Effect of slump stretching versus lumbar mobilization with exercise in subjects with non-radicular low back pain: a randomized clinical trial

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Previous case reports, case series, and pilot studies have suggested that slump stretching may enhance the effects of spinal mobilization and stabilization exercises in patients with non-radicular low back pain (NRLBP). The purpose of this trial was to determine if slump stretching results in improvements in pain, disability, and fear and avoidance beliefs in patients with NRLBP with neural mechanosensitivity. Sixty patients, 18–60 years of age presenting with NRLBP with symptom duration >3 months, were randomized into one of two, 3-week physical therapy programs. Group one received lumbar spinal mobilization with stabilization exercises while group two received slump stretching in addition to lumbar spinal mobilization with exercise. Outcomes including the modified Oswestry disability index (ODI), numeric pain rating scale (NPRS), and the fear-avoidance belief questionnaire (FABQ) were collected at baseline, and at weeks 1, 2, 3, and 6. A doubly multivariate analysis of variance revealed a significant group-time interaction for ODI, NPRS, and FABQ. There were large within-group changes for all outcomes with $P < 0.01$ and large between-group differences at weeks 3 and 6 for the ODI and weeks 1, 2, 3, and 6 for the NPRS and FABQ at $P < 0.01$. A linear mixed-effect model comparing the composite slopes of the improvement lines revealed significant differences favoring the slump stretching group at $P < 0.01$. The findings of the present study further support the use of slump stretching with spinal mobilization and stabilization exercises when treating NRLBP.

Keywords: Low back pain, Neurodynamics, Slump test, Slump stretching

Introduction

Physical therapists commonly examine and treat patients with low back pain (LBP) since the condition is experienced by at least 80% of adults and is associated with substantial socioeconomic and health care costs.¹ Lumbar conditions are separated into non-radicular and radicular conditions with the former being defined as pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds in the lumbosacral region; without leg pain (sciatica).² Non-radicular symptoms lack nerve root involvement and imply a less severe condition even though the symptoms themselves may be substantial. The clinical diagnosis of non-radicular low back pain (NRLBP) is made by ruling out hard neurological involvement.²

The straight leg raise (SLR) and the slump tests are common examination techniques for a neurologic

screen. Both tests have been found to be sensitive but neither is specific enough to rule in nerve root involvement.^{3,4} A positive test cannot be relied on to determine that a radiculopathy exists yet it would seem that the neurologic system is somehow compromised in this circumstance. This reasoning may have led both Cyriax and Maitland to suggest that neurodynamic tests are useful in the differentiation between neural and non-neural structures.^{5,6}

In recent years, neurodynamic test procedures have been used as interventions to potentially resolve abnormal physiology within the nervous system. The full spectrum of clinical presentations likely to respond may not have been fully identified at this time; however, one category of patients has shown promise. Patients with LBP and lower extremity pain that do not respond to directionally specific trunk exercises and who do not present with radiculopathy have responded to slump stretching as an intervention.^{7,8} However, limited evidence exists to support the

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effectiveness of using the slump test as a treatment approach and has only been presented in the form of case reports, case series, or a small sample clinical pilot study.^{7–11}

George, in a case series, used the slump stretch as the only treatment which showed promise for six subjects. Cleland *et al.* found that the combination of lumbar mobilization, stabilization exercises, and slump stretching produced more effective targeted approach for the treatment of NRLBP.⁷ Therefore, in an effort to provide a more comprehensive treatment program, the purpose of this study was to examine slump stretching coupled with lumbar spine mobilization and stabilization exercises compared to lumbar spine mobilization and stabilization exercises alone.

Methods

A single blinded, randomized controlled trial was conducted between September 2009 and June 2010 in an outpatient clinic in Durg, India. Subjects were referred by their health care providers as well as recruited via advertisements in local newspapers and health magazines. The study sample consisted of individuals between 18 and 60 years of age, with acute NRLBP that referred distal to the buttocks with reproduction of their symptoms during slump testing. Subjects were excluded if their symptoms were consistent with spinal infection, neoplasm, osteoporosis, spinal fracture, demonstrated positive neurologic signs or symptoms suggestive of nerve root involvement (diminished lower extremity reflexes, sensation to sharp and dull, or strength), or signs of upper motor neuron involvement. In addition, subjects were excluded if they were pregnant, had a history of spinal surgery, or a positive SLR test of $<45^\circ$ as previously described in the literature.⁷ The study was approved by the ethical committee at Apollo Physiotherapy College (Durg, India). All subjects provided informed consent and their rights were protected.

Before randomization, subjects completed several self-report outcome measures. The 11-point numeric pain rating scale (NPRS) with 0 representing 'no pain' and 10 representing 'worst pain' was used to measure the intensity of their current pain. The NPRS is a reliable and valid outcome measure and has been used extensively in LBP research.¹² Stratford and Spadoni¹³ found the intraclass correlation coefficient (ICC) for internal consistency ranged between 0.64 and 0.86 for many diagnoses including LBP.

The participant's perceived disability was assessed by using modified Oswestry disability questionnaire (ODI). The ODI is a valid and reliable measure of disability in individuals with LBP with ICCs of 0.90

and a standard error of measurement of 5.40.¹⁴ The ODI features 10 items scored from 0 to 5. The sum total score of all 10 items is doubled and represented as a percentage from 0–100, with a higher total score indicating greater disability.¹⁴

The patient's fear of pain and beliefs about avoiding activity was assessed by the fear-avoidance belief questionnaire (FABQ). This measure was collected to assess the potential confounding effects of fear-avoidance beliefs on pain and disability outcomes. The FABQ is a self-report instrument that uses a 7-point Likert scale (0=completely disagree; 6=completely agree) to examine 16 items. A higher score indicates more strongly held fear-avoidance belief.¹⁵ The FABQ is a reliable outcome measure to assess the fear of patient with LBP with an ICC range of 0.72–0.91.¹⁶

Following completion of the self-report measures, subjects underwent a baseline clinical examination which included screening tests intended on ruling out causes of LBP that would have excluded the individual from the study. All recordings were taken by an independent observer with the principle investigator blinded to the examination findings. After the baseline examination was completed, the examining therapist left the room and a second, blinded therapist entered. A sealed, opaque envelope was then opened indicating the treatment group to which the subjects were randomized. A computer-generated randomized block of numbers obtained before the study was used to determine group assignment. Subjects were randomized to receive lumbar spine mobilization and exercises, group 1, or slump stretching coupled with the lumbar spine mobilization and exercises, group 2. The outcome measures of NPRS, ODI, and FABQ were captured at baseline, 1, 2, 3, and 6 weeks.

Group 1: the lumbar spine mobilization and stabilization exercises

Group 1 began each treatment session with a 5-minute stationary bicycle warm-up. Each subject then received approximately 10 minutes of lumbar spine mobilization to the hypomobile segments identified during the initial examination. Each subject was positioned in prone with a small pillow placed under the abdomen to enhance their comfort. A graded posterior-anterior mobilization⁶ was provided to the most provocative vertebral segment for three bouts of 40-second oscillations. All other hypomobile lumbar segments were mobilized for two bouts of 40-second oscillations. The grade of each mobilization performed was based on clinical reasoning from a patient response model and involved either grade III or IV movements that stopped short of significant symptom production.

Figure 1 Slump stretch technique.

Following mobilization, the subjects performed lumbar stabilization exercise. Each subject performed two sets of 10 repetitions of wall squats, bridges, pelvic tilts, and quadruped arm and leg lifts as described by Childs *et al.*¹⁷ This exercise program was progressed by the physical therapist according to symptom response.

Group 2: slump stretching coupled with lumbar spine mobilization and stabilization exercises

Group 2 completed the same intervention program as group 1 described above including a warm-up, lumbar mobilization and stabilization exercises. In addition, group 2 received slump stretching exercises provided by the physical therapist. The subject was positioned in long sitting, feet against a wall to maintain neutral dorsiflexion angle, trunk flexed to enhance dural elongation, while the therapist applied cervical overpressure to ensure a consistent pressure just at the onset of symptom provocation. Five repetitions of 30-second holds were performed as in Fig. 1.

Patients in group 2 were given a home exercise program of self-slump stretching. This exercise was similar to the clinic-based intervention but involved active neck flexion with overpressure from their hands until the onset of symptoms (Fig. 2). This position was maintained for 30 seconds and was performed twice. For both groups, treatment was provided twice weekly for 3 weeks resulting in six total treatment sessions.

Data analysis

Baseline characteristics including means and standard deviations (SDs) were described with continuous variables being analyzed using independent *t*-tests and categorical variables being analyzed with chi-square. A linear mixed-effect (LME) model was used to fit linear regression lines to each subject of both groups for each outcome with the slopes of the average group lines being analyzed to determine if they were significantly different. A doubly multivariate analysis of variance was used to determine if between- and/or within-group differences existed and to determine at what point in the treatment

Figure 2 Self-slump stretching home exercise program.

continuum those differences existed. An *a priori* alpha level of 0.05 was used. Subject characteristic data and the doubly multivariate analysis of variance were analyzed with SPSS version 17.0 (IBM, Cary, NC, USA) and the LME analysis was performed in the statistical package R.

Results

Seventy subjects were screened for eligibility with seven subjects failing to satisfy the inclusion/exclusion criteria and three subjects declining to participate. Sixty subjects remained and were randomized with 30 subjects into each group. All 60 subjects completed the study and were included in the analysis. A visual representation of the study flow can be seen in the CONSORT diagram in Fig. 3. The baseline characteristics were analyzed and found to be similar between groups and are displayed in Tables 1 and 2.

The LME revealed that both groups improved rapidly over time and at significantly different rates since the analysis showed a difference between the groups' slopes for each outcome of interest. The experimental group improved at a faster rate compared to the control group for all three dependent variables (Fig. 4).

The doubly multivariate analysis of variance for the ODI revealed a significant main effect for group differences, $F(1,58)=36.95$, $P<0.01$, and for time, $F(2.67,58)=3369.77$, $P<0.01$. There was also a significant group-time interaction, $F(2.67,58)=477.12$, $P<0.01$. The analysis of NPRS revealed a significant main effect for group differences, $F(1,58)=36.95$, $P<0.01$, and for time, $F(2.67,58)=3369.77$, $P<0.01$. There was also a significant group-time interaction, $F(2.67,58)=477.12$, $P<0.01$. There were within-group differences for improvement in the NPRS, ODI, and FABQ in both groups at $P<0.01$. Both groups also demonstrated significant levels of regression from week 3 to week 6. Despite the significant regression in pain, disability, and fear during the final 3 weeks of follow-up, all outcomes were still significantly less than those from baseline ($P<0.01$).

Figure 3 CONSORT flow diagram.

The main effect for time demonstrated that there were significant differences at all time points for ODI, NPRS, and FABQ at $P < 0.01$ except for FABQ at 3 and 6 weeks which was non-significant at $P = 0.313$. Each dependent variable showed reductions in severity from baseline to 3 weeks and increases from 3 to 6 weeks.

The between-group analysis indicated that there was significantly greater improvement in NPRS, ODI, and FABQ favoring group 2 at many time points. The ODI had between-group differences at 3 and 6 weeks ($P < 0.01$), and both the NPRS and FABQ had between-group differences at 1, 2, 3, and 6 weeks ($P < 0.01$) (Fig. 5).

Discussion

The results of the present study suggest that when slump stretching is added to a treatment program of mobilization and stabilization exercise, significant improvement in NRLBP may occur. Both forms of statistical analysis revealed that both treatment groups improve rapidly and have meaningful reductions in their disability, pain, and fear but group 2, which included slump stretching in the clinic and as part of a home exercise program, improved more rapidly and substantially. This study confirms previous reports that slump stretching may be part of a comprehensive treatment program for NRLBP that is referred distal to the buttocks^{7,8} but in contrast, used

Table 1 Baseline characteristics of the sample

Variable	Slump stretching	Mobilization with exercises
Age (years)	38.2 (3.47)	37.76 (4.70)
Gender	Male: 9 Female: 21	Male: 12 Female: 18
Duration of symptoms (weeks)	15.26 (2.57)	14.76 (1.79)

Table 2 Between-group change score from baseline to 1, 2, 3, and 6 weeks

Variables	At 1 week			At 2 weeks			At 3 weeks			At 6 weeks		
	Change score Slump stretching	Change score Mob + exercises	Change score Mob + exercises	Change score Slump stretching	Change score Mob + exercises	Change score Mob + exercises	Change score Slump stretching	Change score Mob + exercises	Change score Mob + exercises	Change score Slump stretching	Change score Mob + exercises	Change score Mob + exercises
	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)	Mean/SD (95%CI)
Numeric pain rating scale	5.4 0.93 5.07-5.73	6.1 1.09 5.69-6.50	4.73 0.94 4.38-5.07	3.6 0.77 3.32-3.88	4.66 4.67 42.99-46.33	51 6.49 49.2-52.8	2.1 0.54 1.91-2.29	3.16 0.95 2.81-3.51	39.46 7.25 36.79-42.12	2.36 0.80 2.07-2.65	4.33 1.12 3.91-4.74	0.00/2.05
Oswestry disability index	51.8 3.68 50.48-53.12	55.06 6.90 52.59-57.53	0.02/0.61	44.66 4.67 42.99-46.33	51 6.49 49.2-52.8	28 3.93 26.59-29.41	0.00/1.32	39.46 7.25 36.79-42.12	0.00/1.96	28.2 4.11 26.13-29.07	44.13 6.40 41.84-46.42	0.00/2.96
Fear-avoidance belief questionnaire	44.43 3.77 43.08-45.78	48.06 4.41 46.43-49.68	0.00/0.88	35.3 3.45 34.07-36.53	40.5 5.11 38.67-42.33	25.1 4.50 23.49-26.71	0.00/1.19	33.46 4.53 31.84-35.08	0.00/1.85	32.3 8.04 29.42-35.18	44.5 4.64 42.79-46.20	0.00/1.85

Figure 4 Results of the linear mixed-effect model. The composite slopes were significantly different with group 2 improving faster than group 1.

a larger sample size, which resulted in more robust findings at the end of care (3 weeks) with similar findings after 3 weeks of no treatment (6 weeks total). In addition, subjects in the current study were reporting greater levels of pain, disability, and fear-avoidance behavior when compared to a previous pilot study⁷ and attained similar improvements.

Group 2 experienced a mean pain reduction in the NPRS of 4.93 points compared to group 1 who had a mean NPRS change of 2.97 points. Group 2 also experienced a mean reduction in disability in the ODI of 30.26 as compared to group 1 who experienced a reduction of 13.93. Lastly, group 2 experienced a mean fear and avoidance behavior reduction in the FABQ of 19.07 points compared to group 1 who experienced a reduction of 9.5 points. These results are not only statistically significant but clinically relevant. Multiple studies of the NPRS have found the minimal clinically important difference (MCID) to be between 1 and 2 with the value increasing

Figure 5 Mean outcome scores with standard deviations. * denotes statistical significance.

with level of baseline measurement and a relative change of 30% being meaningful.^{18–21} In this study, both treatment groups attained clinically meaningful changes at 67.7% for group 2 and 40.7% for group 1. The ODI has demonstrated MCID values that range between 6 and 11.^{14,18} Investigators have dichotomized clinical results as ‘successful’ and ‘unsuccessful’ based on a 50% improvement when a minimum baseline value of 30 was observed.^{17,22,23} In this study, group 2 demonstrated a successful outcome on average with a 52% improvement more than doubling the group 1 improvement of 23.2% on average. There currently is no accepted MCID for the FABQ but the between-group differences show twice the improvement in group 2. The results indicate significant between-group differences for NPRS, ODI, and FABQ favoring the addition of slump stretching approach over the isolated lumbar spinal mobilization and exercise approach for subjects with NRLBP.

A variety of randomized controlled trials exist indicating the efficacy of lumbar spinal mobilization in reducing pain intensity in patients with NRLBP.^{24–26} Both mechanical and neurophysiologic mechanisms have been described to explain pain reduction and improved mobility following joint mobilization, and it is conceivable that both mechanisms played a role in the findings of the present study. Yet definitive determination of these mechanisms of action has not been adequately elucidated and applying them to the results in this study would be speculative. The spinal stabilization program from this study has been found to be an effective intervention for NRLBP.^{7,23,27} Subjects with LBP have shown both asymmetry and atrophy of the multifidus muscle on the side of pain,²⁸ and a decreased ability to recruit multifidus in chronic LBP²⁹ and deficits in the ability to recruit the transverses abdominus across all subcategories of LBP.³⁰ These findings suggest that anyone with LBP may benefit from the inclusion of stabilization; nevertheless, multiple studies have revealed that not all subjects with LBP benefit equally from stabilization exercises.^{23,27}

Manual therapy has been found to be clinically effective in treating forms of LBP including NRLBP. Mobilization specifically has moderate evidence to support its use. Evidence supports the use of stabilization for specific forms of LBP. While subjects who demonstrate clinical or radiographic signs of instability appear to have better gains, evidence for the use of stabilization in subjects who do not have instability also exists. There are fewer studies that have examined mobilization and stabilization exercise in combination but studies that have examined this bimodal approach in shoulder impingement,^{31,32} and osteoarthritis of the knee³³ and a multimodal approach of stabilization, traction, and manual therapy for cervical radiculopathy³⁴ have all found improved outcomes when adding manual therapy to exercise programs, suggesting that manual therapy may somehow enhance the effect of exercise. In this study, the inclusion of a very specific stretch would seem to enhance the outcomes over the bimodal, mobilization, and stabilization approach. This subset of homogeneous subjects who demonstrate a positive slump test but who do not have specific neurologic deficits consistent with a radiculopathy seem to benefit from a technique purported to enhance dural movement,³⁵ perhaps enhancing the physiology of the nerve itself. It should be stated that a lack of hard neurologic signs does not preclude the possibility of the presence of a radiculopathy since lower grade radiculopathy may not present with neurologic signs³⁶ and the diagnostic accuracy of special testing for nerve root involvement is uncertain. On the contrary, the large effect observed in this study would suggest potential nervous tissue involvement.

Study limitation

The study has several limitations. The absence of a true control group makes it difficult to differentiate between the treatment effect and the natural course of the disorder, thus threatening the internal validity of the study. Nevertheless, the natural course of the disorder would not explain the between-group differences found in this study nor the large and rapid changes in pain and disability in subjects with long-standing (3.5 months) pain. This study employed a relatively small sample size which is known to affect the validity and generalizability of the results; however, the subcategory of LBP examined is naturally a small subgroup of NRLBP and this limitation has been identified in the methods of previous studies examining the slump stretching technique.^{7,8} Generalizability of the findings may be limited by the short-term follow-up used in this study as effect sizes tend to regress with longer-term follow-up (noted in this study between 3 and 6 weeks) but this time period is an enhancement over previous studies exploring the same intervention. Future studies should explore 3- to 6-month outcomes and are recommended. This study only examined the effectiveness of slump stretching in conjunction with lumbar spine mobilization and stabilization exercises in patients with NRLBP. Future studies could compare slump stretching with manual therapy techniques for NRLBP or explore other potential subgroups that may benefit from their use in order to determine effectiveness further. We excluded subjects with an SLR<45°, thus potentially excluding patients with more severe neural mechanosensitivity, thus the results may not generalize to this patient population.

Conclusion

In patients with NRLBP who demonstrate a positive slump test on examination, slump stretching in a clinical and home exercise program along with lumbar spine mobilization and stabilization exercises appears to be more beneficial for rate and magnitude of recovery of self-reported disability, pain, and fear-avoidance behavior compared to treatment without slump stretching. Future research examining longer-term follow-up periods, expanded inclusion criteria, and additional interventions with slump stretching are recommended.

References

- 1 Frymoyer JW. Back pain and sciatica. *N Engl J Med* 1988;318:291-300.
- 2 Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. *BMJ* 2006;332:1430-4.
- 3 Stankovic R, Johnell O, Maly P, Willner S. Use of lumbar extension, slump test, physical and neurological examination in the evaluation of patients with suspected herniated nucleus pulposus. A prospective clinical study. *Man Ther* 1999;4:25-32.
- 4 Vroomen PC, de Krom MC, Wilmink JT, Kester AD, Knottnerus JA. Diagnostic value of history and physical examination in patients suspected of lumbosacral nerve root compression. *J Neurol Neurosurg Psychiatry* 2002;72:630-4.
- 5 Cyriax J. Textbook of orthopaedic medicine, Volume one: diagnosis of soft tissue lesions. 6th ed. London: Baillière Tindall; 1975. p. 390-7.
- 6 Maitland G, Hengeveld E, Banks K, English K. Maitland's vertebral manipulation. 6th ed. Oxford: Butterworth-Heinemann; 2001. p. 328-83.
- 7 Cleland JA, Childs JD, Palmer JA, Eberhart S. Slump stretching in the management of non-radicular low back pain: a pilot clinical trial. *Man Ther* 2006;11:279-86.
- 8 George SZ. Characteristics of patients with lower extremity symptoms treated with slump stretching: a case series. *J Orthop Sports Phys Ther* 2002;32:391-8.
- 9 Cleland JA, Whitman JM, Fritz JM. Effectiveness of manual physical therapy to the cervical spine in the management of lateral epicondylalgia: a retrospective analysis. *J Orthop Sports Phys Ther* 2004;34:713-22.
- 10 Cleland J, McRae M. Complex regional pain syndrome I: management through the use of vertebral and sympathetic trunk mobilization. *J Man Manipulative Ther* 2002;10:188-99.
- 11 George SZ. Differential diagnosis and treatment for a patient with lower extremity symptoms. *J Orthop Sports Phys Ther* 2000;30:468-72.
- 12 Jensen MP, Turner JA, Romano JM. What is the maximum number of levels needed in pain intensity measurement? *Pain* 1994;58:387-92.
- 13 Stratford PW, Spadoni GF. The reliability, consistency, and clinical application of a numeric pain rating scale. *Physiother Can* 2001;51:88-91.
- 14 Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. *Phys Ther* 2001;81:776-88.
- 15 Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain* 1993;52:157-68.
- 16 Jacob T, Baras M, Zeev A, Epstein L. Low back pain: reliability of a set of pain measurement tools. *Arch Phys Med Rehabil* 2001;82:735-42.
- 17 Childs JD, Fritz JM, Flynn TW, Irrgang JJ, Johnson KK, Majkowski GR, et al. A clinical prediction rule to identify patients with low back pain most likely to benefit from spinal manipulation: a validation study. *Ann Intern Med* 2004;141:920-8.
- 18 Lauridsen HH, Hartvigsen J, Manniche C, Korsholm L, Grunnet-Nilsson N. Responsiveness and minimal clinically important difference for pain and disability instruments in low back pain patients. *BMC Musculoskelet Disord* 2006;7:82.
- 19 Childs JD, Piva SR, Fritz JM. Responsiveness of the numeric pain rating scale in patients with low back pain. *Spine (Phila Pa 1976)* 2005;30:1331-4.
- 20 Ostelo RW, Deyo RA, Stratford P, Waddell G, Croft P, Von Korf M, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. *Spine (Phila Pa 1976)* 2008;33:90-4.
- 21 Farrar JT, Young JP, Jr, LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain* 2001;94:149-58.
- 22 Flynn T, Fritz J, Whitman J, Wainner R, Magel J, Rendeiro D, et al. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. *Spine (Phila Pa 1976)* 2002;27:2835-43.
- 23 Fritz JM, Whitman JM, Childs JD. Lumbar spine segmental mobility assessment: an examination of validity for determining intervention strategies in patients with low back pain. *Arch Phys Med Rehabil* 2005;86:1745-52.
- 24 Chiradejnant A, Maher CG, Latimer J, Stepanovitch N. Efficacy of 'therapist-selected' versus 'randomly selected' mobilisation techniques for the treatment of low back pain: a randomised controlled trial. *Aust J Physiother* 2003;49:233-41.
- 25 Powers CM, Beneck GJ, Kulig K, Landel RF, Fredericson M. Effects of a single session of posterior-to-anterior spinal mobilization and press-up exercise on pain response and lumbar spine extension in people with nonspecific low back pain. *Phys Ther* 2008;88:485-93.

- 26 Goodsell M, Lee M, Latimer J. Short-term effects of lumbar posteroanterior mobilization in individuals with low-back pain. *J Manipulative Physiol Ther* 2000;23:332–42.
- 27 Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. *Arch Phys Med Rehabil* 2005;86:1753–62.
- 28 Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine (Phila Pa 1976)* 1996;21:2763–9.
- 29 Danneels LA, Coorevits PL, Cools AM, Vanderstraeten GG, Cambier DC, Witvrouw EE, *et al.* Differences in electromyographic activity in the multifidus muscle and the iliocostalis lumborum between healthy subjects and patients with sub-acute and chronic low back pain. *Eur Spine J* 2002;11:13–9.
- 30 Kiesel KB, Underwood FB, Mattacola CG, Nitz AJ, Malone TR. A comparison of select trunk muscle thickness change between subjects with low back pain classified in the treatment-based classification system and asymptomatic controls. *J Orthop Sports Phys Ther* 2007;37:596–607.
- 31 Bang MD, Deyle GD. Comparison of supervised exercise with and without manual physical therapy for patients with shoulder impingement syndrome. *J Orthop Sports Phys Ther* 2000;30:126–37.
- 32 Senbursa G, Baltaci G, Atay A. Comparison of conservative treatment with and without manual physical therapy for patients with shoulder impingement syndrome: a prospective, randomized clinical trial. *Knee Surg Sports Traumatol Arthrosc* 2007;15:915–21.
- 33 Deyle GD, Henderson NE, Matekel RL, Ryder MG, Garber MB, Allison SC. Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee. A randomized, controlled trial. *Ann Intern Med* 2000;132:173–81.
- 34 Cleland JA, Fritz JM, Whitman JM, Heath R. Predictors of short-term outcome in people with a clinical diagnosis of cervical radiculopathy. *Phys Ther* 2007;87:1619–32.
- 35 Walsh MT. Upper limb neural tension testing and mobilization. Fact, fiction, and a practical approach. *J Hand Ther* 2005;18:241–58.
- 36 Bogduk N, McGuirk B. Pain research and clinical management: medical management of acute and chronic low back pain. An evidence-based approach. Amsterdam: Elsevier; 2002. p. 28–30.