

Supplementation of general endurance exercise with stabilisation training versus general exercise only Physiological and functional outcomes of a randomised controlled trial of patients with recurrent low back pain

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Received 26 July 2004; accepted 30 December 2004

Abstract

Background. Determination of the mode of action of new exercise techniques in different back pain populations is lacking. The effectiveness of supplementing an exercise programme with stabilisation exercises concerning physiological and functional parameters in non-specific back pain patients is unknown.

Methods. Randomised controlled trial, comparing a general trunk muscle endurance exercise approach enhanced with specific muscle stabilisation exercises (S&G group) with a general exercise approach only (G group). 55 patients with recurrent back pain were randomised in S&G group ($n = 29$) and G group ($n = 26$). Both groups received an 8-week exercise intervention and written advice. Paraspinal muscle strength and electromyographic fatigue of the erector spinae and multifidus were measured. Additionally, 3 functional speed tests were assessed. Outcomes were collected pre- and post-intervention.

Findings. No differences were detected for any of the paraspinal fatigue characteristics either within or between groups, apart from a significant decrease in normalised median frequency slope of the erector spinae for the G group. Paraspinal muscle strength and all functional tests have demonstrated significant within-group improvements for both groups, without any between-group differences.

Interpretation. An 8-week stabilisation exercise-enhanced approach presented equal benefits to a general endurance-based exercise programme for patients with recurrent non-specific back pain. A slightly steeper slope for the erector spinae in the G group was the only electromyographic fatigue alteration noted. Concomitant strength improvement probably reflects neural input changes rather than histochemical muscle changes. Physical exercise alone and not the exercise type was the key determinant for improvement in this patient group.

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Keywords: Rehabilitation; Muscle fatigue; Electromyography; Erector spinae; Function

1. Introduction

The low back pain (LBP) epidemic is responsible for a great number of reported disability days (Maniadakis and Gray, 2000). A better understanding regarding the extent of physiological and functional effects of more modern exercise techniques used in LBP rehabilitation,

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like stabilisation exercise training, is currently considered an important area of research (Chartered Society of Physiotherapy, 1999; American Physical Therapy Association, 2000).

Classic trunk exercises performed in physiotherapy, activate the abdominal and paraspinal muscles as a whole and at a relatively high contraction level (Arokoski et al., 1999). Although there are several randomised controlled trials on the usefulness of classic trunk exercises (Kellelt et al., 1991; Hansen et al., 1993; Risch et al., 1993), recently, increasing attention has been paid to the preferential re-training of the local stabilising muscles of the spine (Hides et al., 1996; O'Sullivan et al., 1997; Hides et al., 2001; Danneels et al., 2001). Biomechanical models suggest that all the muscles with intervertebral attachments are better suited for intersegmental stability provision and are categorised under this group (multifidus, transversus abdominis, internal oblique), as opposed to the longer trunk muscles (erector spinae, rectus abdominis), which are dedicated to movement generation (Bergmark, 1989). Inadequate activation of the local stabilising trunk muscles may lead to instability of the lumbar spine (Panjabi, 1992) and some clinical research has demonstrated that re-training those muscles leads to a decrease in short and long term LBP symptoms in some special populations with apparent instability pre-disposition (Hides et al., 1996; O'Sullivan et al., 1997; Hides et al., 2001). What remains currently unknown is whether stabilisation exercises can be generally applied to any patient with LBP.

There seems to be a lack of knowledge concerning stabilising exercises evaluated with electromyographic (EMG) muscle fatigue. Muscle fatigue functional assessment with EMG, is an approach that presents the main advantages of overcoming the motivational problems of prolonged contractions that classic endurance assessment methods require, as well as the ability to concurrently monitor the fatigue patterns of different muscles during a sunergistic contraction (Roy and Oddsson, 1998). Endurance measurement is particularly relevant for the paraspinal muscles, which have an anti-gravity role (Mannion, 1999) and subsequently sufficient endurance of the low back musculature should offer the necessary stability to the spine over strenuous and prolonged physical tasks. The median frequency (MF) shift of the EMG power spectrum towards lower values is considered a valid descriptor of fatigue time-dependent muscle changes, representing mainly the decrease in motor unit conduction velocity associated with fatigue (Roy and Oddsson, 1998). Previous studies have demonstrated that the EMG fatigue assessment method is able to monitor significant improvements in fatigue characteristics (i.e. less steep MF slopes) following exercise (Kankaanpää et al., 1999; Roy et al., 1995), although alternative findings have also been reported (Mannion et al., 2001; Capodaglio et al., 1995).

Paraspinal muscle strength performance is a variable often included in trunk function assessment batteries (Newton and Waddell, 1993). According to some authors trunk strength itself is considered less important than motor control-related parameters for the treatment outcome of patients with LBP (Richardson et al., 1999a), as strength performance is influenced by both physiological muscle state (Rissanen et al., 1995; Sale, 1988) and psychological factors (Al-Obaidi et al., 2000; Lackner and Carosella, 1999).

In contrast, limitation in the performance of functional daily activities is currently considered as the principal outcome measure for back pain (Deyo et al., 1998; Simmonds et al., 1998), particularly for clinically-based assessments. As discrepancies between patients' self-reported disability and actual physical performance have been previously identified, assessing functional activities that are fundamental to day-to-day practice and that are compromised by LBP is deemed as more objective and direct (Simmonds et al., 1998).

The aim of this study was to investigate whether spinal stabilisation exercises are a useful supplement to general trunk exercises in patients with simple recurrent non-specific LBP. Our experimental hypothesis was that a general exercise programme combined with specific trunk muscle stabilisation exercise techniques would be more beneficial than a programme including only general exercise, for a range of physiological and functional outcomes.

2. Methods

2.1. Design

A randomised controlled trial (RCT) was performed with patients being allocated to one of two treatment groups: general exercise combined with specific trunk muscle stabilisation exercise techniques or general exercise only.

The research physiotherapist in charge of the study who performed the outcome assessments of participants and data analyses was blind to group allocation throughout. However, the clinical physiotherapist administering the exercise programmes could not be blinded. Patients were not aware of the theoretical underpinnings of each of the exercise regimes, as the study's objective was described to them as "to identify any differential effect between two exercise regimes for the trunk muscles, which have a role in protecting the spine from further injury".

2.2. Participants

Patients were recruited from the orthopaedic clinic of one local hospital and several General Practitioners'

clinics. Ethical permission for the study was granted by the Central Manchester ethical committee and patients gave informed consent to take part, in accordance with the 1964 Declaration of Helsinki. Participants were eligible for the study if they had a history of recurrent LBP (repeated pain episodes in past year collectively lasting for less than 6 months) (Von Korff, 1994) of non-specific nature, defined as back pain complaints occurring without identifiable specific anatomical or neurophysiological causative factors (Evans and Richards, 1996). All patients included in the trial had a prior thorough clinical examination by their doctor, including an X-ray or an MRI. Patients with previous spinal surgery, red flags i.e. serious spinal pathology or nerve root pain signs (Evans and Richards, 1996), and patients with instability signs and symptoms (O'Sullivan, 2000) were excluded. Patients were recruited to the trial at the sub-acute or chronic stage (onset of their current episode >6 weeks) (Evans and Richards, 1996) if their symptoms persisted. The anthropometric and LBP history data of patients that took part in the RCT are presented in Table 1. Patients had to be medically fit (no heart problems, pregnancy or inflammatory arthritis) and willing to participate in the exercise program and able to travel independently to the hospital. All patients were employed at the time of study and not involved in any current compensation or litigation procedures.

2.3. Procedure

2.3.1. Enrollment/data collection

All participants were interviewed and examined by a blinded physiotherapist to ensure that all set inclusion-exclusion criteria were fulfilled. Suitable patients were asked to complete a number of questionnaires (Koumantakis et al., 2005) and to attend for comprehensive physiological and functional testing. Follow-up assessments were conducted immediately post-treatment (8 weeks) on all parameters described herein.

2.3.2. Randomisation

Following completion of all pre-intervention assessments, participants were randomly assigned to one of the two treatment groups via a computer-generated random number sequence. Randomisation codes were kept in sealed envelopes with consecutive numbering. Participants were sequentially enrolled at the end of their second assessment visit.

2.3.3. Intervention

Common components of the two programmes included a warm up period for 15 min in total (stretching exercises, static bike). For the *specific* stabilisation exercise administration and the progressive integration with general exercises (S&G group) a staged approach was followed, according to previous recommendations (Richardson et al., 1999b). The first session was performed on an individual basis for patients randomised to this group and lasted 30–45 min. On this session, patients were given individual leaflets to take home, illustrating the anatomy of the local stabilising muscles, with written clear instructions on how to preferentially activate these muscles. Briefly, low-load activation of the local stabilising muscles was initially administered, with no movement (isometrically) and in minimal loading positions (4-point kneeling, supine lying, sitting, standing). Progressively, the holding-time and then the number of repetitions were increased in those positions up to 10 repetitions \times 10-s duration contractions (weeks 1 and 2) (Richardson et al., 1999b). Various facilitation techniques were used throughout the programme to draw patients' attention to the specific nature of the desired muscle contractions (Richardson et al., 1999b). Patients were shown and told to avoid several incorrect muscle activation ("substitution") strategies, where a movement muscle takes over the control of movement from the stabilising muscles. Integration with dynamic function through incorporation of the stabilising muscles co-contraction into light functional tasks was advised as soon as the specific pattern of co-activation

Table 1
Between-groups baseline comparisons of participants' characteristics with independent samples *t*-tests

	Specific and general (<i>n</i> = 29)		General only (<i>n</i> = 26)		<i>P</i>
<i>Anthropometry</i>					
Age (years) ^a	39.2	11.4	35.2	9.7	0.16
Height (cm) ^a	170.1	7.5	174.4	9.1	0.06
Body mass (kg) ^a	75.9	12.8	80.5	12.0	0.18
BMI (kg/m ²) ^a	26.2	4.2	26.4	3.2	0.87
Gender (female/male) ^b	19/10		10/16		0.045
<i>LBP history</i>					
Time since 1st onset (months)	57.1	48.1	44.2	51.6	0.34
Current duration (weeks) ^c	12.0	7.3–22.0	12.0	8.0–12.0	0.78

^a Values are mean (SD).

^b Nominal data; analysed with chi-square test.

^c Median-IQRs data; analyzed with Mann-Whitney U test.

was achieved in the minimally loading positions and 10 repetitions \times 10-s guideline could be comfortably performed by the patients (weeks 3–5). Heavier load functional tasks, with similar exercises to the ones performed by the general exercise group, were progressively introduced in the three last weeks of the programme (Richardson et al., 1999b).

For the *general* exercise only group (G group), simple classic exercises activating the extensor (paraspinals) and flexor (abdominals) muscle groups were administered. As muscle contraction occurring with exercise imposes extra loading to the spinal tissues, the general exercises were selected on the basis of maximising the contraction benefit/spinal loading ratio, according to recommendations provided from experimental studies (McGill, 1998). Details of both programmes are presented elsewhere (Koumantakis et al., 2005).

The same frequency (twice/week) and programme duration (8 weeks) were provided for both groups. A previous study has shown that patients with sub-acute and chronic LBP activate their paraspinal muscles at about 30% of their maximum activation level during the performance of stabilisation exercises and at about 60–70% during the performance of strength exercises (trunk and leg extensions from prone) (Danneels et al., 2002). Based on this literature, we set the pure total trunk and abdominal muscle exercise time for the G group (99 min, 10 s) to about half of that in the S&G group (180 min, 40 s). This approach was followed in order to balance the groups with respect to the amount of estimated total force output of the trunk muscles targeted by the exercises.

A clinical physiotherapist very familiar with the exercise interventions demonstrated, monitored and progressed the exercises on *every* session. Progressions were made by the clinical physiotherapist, based on correct performance of the previous exercise stage. Eight different exercise levels of progressively increasing difficulty were provided for both groups, participants were able to progress each week to a new level, based on their performance, allowing individualisation of progress. Patients exercised in groups of 5–10 participants and were additionally asked to repeat the exercises at home, for a maximum of half an hour 3 times per week, from the beginning of the programme. The clinical physiotherapist monitored *class compliance* and participants were required to keep an exercise diary monitoring *home compliance*. The number of sessions in class environment and at home was recorded.

2.3.4. Participant education

All patients received an information booklet (“The Back Book”) (Roland et al., 1997) at the beginning of the programme. The main aim of this booklet is to change patient beliefs and behavior about back pain (Burton et al., 1999).

2.4. Measurement

Self-report outcomes for this RCT have been reported elsewhere (Koumantakis et al., 2005) and this paper specifically deals with changes in the following physiological and functional performance domains.

2.4.1. Paraspinal muscle strength and fatigue

Tests were performed according to a well-described, reliable method, details of which were previously reported (Koumantakis et al., 2001). Briefly, a custom-made isomyometer was used and testing was performed in a standing position, with appropriate stabilisation of the lower limbs and pelvis. Force was registered on a load cell (250 kg, Teda Huntleigh, Cardiff, UK), positioned directly in front of participants’ chest. An inextensible strap made of nylon linked the load cell to the participants’ back around the 6–7th thoracic (T6–7) level. Paraspinal muscle maximum voluntary isometric contraction (MVIC) was determined as the highest of three or more MVIC attempts, until the efforts were within 5–10% of each other.

The muscle fatigue test required a 60-s isometric contraction of the paraspinals at 60% MVIC. A four-channel EMG recorder (MP100 WSW, BIOPAC Systems Inc, Santa Barbara, CA, USA) was used to collect myoelectric signals from 2 different back muscle groups bilaterally, the erector spinae (L2/3) and multifidus (L4/5). Those muscles are considered to have different roles in back muscle function and there was the possibility to be influenced differently by the exercise programmes. EMG recording and analysis details are provided elsewhere (Koumantakis et al., 2001). The EMG signal was on-line analysed by a graphical programming analysis system (LabVIEW 5.0TM, National Instruments, TX, USA), to continuously derive the median frequency (MF) of the power density spectrum (the frequency that divides the spectrum in two equal halves) every second, using a Fast Fourier Transform (FFT) algorithm. Data epochs were normalised against their respective initial values (average of the first 2 data points) and a linear regression line was fitted through the MF 60-s history, to obtain measures of the normalised rate of MF decrease (nMF).

2.4.2. Activity-based functional assessment

Three tests with previously demonstrated very good reliability and validity (Simmonds et al., 1998) were used.

Repeated trunk flexion (fast walking): Participants were required to flex at the limit of their range and, as fast as tolerated, return to upright standing 10 times.

Repeated sit-to-stand (fast sit/stand): Participants were required to rise to a standing position and return to a sitting position as fast as possible 5 times.

Fifty-foot walk (fast walking): Participants were required to walk along a 25-foot walkway, turn around and walk back to the starting line as fast as possible.

Participants had to perform each test twice, with 1-min rest period in between. The total time taken to perform each of the procedures was timed with a digital stopwatch and the average time of 2 repeats was the resulting score.

2.5. Sample-size estimation

For the trial to have sufficient power (80%) to detect between-group differences in the MF slope, data from a previous study (Kankaanpää et al., 1999) on the pooled (R/L side) L4/5 level MF slope data were used (7.6%/min difference in slope in an active exercise group versus 1%/min difference in slope in the control group). A 7.6%/min decrease in the slope represented a 35.3% decrease from its initial slope value (−21.5%/min) (Kankaanpää et al., 1999). Sample size estimation was performed with the nQuery Advisor version 3.0 software (Statistical Solutions, Saugus, MA, USA). Using a two-group *t*-test ($\alpha = 0.05$), 26 participants per group were required to detect significant between-group differences. The study we based our power calculations on, satisfied the criterion of the smallest detectable difference (SDD, a diagnostic tests index indicating the level of per cent change in a parameter attributed with 95% certainty to a true change in the condition of a subject instead of being caused by test-retest errors), which in a previous study with healthy participants was found to be up to 33–34% (Koumantakis et al., 2001).

2.6. Statistical analysis

Data were normally distributed (Kolmogorov–Smirnov test), and therefore analysed with parametric statistics (*t*-tests). Raw data are presented in Table 2. Independent *t*-tests were made between groups pre-treatment. Dependent *t*-tests (within-group) were performed pre–post-treatment. Using the individual differences pre–post-treatment the between-group mean difference and 95% confidence intervals were calculated for each variable, and were analysed with independent *t*-tests. To compare the magnitude of the interventions-induced changes between the groups, the effect size (ES) was calculated for variables that were significantly different within groups, as follows: $ES = (\text{mean post-treatment value} - \text{mean pre-treatment value}) / SD$ of mean pre-treatment value. An ES of 0.8 and above is considered large, around 0.5 moderate and around or less 0.2 small (Thomas and Nelson, 1990). Home compliance data were negatively skewed ($P = 0.02$), thus were analysed with non-parametric statistics (Mann–Whitney *U* test). The level of significance was set at $\alpha = 0.05$. All analyses were performed primarily according to the

“intention-to-treat” (ITT) principle, with all randomised patients analysed in their assigned groups (Friedman et al., 1998; Lewis and Machin, 1993). However, as suggested for cases that withdrawals are inevitable both a per protocol (using data from only patients who provided follow-ups, $n = 45$) and an ITT analysis were performed; if both analyses concur, the result can be accepted with more confidence (Friedman et al., 1998). Statistical analyses were performed using the SPSS software version 9.0.

3. Results

Out of 126 referrals to the trial, 67 participants fulfilled the set criteria for inclusion. 12 of those were not randomised although initially assessed, as they later decided they could not participate. From the 55 randomised patients, 10 dropped out of the treatment ($n = 5$ per group), most of them due to time constraints and 2 patients in the S&G group due to pain increase during the exercise programme. No between-groups significant differences could be detected in the pre-treatment data, apart from gender distribution ($P = 0.045$, Table 1) and nMF slope-L4/5 data ($P = 0.04$, Table 2). The number of class sessions attended was similar for both groups (mean 12.2 (SD 2.7) for S&G group and mean 11.3 (SD 2.7) for G group, $P = 0.28$). Again, there were no significant between-group differences for the number of home sessions (median 23.5 (IQR 20.0–24.0) for S&G group and median 22.0 (IQR 15.0–24.0) for G group, $P = 0.57$).

3.1. Main analysis—changes with exercise

Results were the same with both the ITT and the per protocol analyses, therefore only those of ITT analyses are presented (Table 2). For the fatigue parameters (IMF and nMF slopes) no differences could be detected either within or between the two exercise approaches (Table 2). Only a slight statistically significant change could be detected for the nMF slope-L2/3, becoming steeper at the end of the exercise programme (−4.3%/min, $P = 0.04$) for the G group, however the effect size for this change, $ES = -4.3/14.1 = 0.30$, therefore rather small. For the nMF slope-L2/3 data in the G group, 3 patients' data exceeded a previously reported SDD value for this muscle site (13.66%/min) (Koumantakis et al., 2001) and 5 more patients' data demonstrated a change close to the SDD, between −10.2 and up to −12.7%/min. Therefore, only 8 patients out of 26, representing 30.7% of the general group demonstrated change values of over or very close to a clinically important change in this parameter.

In contradistinction, as can be seen from Table 2, muscle strength and all functional tests have indicated

Table 2
Scores by group over time and within/between group analysis

	Pre-treatment				Eight weeks				Within-group differences				Between-group mean difference ^a	95% CI
	S&G group (n = 29)		G group (n = 26)		S&G group (n = 29)		G group (n = 26)		S&G group (n = 29)		G group (n = 26)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
<i>Paraspinal muscle fatigue</i>														
IMF-L2/3 (Hz)	61.1	13.9	65.5	12.5	64.6	13.8	67.4	12.1	3.5	9.1	2.0	9.0	1.59	−3.42 to 6.60
IMF-L4/5 (Hz)	79.3	20.4	87.2	21.2	78.8	16.1	88.1	17.0	−0.4	14.8	0.9	18.1	−1.33	−10.4 to 7.73
nMF _{slope-L2/3} (%/min)	−8.4	13.9	−9.6	14.1	−9.7	16.1	−13.9	10.3	−1.4	11.1	−4.3 ^b	9.8	2.92	−2.89 to 8.72
nMF _{slope-L4/5} (%/min)	−12.1 ^c	10.4	−18.3 ^c	11.9	−11.8	13.0	−19.8	11.8	0.3	6.9	−1.5	11.9	1.86	−3.43 to 7.15
<i>Paraspinal muscle strength</i>														
MVIC (kg)	56.7	18.5	65.7	32.4	67.0	15.0	78.1	21.8	10.3 ^b	10.7	12.4 ^b	26.3	2.1	12.7 to −8.5
<i>Functional speed tests</i>														
Fast bending (s)	24.9	10.2	24.2	7.5	19.6	6.1	20.5	6.3	−5.4 ^b	7.8	−3.7 ^b	4.3	1.64	−1.81 to 5.10
Fast sit/stand (s)	12.6	4.1	12.9	3.4	10.6	2.7	10.8	3.3	−2.1 ^b	3.1	−2.2 ^b	2.4	0.13	−1.40 to 1.60
Fast walking (s)	12.4	2.0	12.3	1.8	11.9	1.74	11.7	2.0	−0.5 ^b	1.3	−0.5 ^b	0.9	0.02	−0.60 to 1.60

Hz: Hertz, kg: kilograms, min: minute, s: seconds.

^a Non-significant between-group differences analysed with independent *t*-test.

^b Significant within-group differences analysed with dependent *t*-test.

^c Independent samples *t*-test showed no differences at baseline among the 2 groups for all outcome measures ($P > 0.05$) apart from nMF_{slope-L4/5} ($P = 0.04$).

statistically significant within-group improvements for both groups ($P < 0.01$), but again no between-group differences could be demonstrated. For those parameters the improvement was of similar magnitude, shown by the small between-group mean differences and their 95% confidence intervals (Table 2). The within-group effect sizes were for strength low to moderate, $ES = 0.56$ (S&G group) and $ES = 0.38$ (G group). For the fast bending test moderate, $ES = 0.53$ (S&G group) and $ES = 0.49$ (G group). For the fast sit/stand test moderate also, $ES = 0.51$ (S&G group) and $ES = 0.65$ (G group). For the fast walking test, however, they were small, $ES = 0.25$ (S&G group) and $ES = 0.28$ (G group).

4. Discussion

In the field of rehabilitation nowadays there are many treatment options for LBP, with exercise being one of the key determinants of improvement for many LBP sufferers (van Tulder et al., 2000). However, it has not been definitively proven whether physiological or other factors mediate this improvement and it is a question that requires to be researched thoroughly (Chartered Society of Physiotherapy, 1999; American Physical Therapy Association, 2000). In a previous report we demonstrated the short-term superiority of general exercise only following an 8-week exercise period for self-reported disability (Koumantakis et al., 2005), however, this patient-perceived improvement was not reflected in the physiological and functional measures of this study. A small effect size was only demonstrated for the G group fatigue slopes at L2/3, with the particular slopes indicating an increased fatigue rate at the end of the programme. Such a change to the 'opposite' than expected direction has been previously reported (Capodaglio et al., 1995; Mannion et al., 2001) and could possibly signify the beginning of an enhancement in the activation of the erector spinae, therefore them becoming more susceptible to fatigue. In general, all other physiological and functional measures utilised in this study suggested that for recurrent non-specific LBP patients there was no additional benefit to be gained by supplementing a general trunk muscle endurance exercise programme with stabilisation exercises. These findings are in agreement with previous studies examining the differential physiological effect between other exercise programmes for LBP (Danneels et al., 2001; Käser et al., 2001; Hansen et al., 1993).

Physiological adaptations in muscles induced with training can range from neural adaptations to muscle hypertrophy and fibre type conversions (Jones and Round, 1990). Factors influencing the extent of these adaptations are the intensity, the frequency, the length and also the mode (eccentric/concentric/isometric) of training (Jones and Round, 1990; Walker et al., 1998).

The design of this study was such to reflect current physiotherapy practice. Thus, specific exercises were initially isometric and more selective, to ensure sufficient activation of the deep trunk muscles, and once this was achieved contraction of the stabilising muscles was integrated with more functional exercises and daily activities. The level of the exercises adopted was between 30–60% of MVIC for the paraspinals, to influence their endurance characteristics. The dose of the studied intervention was deemed appropriate to demonstrate some benefit, as a few other studies have managed to demonstrate some moderate improvements in the EMG fatigue characteristics of the paraspinals with exercise programmes lasting between 1–3 months (Kankaanpää et al., 1999; Roy et al., 1995). However, the levels of mechanical stimulus for hypertrophy of the paraspinals (mainly of the type II fibres) and the time required for such physiological adaptations to occur may need to be higher than 60% of an MVC and longer than 2 months (Danneels et al., 2001; Käser et al., 2001; Rissanen et al., 1995). The change in slope demonstrated in this study might then have become larger and also expanded to all muscle sites measured.

Strength increases on the other hand have been more readily observed in several exercise studies (Mannion et al., 2001; Risch et al., 1993; Roy et al., 1995), that have used a range of submaximal to maximal training intensity programmes. A more likely explanation of the strength increases noted in both groups of this study, considering also the minimal change in the fatigue slopes, would be that during the 8-week exercise regimen mostly neural drive adaptations occurred. These are more prominent at the beginning of any training regimen (related to training specificity and skill acquisition) and have a positive effect on strength performance (Sale, 1988). The increase in strength performance may also be related to the decrease in pain perception and the psychological improvement the patients experienced during the programme (Koumantakis et al., 2005), as such improvements have been related to a positive strength performance before (Mannion et al., 2001; Risch et al., 1993).

With regard to the functional speed tests the improvements observed might indicate either pure physical ability enhancement or more likely these may be related to the documented improvements in the psychological domain of the patients, as previously demonstrated (Novy et al., 2002). Increasing the functional performance of patients with LBP is a desirable and tangible outcome to researchers but most importantly to patients. Of the three tests employed, fast walking demonstrated the lowest ES, registering mean improvements of about 0.5 s for both groups. Possible ceiling effects in a moderately disabled population with no major limitations in walking speed could have accounted for these findings.

The results of our study cannot confirm that specific stabilising exercises selectively enhance multifidus

activation, at least not within the first 2 months of training. From a clinical viewpoint, general exercise, if performed under a sound theoretical rationale as described in this study, it may be sufficient to activate the stabilising system *in parallel* with the mobilising muscles. Although some studies have demonstrated this hypothesis in healthy participants (Cholewicki and Van Vliet IV, 2002; Arokoski et al., 1999; Ng and Richardson, 1994; Richardson et al., 1990) and also in patient populations (Danneels et al., 2001; Flicker et al., 1993), this still remains a matter for debate. It may be that the therapeutic exercises used in our study that were not performed at a very high MVIC level (up to 60% MVIC) did not favor global muscle compensation strategies. It is also possible that specific muscle stabilisation re-training is only relevant to populations with “instability” symptoms. At the moment these cases comprise an unknown sub-group of non-specific LBP patients, as firm diagnostic criteria of instability have not yet been established (Nachemson, 1985; O’Sullivan, 2000).

5. Conclusions

From our study there is no indication that emphasis on specific re-training of the deep trunk muscles in conjunction with general endurance exercise is of any more benefit than general endurance exercise alone for non-specific LBP patients. It is possible that effective rehabilitation outcomes can also be promoted with general exercises, for patients with non-specific recurrent LBP, activating both the stabilising and mobilising muscles. The positive effects of active exercise seem to be independent of the method of delivery for this patient group, as long as these exercises are carefully selected not to cause aggravation of symptoms.

Acknowledgments

We are grateful for the financial support primarily received by the Greek State Scholarships Foundation (IKY), Athens, Greece (grant T104830098) and a supplementary grant (99/2) from the Hospital Saving Association (HSA), London, UK. Special thanks also to Mr Andre Kocialkowski FRCS (Orths) for his support to the trial and to Mrs Fiona Randall PT, MCSP for treating the study participants.

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