 | 0.239 |
| Normal | 0.801 | 0.839 | 0.798 | 0.813 |
| SD | 0.116 | 0.127 | 0.130 | 0.143 |

Note**:** EMG electrode channels 1-4 were placed on the left side and channels 6-8 on the right side. The muscles include: trapezius(Channel 1 and 5), longissimus dorsi(Channel 2 and 6), erector spinae (Channel 3 and 7), and external oblique (Channel 4 and 8).

**Table 2 Average Pre- and Post-Treatment EMG Correlation Coefficients for LBP Patients in Both Symmetrical and Asymmetrical Tasks**

| Channel | Symmetrical | SD | Asymmetrical | SD |
|---|---|---|---|---|
| 1 | 0.86 | 0.043 | 0.44 | 0.043 |
| 2 | 0.65 | 0.065 | 0.76 | 0.17 |
| 3 | 0.78 | 0.25 | 0.64 | 0.32 |
| 4 | 0.93 | 0.15 | 0.48 | 0.32 |
| 5 | 0.58 | 0.065 | 0.59 | 0.032 |
| 6 | 0.64 | 0.095 | 0.80 | 0.098 |
| 7 | 0.89 | 0.16 | 0.57 | 0.056 |
| 8 | 0.71 | 0.23 | 0.37 | 0.17 |

**Table 3 Peak Torques (Nm) of LBP Patients During Isokinetic and Isometric Lifting**

| | Isokinetic (knee level) | Isokinetic (waist level) | Isokinetic (shoulder level) | Isometric lifting (waist level) |
|---|---|---|---|---|
| Pre-treatment (Mean $\pm$ SD) | 8.01 $\pm$ 3.34 | 6.62 $\pm$ 2.8 | 6.58 $\pm$ 2.60 | 7.79 $\pm$ 2.78 |
| Post-treatment (Mean $\pm$ SD) | 8.76 $\pm$ 3.06 | 7.33 $\pm$ 2.57 | 7.4 $\pm$ 2.71 | 10.4 $\pm$ 4.2 |
| % change | 9.4% | 9.8% | 11.1% | 24.3% |
| T - test | P = 0.07 | P = 0.19 | P = 0.04 | P = 0.001 |

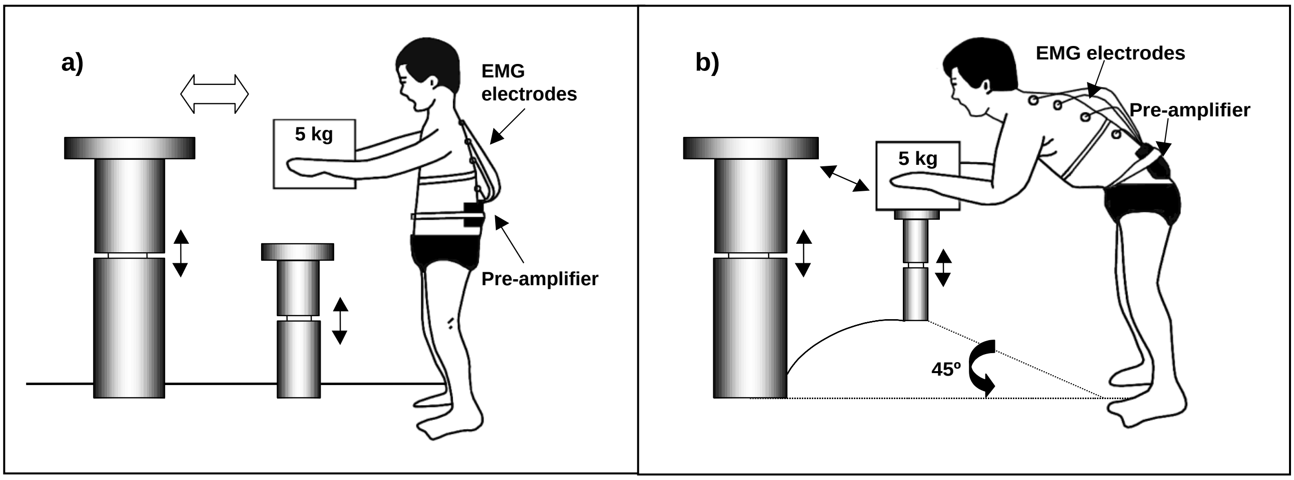


**Figure 1 - Schematic diagram of EMG testing. After performing maximum voluntary contractions, participants were asked to lift a weight (5Kg) from a low position (waist level) to a higher position (shoulder level) a) without rotation of trunk (symmetrical), or b) with a 45° rotation (asymmetrical).**