Chapter II
REVIEW OF LITERATURE

Introduction

A literature review is a body of text that aims to review the critical points of current knowledge, including substantive findings as well as theoretical and methodological contributions to a particular topic.¹ A crucial element of all research degrees is the review of relevant literature. So important is this chapter that its omission represents a void or absence of a major element in research.² According to Bourner,³ there are good reasons for spending time and effort on a review on the literature before embarking on a research project. These reasons include;

- to identify gaps in the literature
- to avoid reinventing the wheel (at the very least this will save time and it can stop you from making the same mistakes as others)
- to carry on from where others have already reached (reviewing the field allows you to build on the platform of existing knowledge and ideas)
- to identify other people working in the same fields (a researcher network is a valuable resource)
- to increase your breadth of knowledge of your subject area
- to identify seminal works in your area
- to provide the intellectual context for your own work, enabling you to position your project relative to other work
- to identify opposing views
- to put your work into perspective
- to demonstrate that you can access previous work in an area
- to identify information and ideas that may be relevant to your project
- to identify methods that could be relevant to your project

A researcher tried to bring the reviews on this way. For classified this chapter in the true way, the literature review of this chapter investigated in four parts;

a) Reviews related to compared patients with low back pain and healthy people.
b) Reviews related to stabilization exercises as a remedy for non specific chronic low back pain.

c) Reviews related to stretching exercises as a remedy for non specific chronic low back pain.

d) Reviews related to validity and reliability of the measurement tools used for this study.

2.1 Reviews related to compared patients with low back pain and healthy people

N. Pulkovski (2011) investigated Ultrasound assessment of the transversus abdominis muscle contraction ratio during abdominal hollowing between patients with chronic low back pain and healthy controls. Spine stabilization exercises, in which patients are taught to preferentially activate the transversus abdominus (TrA) during “abdominal hollowing” (AH), are a popular treatment for chronic low back pain (cLBP). The present study investigated whether performance during AH differed between cLBP patients and controls to an extent that would render it useful diagnostic tool. 50 patients with cLBP (46.3 ± 12.5 years) and 50 healthy controls (43.6 ± 12.7 years) participated in this case–control study. They performed AH in hook-lying. Using M-mode ultrasound, thicknesses of TrA, and obliquus internus and externus were determined at rest and during 5 s AH (5 measures each body side). The TrA contraction-ratio (TrA-CR) (TrA contracted/rest) and the ability to sustain the contraction [standard deviation (SD) of TrA thickness during the stable phase of the hold] were investigated. There were no significant group differences for the absolute muscle thicknesses at rest or during AH, or for the SD of TrA thickness. There was a small but significant difference between the groups for TrA-CR: cLBP 1.35 ± 0.14, controls 1.44 ± 0.24 (p>0.05). However, Receiver Operator Characteristics (ROC) analysis revealed a poor and non-significant ability of TrA-CR to discriminate between cLBP patients and controls on an individual basis (ROC area under the curve, 0.60 [95% CI 0.495; 0.695], p = 0.08). In the patient group, TrA-CR showed a low but significant correlation with Roland Morris score (Spearman Rho = 0.328; p = 0.02). In conclusion, the difference in group mean values for TrA-CR was small and of uncertain clinical relevance. Moreover, TrA-CR showed a poor ability to discriminate between control and cLBP subjects on an individual basis. They conclude that the TrA-CR during abdominal hollowing does not distinguish well between patients with chronic low back pain and healthy controls.
Tracy L. Wallwork et al. (2009)\(^5\) investigated the effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. Decreases in the size of the multifidus muscle have been consistently documented in people with low back pain. Recently, ultrasound imaging techniques have been used to measure contraction size of the multifidus muscle, via comparison of the thickness of the muscle at rest and on contraction. The aim of this study was to compare both the size (cross-sectional area, CSA) and the ability to voluntarily perform an isometric contraction of the multifidus muscle at four vertebral levels in 34 subjects with and without chronic low back pain (CLBP). Ultrasound imaging was used for assessments, conducted by independent examiners. Results showed a significantly smaller CSA of the multifidus muscle for the subjects in the CLBP group compared with subjects from the healthy group at the L5 vertebral level (F \(\frac{1}{4} 29.1\), \(p \frac{1}{4} 0.001\)) and a significantly smaller percent thickness contraction for subjects of the CLBP group at the same vertebral level (F \(\frac{1}{4} 6.6\), \(p \frac{1}{4} 0.02\)). This result was not present at other vertebral levels (\(p > 0.05\)). The results of this study support previous findings that the pattern of multifidus muscle atrophy in CLBP patients is localized rather than generalized but also provided evidence of a corresponding reduced ability to voluntarily contract the atrophied muscle.

Julie Hides et al. (2008)\(^6\) investigated Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Previous studies have provided evidence of multifidus muscle atrophy in people with low back pain (LBP). In cases of acute LBP, these studies have shown that the pattern of atrophy is both vertebral level and side specific. For chronic LBP, there are conflicting reports about the extent and location of muscle atrophy. The purpose of this study was to compare chronic LBP patients and asymptomatic subjects on measures of multifidus size (cross-sectional area; CSA) and symmetry (proportional difference of relatively larger side to smaller side). Data were obtained from 40 asymptomatic subjects without a prior history of LBP (13 females, 27 males), and a retrospective audit was undertaken of records from 50 chronic low back pain patients (27 females, 23 males) presenting to a back pain clinic. Results of the analysis showed that chronic LBP patients had significantly smaller multifidus CSAs than asymptomatic subjects at the lowest two vertebral levels. Males were found to have significantly larger multifidus CSAs than females at all vertebral levels except L5, the most common symptomatic level as determined by manual examination. The greatest asymmetry between sides was seen at the L5 vertebral level in patients with unilateral
pain presentations. The smaller multifidus CSA was reported side of pain in all cases. The results of this study support previous findings that the pattern of multifidus muscle atrophy in chronic LBP patients is localized rather than generalized. Furthermore, between sides asymmetry may be seen in chronic LBP patients presenting with a unilateral pain distribution.

Eythor Kristjansson (2004) investigated Reliability of ultrasonography for the cervical multifidus muscle in asymptomatic and symptomatic subjects. A test–retest and inter-tester study was designed to assess the reliability of ultrasonography to depict the size of the cervical multifidus muscle in asymptomatic and symptomatic subjects. Ten asymptomatic women (range 19–48 years) and 10 women with chronic whiplash associated disorder (WAD), grade II, (range 19–49 years), matched for height and weight participated. The women were imaged by ultrasonography on two separate occasions by two different testers. On each occasion the cross-sectional area (CSA) and the transverse versus the anterior–posterior dimensions (shape ratio) at the C4 level were measured. The repeated measurements of the CSA were plotted against their means to reveal the limit of agreement. Good agreement was found for the asymptomatic group measurements and the intra-tester agreement for the symptomatic group. The inter-tester agreement for the symptomatic group was questionable. The size of the multifidus muscle was significantly reduced in the symptomatic group \( (P<0.05) \). The results indicate that loss of clarity of the fascial layer between the semispinalis cervicis muscle and the cervical multifidus muscle may be a diagnostic sign of muscle atrophy. Ultrasonography can be used to precisely measure the size of the cervical multifidus muscle at the C4-level in asymptomatic young female subjects; it is also reliable for symptomatic subjects if the same tester performs the measurements. Additional criteria are recommended to improve the inter-tester agreement for symptomatic subjects.

Kyle B. Kiesel and Frank B. Underwood (2007) investigated A Comparison of Select Trunk Muscle Thickness Change between Subjects with Low Back Pain Classified in the Treatment-Based Classification System and Asymptomatic Controls. STUDY DESIGN: Cross-sectional descriptive. OBJECTIVES: To investigate if muscle thickness change, as measured with rehabilitative ultrasound imaging (RUSI), is different across subgroups of patients with low back pain (LBP), classified in the Treatment-Based Classification (TBC) system, when compared to controls.
BACKGROUND: Researchers have demonstrated that subgroups of patients with LBP exist and respond differently to treatment, challenging the assertion that LBP is “nonspecific.” The TBC system uses 4 categories (stabilization, mobilization, direction specific exercise, or traction) to subgroup patients. Recently, researchers have demonstrated impairments of the transverse abdominis (TrA) and lumbar multifidus (LM) in those with LBP, regardless of classification. Although distinct differences impairments have been identified between subgroups, TrA and LM impairments have not been studied and may be present across categories of the TBC system.

METHODS AND MEASURES: RUSI was utilized to measure percent thickness change from rest to contracted state during a voluntary task of the TrA and during an upper extremity task known to activate the LM in 56 subjects classified in the TBC system and 20 controls.

RESULTS: During the prone upper extremity lifting task with a hand weight, there was a significant group difference for the LM at L4-L5 ($P = .03$) and at L5-S1 ($P = .04$), and during volitional activation for the TrA ($P < .01$). Post hoc testing revealed the differences were between control and both the direction specific and stabilization categories at the L4-L5 level, between control and direction specific category for the L5-S1 level, and between controls and all 3 categories for the TrA. CONCLUSION: Deficits in the ability to generate muscle thickness changes in the TrA and LM occurred across categories of the TBC system. Intervention studies should be performed to determine if intervention can correct these deficits and if deficit corrections are related to outcomes.

Bilge Kara et al. (2011)\(^9\) Used of Tape Measure in People with or without Back Pain in Assessment of Reposition Error. Aim: Examining lumbar repositioning error (RE) using a tape measure in nonspecific low back pain (NLBP) and control groups and determining whether RE is different in subjects with nonspecific back pain than in controlled subjects.

Material and Methods: The study was totally applied to 36 subjects of whom 18 were healthy subjects and 18 were NLBP patients. The ability of the subjects to take the targeted positions was assessed. In subjects with NLBP the evaluation of the pain was assessed by using Visual Analog Scale (VAS), and disability measurement was made using Oswestry Disability Index (ODI). Results: RE was found in all the measurements except for lumbar flexion with eyes open ($p=0.15$) in control group ($p<0.05$). There were RE for all the measurements in NLBP group ($p<0.05$). When RE of two groups compared only lumbar flexion with eyes open measurement ($p = 0.04$) in NLBP group was higher than control group. Conclusion: As a result of our study, it has been seen
that RE measurement of the lumbar spine with tape measure, which is cheap and clinically practical, is a reliable method, and can be used in the assessment of NLBP patients and in the determination of the rehabilitation program.

### 2.2 Reviews related to stabilization exercises as a remedy for non specific chronic low back pain

Spinal stabilization exercises are commonly used for the management of low back pain (LBP). There is limited evidence relating to patients’ experiences of their involvement in such programmes. Oluwaleke et al. (2009) did the study, the aim of this study was to explore the experiences of a sample of individuals with chronic LBP who participated in a randomized controlled trial (RCT) investigating the most efficacious dosage and frequency of spinal stabilization exercise. The qualitative study involved nine participants who took part in focus group discussions. The data were analyzed using thematic content analysis and provided insights into the experiences of the participants. Four themes emerged: Physical dimensions of the LBP experience, emotional and psychological dimensions of the LBP experience and perceived effects of the programme and lastly, the impact of the treatment programme on participants’ knowledge, understanding and adherence. In conclusion participants’ experiences were not limited to the positive effect of stabilization exercise on pain, functional disability and quality of life, but also reflected increases in confidence, the formulation of self help strategies and the ability to exert better control over their LBP. The findings highlight the importance of well planned associated educational support packages in the treatment of LBP paving the way for future qualitative research.

Julie Hides et al. (2008) investigated the Effect of Stabilization Training on Multifidus Muscle Cross-sectional Area among Young Elite Cricketers with Low Back Pain. Study design: A single-blinded, pretreatment-post treatment assessment. Background: To investigate, using ultrasound imaging, the cross-sectional area (CSA) of the lumbar multifidus muscle at 4 vertebral levels (L2, L3, L4, L5) in elite cricketers with and without low back pain (LBP), and to document the effect of staged stabilization training program on multifidus muscle CSA. Method and measures: Despite high fitness levels and often intensive strength training programs, athletes still suffer LBP. The incidence of LBP among Australian cricketers is 8% and as high as 14% among fast bowlers. Previous researchers have found that the multifidus muscle contributes to segmental stability of the lumbopelvic region; however, the CSA of this muscle has not
been previously assessed in elite cricketers. Results: CSAs of the multifidus muscles were assessed at rest on the left and right sides for 4 vertebral levels at the start and completion of a 13-week cricket training camp. Participants who reported current or previous LBP were placed in a rehabilitation group. The stabilization program involved voluntary contraction of the multifidus, transversus abdominis, and pelvic floor muscles, with real-time feedback from rehabilitative ultrasound imaging (RUSI), progressed from non-weight-bearing to weight-bearing positions and movement training. Pain scores (using a visual analogue scale) were also collected from those with LBP. Conclusion: The CSAs of the multifidus muscles at the L5 vertebral level increased for the 7 cricketers with LBP who received the stabilization training, compared with the 14 cricketers without LBP who did not receive rehabilitation ($P = .004$). In addition, the amount of muscle asymmetry among those with LBP significantly decreased ($P = .029$) and became comparable to cricketers without LBP. These effects were not evident for the L2, L3, and L4 vertebral levels. There was also a 50% decrease in the mean reported pain level among the cricketers with LBP.

Slade and Keating JL (2012)\textsuperscript{12} determine the effect of lumbar spine-strengthening exercises on outcomes for people with chronic low back pain. METHODS: Two independent reviewers followed Cochrane Back Review Group and QUORUM Statement guidelines to complete this systematic review. Exercise effects were reported as standardized mean difference (SMD) with 95% confidence intervals. RESULTS: Thirteen high-quality randomized controlled trials were included. For chronic low back pain, trunk strengthening is more effective than no exercise on long-term pain (SMD 0.95 [0.35-1.55]; intensive trunk strengthening is more effective than less intensive on function (pooled SMD: short-term, 0.58 [0.22-0.94]; long-term, 0.77 [0.33-1.20]). Compared with physiotherapy or aerobics, effects are comparable on pain and function. Motivation strategies increase effectiveness. After disk surgery, effects are significant for function (pooled SMD: short-term, 1.08 (0.76-1.41); long-term, 0.53 (0.03-1.04). For severe degeneration, trunk strengthening is less favorable than fusion on long-term pain (SMD, -0.50 [-0.99 to -0.01]) or function (SMD, -0.76 [-1.25 to -0.26]). Intensive trunk strengthening is less effective than McKenzie exercises for pain reduction (SMD: short-term, -0.29 [-0.54 to -0.05]; long-term, -0.31 [-0.55 to -0.06]). We estimated that moderate effect sizes (0.5) indicate that approximately 50% of participants and large effect sizes (0.8) indicate that approximately 80% of participants would achieve
important improvement. **CONCLUSIONS:** Trunk strengthening appears effective compared with no exercise. Increasing exercise intensity and adding motivation increase treatment effects. Trunk strengthening, compared with aerobics or McKenzie exercises, showed no clear benefit of strengthening. It is unclear whether observed benefits are due to tissue loading or movement repetition.

Anne F et al. (2009) investigated Spinal segmental stabilization exercises for chronic low back pain. Summery: Exercise rehabilitation is one of the few evidence-based treatments for chronic non-specific low back pain (cLBP), but individual success is notoriously variable and may depend on the patient’s adherence to the prescribed exercise regime. **Aim:** This prospective study examined factors associated with adherence and the relationship between adherence and outcome after a programme of physiotherapeutic spine stabilization exercises. Method: A total of 32/37 patients with cLBP completed the study (mean age, 44.0 (SD = 12.3) years; 11/32 (34%) male). Adherence to the 9-week programme was documented as: percent attendance at therapy, percent adherence to daily home exercises (patient diary) and percent commitment to rehabilitation (Sports Injury Rehabilitation Adherence Scale (SIRAS)). The average of these three measures formed a multidimensional adherence index (MAI). Psychological disturbance, fear-avoidance beliefs, exercise self-efficacy and health locus of control were measured by questionnaire; disability in everyday activities was scored with the Roland–Morris disability scale and back pain intensity with a 0–10 graphic rating scale. **Results:** Overall, adherence to therapy was very good (average MAI score, 85%; median (IQR), 89 (15)%). The only psychological/ beliefs variable showing a unique significant association with MAI was exercise self-efficacy (Rho = 0.36, P = 0.045). Pain intensity and self-rated disability decreased significantly after therapy (each P < 0.01). Adherence to home exercises showed a moderate, positive correlation with the reduction in average pain (Rho = 0.54, P = 0.003) and disability (Rho = 0.38, P = 0.036); higher MAI scores were associated with greater reductions in average pain (Rho = 0.48, P = 0.008) and a (n.s.) tendency for greater reductions in disability (Rho = 0.32, P = 0.07) Neither attendance at therapy nor SIRAS were significantly related to any of the outcomes. **Conclusion:** The benefits of rehabilitation depended to a large extent on the patient’s exercise behavior outside of the formal physiotherapy sessions. Hence, more effort should be invested in finding ways to improve patients’ motivation to take responsibility for the success of their own therapy.
perhaps by increasing exercise self-efficacy. Whether the “adherence–outcome” interaction was mediated by improvements in function related to the specific exercises, or by a more “global” effect of the programme, remains to be examined.

O’Sullivan et al. (2009)\textsuperscript{14} determined the efficacy of a specific exercise intervention in the treatment of patients with chronic low back pain and a radiologic diagnosis of spondylolysis or spondylolisthesis. Summary of Background Data. A recent focus in the physiotherapy management of patients with back pain has been the specific training of muscles surrounding the spine (deep abdominal muscles and lumbar multifidus), considered to provide dynamic stability and fine control to the lumbar spine. In no study have researchers evaluated the efficacy of this intervention in a population with chronic low back pain where the anatomic stability of the spine was compromised. Study Design; A randomized, controlled trial, test-retest design, with a 3-, 6-, and 30-month postal questionnaire follow-up. Methods; Forty-four patients with this condition were assigned randomly to two treatment groups. The first group underwent a 10-week specific exercise treatment program involving the specific training of the deep abdominal muscles, with co-activation of the lumbar multifidus. The activation of these muscles was incorporated into previously aggravating static postures and functional tasks. The control group underwent treatment as directed by their treating practitioner. Results; after intervention, the specific exercise group showed a statistically significant reduction in pain intensity and functional disability levels, which was maintained at a 30-month follow-up. The control group showed no significant change in these parameters after intervention or at follow-up.

Mohseni-Bandpei et al. (2009)\textsuperscript{15} investigated the effect of pelvic floor muscle (PFM) exercise for the treatment of chronic LBP. Dysfunction of spinal stability seems to be one of the causes of low back pain (LBP). It is thought that a large number of muscles have a role in spinal stability including the PFM. After ethical approval, a randomized controlled clinical trial was carried out on 20 women with non-specific chronic LBP. Patients were randomly allocated into two groups: an experimental and a control group. The control group was given routine treatment including electrotherapy and general exercises; and the experimental group received routine treatment and additional PFM exercise. Pain intensity, functional disability and PFM strength and endurance were measured before, immediately after intervention and at 3 months follow-up. In both groups pain and functional disability were significantly reduced following treatment (p<0.01), but no
significant difference was found between the two groups (p>0.05). All measurements were improved in both groups (p<0.01) although patients in the experimental group showed greater improvement in PFM strength and endurance (p<0.01). It seems that the PFM exercise combined with routine treatment was not superior to routine treatment alone in patients with chronic LBP.

Rydeard et al. (2006) investigated the efficacy of a therapeutic exercise approach in a population with chronic low back pain (LBP). STUDY DESIGN: A randomized controlled trial, pretest-posttest design, with a 3-, 6-, and 12-month follow-up. BACKGROUND: Therapeutic approaches developed from the Pilates method are becoming increasingly popular; however, there have been no reports on their efficacy. METHODS AND MEASURES: Thirty-nine physically active subjects between 20 and 55 years old with non-specific chronic LBP were randomly assigned to 1 of 2 groups. The specific-exercise-training group participated in a 4-week program consisting of training on specialized (Pilates) exercise equipment, while the control group received the usual care, defined as consultation with a physician and other specialists and healthcare professionals, as necessary. Treatment sessions were designed to train the activation of specific muscles thought to stabilize the lumbar-pelvic region. Functional disability outcomes were measured with The Roland Morris Disability Questionnaire (RMQ/RMDQ-HK) and average pain intensity using a 101-point numerical rating scale. RESULTS: There was a significantly lower level of functional disability (P = .023) and average pain intensity (P = .002) in the specific-exercise-training group than in the control group following the treatment intervention period. The posttest adjusted mean in functional disability level in the specific-exercise-training group was 2.0 (95% CI, 1.3 to 2.7) RMQ/RMDQ-HK points compared to a posttest adjusted mean in the control group of 3.2 (95% CI, 2.5 to 4.0) RMQ/RMDQ-HK points. The posttest adjusted mean in pain intensity in the specific-exercise-training group was 18.3 (95% CI, 11.8 to 24.8), as compared to 33.9 (95% CI, 26.9 to 41.0) in the control group. Improved disability scores in the specific-exercise-training group were maintained for up to 12 months following treatment intervention. CONCLUSIONS: The individuals in the specific-exercise-training group reported a significant decrease in LBP and disability, which was maintained over a 12-month follow-up period. Treatment with a modified Pilates-based approach was more efficacious than usual care in a population with chronic, unresolved LBP.
Costa et al. (2009)\textsuperscript{17} investigated the efficacy of motor control exercise for people with chronic low back pain. **BACKGROUND:** The evidence that exercise intervention is effective for treatment of chronic low back pain comes from trials that are not placebo-controlled. **DESIGN:** This was a randomized, placebo-controlled trial. **SETTING:** The study was conducted in an outpatient physical therapy department in Australia. Patients The participants were 154 patients with chronic low back pain of more than 12 weeks' duration. **INTERVENTION:** Twelve sessions of motor control exercise (ie, exercises designed to improve function of specific muscles of the low back region and the control of posture and movement) and placebo (ie, detuned ultrasound therapy and detuned short-wave therapy) were conducted over 8 weeks. **MEASUREMENTS:** Primary outcomes were pain intensity, activity (measured by the Patient-Specific Functional Scale), and patient's global impression of recovery measured at 2 months. Secondary outcomes were pain; activity (measured by the Patient-Specific Functional Scale); patient's global impression of recovery measured at 6 and 12 months; activity limitation (measured by the Roland-Morris Disability Questionnaire) at 2, 6, and 12 months; and risk of persistent or recurrent pain at 12 months. **RESULTS:** The exercise intervention improved activity and patient's global impression of recovery but did not clearly reduce pain at 2 months. The mean effect of exercise on activity (measured by the Patient-Specific Functional Scale) was 1.1 points (95% confidence interval [CI] =0.3 to 1.8), the mean effect on global impression of recovery was 1.5 points (95% CI=0.4 to 2.5), and the mean effect on pain was 0.9 points (95% CI=−0.01 to 1.8), all measured on 11-point scales. Secondary outcomes also favored motor control exercise. Limitation Clinicians could not be blinded to the intervention they provided. **CONCLUSIONS:** Motor control exercise produced short-term improvements in global impression of recovery and activity, but not pain, for people with chronic low back pain. Most of the effects observed in the short term were maintained at the 6- and 12-month follow-ups.

Macedo et al. (2009)\textsuperscript{18} did systematically review randomized controlled trials evaluating the effectiveness of motor control exercises for persistent low back pain. **BACKGROUND:** Previous systematic reviews have concluded that the effectiveness of motor control exercise for persistent low back pain has not been clearly established. **METHODS:** Pain, disability, and quality-of-life outcomes were extracted and converted to a common 0 to 100 scale. **RESULTS:** Fourteen trials were included. Seven trials compared motor control exercise with minimal intervention or evaluated it as a
supplement to another treatment. Four trials compared motor control exercise with manual therapy. Five trials compared motor control exercise with another form of exercise. One trial compared motor control exercise with lumbar fusion surgery. The pooling revealed that motor control exercise was better than minimal intervention in reducing pain at short-term follow-up (weighted mean difference=-14.3 points, 95% confidence interval [CI]=-20.4 to -8.1), at intermediate follow-up (weighted mean difference=-13.6 points, 95% CI=-22.4 to -4.1), and at long-term follow-up (weighted mean difference=-14.4 points, 95% CI=-23.1 to -5.7) and in reducing disability at long-term follow-up (weighted mean difference=-10.8 points, 95% CI=-18.7 to -2.8). Motor control exercise was better than manual therapy for pain (weighted mean difference=-5.7 points, 95% CI=-10.7 to -0.8), disability (weighted mean difference=-4.0 points, 95% CI=-7.6 to -0.4), and quality-of-life outcomes (weighted mean difference=-6.0 points, 95% CI=-11.2 to -0.8) at intermediate follow-up and better than other forms of exercise in reducing disability at short-term follow-up (weighted mean difference=-5.1 points, 95% CI=-8.7 to -1.4). CONCLUSIONS: Motor control exercise is superior to minimal intervention and confers benefit when added to another therapy for pain at all time points and for disability at long-term follow-up. Motor control exercise is not more effective than manual therapy or other forms of exercise.

Asghar Akbari et al. (2008) investigated the effect of motor control exercise versus general exercise on lumbar local stabilizing muscles thickness: Randomized controlled trial of patients with chronic low back pain. Background: The specific training of lumbar local stabilizing muscles is one of the recent focuses in management of patients with chronic LBP. Enhanced stability of the lumbar spine segments is the mechanism for pain relief with this specific exercise. Objective: The aim of this study was to compare the effect of motor control exercises with general exercises on the lumbar local stabilizing muscles thickness, activity limitation and pain in patients with chronic low back pain (LBP). Design: A double-blind, randomized controlled trial. Methods: Forty-nine patients with chronic LBP were randomly assigned to either a motor control (n = 25) or a general exercises group (n = 24). Before and after intervention, we assessed the lumbar multifidus (LM) and Transversus abdominis (TA) muscles thickness (mm) using a 7.5 MHz B-mode transducer ultrasound, pain through visual analog scale and activity limitation through Back Performance Scale (Ordinal). A 16 session’s exercise program which lasted 8 weeks, twice per week, and 30 minutes per session was performed for
both groups. Results: The mean TA thickness increased from $1.87 ± 0.63$ mm to $2.39 ± 0.63$ mm in the motor control group and from $1.93 ± 0.49$ mm to $2.22 ± 0.47$ mm in the general exercise group ($P < 0.0001$). The mean LM thickness increased from $8.63 ± 2.37$ mm to $9.69 ± 2.49$ mm in the motor control group and from $8.83 ± 1.53$ mm to $9.26 ± 1.56$ mm in the general exercise group ($P < 0.0001$). The mean activity limitation decreased from $8.83 ± 3.38$ to $5.42 ± 2.43$ in the motor control group and from $10.67 ± 2.81$ to $7.25 ± 2.73$ in the general exercise group ($P < 0.0001$). After treatment, there was no significant difference between two groups, with the exception of pain ($P > 0.05$). Conclusion: The motor control and general exercises decreased pain and increased TA and LM muscles thickness and lumbar mobility in patients with chronic LBP without any signs of spinal instability. Although, the motor control exercises were more effective than general exercises in pain decreasing.

Koumantakis GA et al. (2005) investigated Trunk muscle stabilization training plus general exercise versus general exercise only. BACKGROUND AND PURPOSE: The purpose of this randomized controlled trial was to examine the usefulness of the addition of specific stabilization exercises to a general back and abdominal muscle exercise approach for patients with sub acute or chronic non-specific back pain by comparing a specific muscle stabilization-enhanced general exercise approach with a general exercise-only approach. SUBJECTS: Fifty-five patients with recurrent, nonspecific back pain (stabilization-enhanced exercise group: $n=29$, general exercise-only group: $n=26$) and no clinical signs suggesting spinal instability were recruited. METHODS: Both groups received an 8-week exercise intervention and written advice (The Back Book). Outcome was based on self-reported pain (Short-Form McGill Pain Questionnaire), disability (Roland-Morris Disability Questionnaire), and cognitive status (Pain Self-Efficacy Questionnaire, Tampa Scale of Kinesiophobia, and Pain Locus of Control Scale) measured immediately before and after intervention and 3 months after the end of the intervention period. RESULTS: Outcome measures for both groups improved. Furthermore, self-reported disability improved more in the general exercise-only group immediately after intervention but not at the 3-month follow-up. There were generally no differences between the 2 exercise approaches for any of the other outcomes. DISCUSSION AND CONCLUSION: A general exercise program reduced disability in the short term to a greater extent than a stabilization-enhanced exercise approach in patients with recurrent nonspecific low back pain. Stabilization exercises do not appear
to provide additional benefit to patients with subacute or chronic low back pain who have no clinical signs suggesting the presence of spinal instability.

Cairns et al. (2006)21 evaluated the effect of adding specific spinal stabilization exercises to conventional physiotherapy for patients with recurrent low back pain (LBP). STUDY DESIGN: Pragmatic, multi centered randomized controlled trial, with 12-month follow-up. SUMMARY OF BACKGROUND DATA: Spinal stabilization exercises are a popular form of physiotherapy management for LBP, and previous small-scale studies on specific LBP subgroups have identified improvement in outcomes as a result. METHODS: A total of 97 patients (18-60 years old) with recurrent LBP were recruited. Stratified randomization was undertaken into 2 groups: "conventional," physiotherapy consisting of general active exercise and manual therapy; and conventional physiotherapy plus specific spinal stabilization exercises. Stratifying variables used were laterality of symptoms, duration of symptoms, and Roland Morris Disability Questionnaire score at baseline. Both groups received The Back Book, by Roland et al. Back-specific functional disability (Roland Morris Disability Questionnaire) at 12 months was the primary outcome. Pain, quality of life, and psychological measures were also collected at 6 and 12 months. Analysis was by intention to treat. RESULTS: A total of 68 patients (70%) provided 12-month follow-up data. Both groups showed improved physical functioning, reduced pain intensity, and an improvement in the physical component of quality of life. Mean change in physical functioning, measured by the Roland Morris Disability Questionnaire, was -5.1 (95% confidence interval -6.3 to -3.9) for the specific spinal stabilization exercises group and -5.4 (95% confidence interval -6.5 to -4.2) for the conventional physiotherapy group. No statistically significant differences between the 2 groups were shown for any of the outcomes measured, at any time. CONCLUSIONS: Patients with LBP had improvement with both treatment packages to a similar degree. There was no additional benefit of adding specific spinal stabilization exercises to a conventional physiotherapy package for patients with recurrent LBP.

or failure) was categorized based on changes in the Oswestry Disability Questionnaire scores after 8 weeks. Results: Eighteen subjects were categorized as treatment successes, 15 as treatment failures, and 21 as somewhat improved. After using regression analyses to determine the association between standardized examination variables and treatment response status, preliminary clinical prediction rules were developed for predicting success (positive likelihood ratio [LR], 4.0) and failure (negative LR, .18). The most important variables were age, straight-leg raise, prone instability test, aberrant motions, lumbar hypermobility, and fear-avoidance beliefs. Conclusions: It appears that the response to a stabilization exercise program in patients with LBP can be predicted from variables collected from the clinical examination. The prediction rules could be used to determine whether patients with LBP are likely to benefit from stabilization exercises.

Ramprasad Muthukrishnan et al. (2010)\textsuperscript{23} considered the differential effects of core stabilization exercise regime and conventional physiotherapy regime on postural control parameters during perturbation in patients with movement and control impairment chronic low back pain. As heterogeneity in CLBP population moderates the effect of intervention on outcomes, in this study, interventions approaches were used based on sub-groups of CLBP. Methods: This was an allocation concealed, blinded, sequential and pragmatic control trial. Three groups of participants were investigated during postural perturbations: 1) CLBP patients with movement impairment (n = 15, MI group) randomized to conventional physiotherapy regime 2) fifteen CLBP patients with control impairment randomized to core stability group (CI group) and 3) fifteen healthy controls (HC). Results: The MI group did not show any significant changes in postural control parameters after the intervention period however they improved significantly in disability scores and fear avoidance belief questionnaire work score (P < 0.05). The CI group showed significant improvements in Fx, Fz, and My variables (p < 0.013, p < 0.006, and p < 0.002 respectively with larger effect sizes: Hedges's g > 0.8) after 8 weeks of core stability exercises for the adjusted p values. Postural control parameters of HC group were analyzed independently with pre and post postural control parameters of CI and MI group. This revealed the significant improvements in postural control parameters in CI group compared to MI group indicating the specific adaptation to the core stability exercises in CI group. Though the disability scores were reduced significantly in CI and MI groups (p < 0.001), the post intervention scores between
groups were not found significant ($p < 0.288$). Twenty percentage absolute risk reduction in flare-up rates during intervention was found in CI group (95% CI: 0.69-0.98). Conclusions: In this study core stability exercise group demonstrated significant improvements after intervention in ground reaction forces (Fz, Mz; $g > 0.8$) indicating changes in load transfer patterns during perturbation similar to HC group.

Kaul Rohini et al. (2007)\textsuperscript{24} Compared of Effects of Specific Stabilization Exercises and Conventional Back Extension Exercises in Management of Chronic Disc Prolapse. The concept of spinal segmental stabilization in one of the least explored interventions for the management of back pain. The purpose of the study was to examine usefulness of stabilization exercises for athletes with chronic disc prolapse. Twelve subjects who were sport persons (age: 20-40 yrs) with MRI findings of disc protrusion and were randomly assigned to three groups viz. Group I (n=4) stabilization exercise regimen, Group II (n=4) conventional extension exercise regimen and Group III (n=4) control. The two experimental groups participated in four weeks of treatment program, five times a week. Outcome was based on self reported pain (visual analogue scale), disability (Ronald and Morris disability questionnaire) and custom made barobag testing of transversus abdominis measured immediately before and after intervention program. Outcome measures of self-reported pain and disability were reduced for both experimental groups. Furthermore, motor control deficit was reduced in stabilization exercise group after intervention period.

2.3 Reviews related to Stretching exercises as a remedy for non specific chronic low back pain

Although manual and movement-based therapies utilizing tissue stretch have shown some therapeutic benefits in clinical trials of low back pain\textsuperscript{25} the mechanisms of these treatments and their underlying pathological substrates are poorly understood. Recently, lumbar paravertebral soft tissues including non-specialized connective tissues have emerged as potentially important components in the pathophysiology of low back pain. Ultrasound imaging has revealed that altered thoracolumbar connective tissue thickness and echogenicity are associated with chronic low back pain, suggesting the presence of inflammation or fibrosis.\textsuperscript{26} Nonspecialized connective tissues in the low back of rodents have intrinsic sensory innervations\textsuperscript{27} and animal models show that
inflammation of other types of connective tissues can be involved in the persistence of pain.  

In addition to its potential role in chronic pain, an important characteristic of connective tissue is its responsiveness to mechanical stimulation. In particular, recent evidence suggests that low amplitude static (non-cyclical) stretching may have beneficial antifibrotic and antiflammatory effects.

França FR et al. (2012) investigated Effects of muscular stretching and segmental stabilization on functional disability and pain in patients with chronic low back pain. OBJECTIVE: a randomized, controlled trial. The purpose of this study was to compare the effects of 2 exercise programs, segmental stabilization exercises (SSEs) and stretching of trunk and hamstrings muscles, on functional disability, pain, and activation of the transversus abdominis muscle (TrA), in individuals with chronic low back pain. METHODS: A total of 30 participants were enrolled in this study and randomly assigned to 1 of 2 groups as a function of intervention. In the segmental stabilization group (SS), exercises focused on the TrA and lumbar multifidus muscles, whereas in the stretching group (ST), exercises focused on stretching the erector spinae, hamstrings, and triceps surae. Severity of pain (visual analog scale and McGill pain questionnaire) and functional disability (Oswestry disability questionnaire) and TrA muscle activation capacity (Pressure Biofeedback Unit, or PBU) were compared as a function of intervention. Interventions lasted 6 weeks, and sessions happened twice a week (30 minutes each). Analysis of variance was used for intergroup and intragroup comparisons. RESULTS: As compared with baseline, both treatments were effective in relieving pain and improving disability (P < .001). Those in the SS group had significantly higher gains for all variables. The stretching group did not effectively activate the TrA (P = .94). CONCLUSION: Both techniques improved pain and reduced disability. In this study, SS was superior to muscular stretching for the measured variables associated with chronic low back pain.

Corey SM et al. (2012) investigated stretching of the back improves gait, mechanical sensitivity and connective tissue inflammation in a rodent model. The role played by nonspecialized connective tissues in chronic non-specific low back pain is not well understood. In a recent ultrasound study, human subjects with chronic low back pain had altered connective tissue structure compared to human subjects without low back pain, suggesting the presence of inflammation and/or fibrosis in the low back.
pain subjects. Mechanical input in the form of static tissue stretch has been shown in vitro and in vivo to have anti-inflammatory and anti-fibrotic effects. To better understand the pathophysiology of lumbar nonspecialized connective tissue as well as potential mechanisms underlying therapeutic effects of tissue stretch, the developed a carrageenan-induced inflammation model in the low back of a rodent. Induction of inflammation in the lumbar connective tissues resulted in altered gait, increased mechanical sensitivity of the tissues of the low back, and local macrophage infiltration. Mechanical input was then applied to this model as in vivo tissue stretch for 10 minutes twice a day for 12 days. In vivo tissue stretch mitigated the inflammation-induced changes leading to restored stride length and intrastep distance, decreased mechanical sensitivity of the back and reduced macrophage expression in the nonspecialized connective tissues of the low back. This study highlights the need for further investigation into the contribution of connective tissue to low back pain and the need for a better understanding of how interventions involving mechanical stretch could provide maximal therapeutic benefit. This tissue stretch research is relevant to body-based treatments such as yoga or massage, and to some stretch techniques used with physical therapy.

Grunnesjö MI et al. (2011)34 have done a randomized controlled trial of the effects of muscle stretching, manual therapy and steroid injections in addition to 'stay active' care on health-related quality of life in acute or subacute low back pain. Objective: To evaluate the health-related quality of life effects of muscle stretching, manual therapy and steroid injections in addition to 'stay active' care in acute or subacute low back pain patients. STUDY DESIGN: A randomized, controlled trial during 10 weeks with four treatment groups. SETTING: Nine primary health care and one outpatient orthopaedic hospital department. SUBJECTS: One hundred and sixty patients with acute or subacute low back pain. INTERVENTIONS: Ten weeks of 'stay active' care only (group 1), or 'stay active' and muscle stretching (group 2), or 'stay active', muscle stretching and manual therapy (group 3), or 'stay active', muscle stretching, manual therapy and steroid injections (group 4). MAIN MEASURES: The Gothenburg Quality of Life instrument subscales Well-being score and Complaint score. RESULTS: In a multivariate analysis adjusted for possible outcome affecting variables other than the treatment given Well-being score was 68.4 (12.5), 72.1 (12.4), 72, 3 (12.4) and 72.7 (12.5) in groups 1-4, respectively (P for trend <0.05). There were significant trends for the well-being components patience (P < 0.005), energy (P < 0.05), mood (P < 0.05) and family situation
(P < 0.05). The remaining two components and Complaint score showed a non-significant trend towards improvement. CONCLUSION: The effects on health-related quality of life were greater the larger the number of treatment modalities available. The 'stay active' treatment group, with the most restricted number of modalities, had the most modest health-related quality of life improvement, while group 4 with the most generous choice of treatment modalities, had the greatest improvement.

**Purepong N et al. (2012)** investigated Effect of flexibility exercise on lumbar angle: a study among non-specific low back pain patients. The study investigated the influence of lumbar flexibility exercise on the lumbar angle among patients with non-specific low back pain (LBP). Pre-experimental one-group pretest-posttest design trial was conducted at Health Service Center, Chulalongkorn University, Thailand. Thirty-five non-specific LBP patients with limitation in lower back range of motion and without neurological deficits were recruited (based on the LBP guidelines by RCGP 1999). Lumbar flexibility exercise program developed based on McKenzie therapy was performed individually each day for 2 weeks. Patients attended an exercise program daily in the first week under the supervision of a physiotherapist. The exercise program consisted of 7 sets a day (3-2-2 in the morning-afternoon-evening) in series of 10 repetitions for each set for 2 weeks. Lumbar angle was measured at the beginning and at the end of 2 weeks in order to determine the range of motion improved. The results indicated that the low back pain symptom improved as well as the angle.

**Kamioka H et al. (2011)** investigated Effectiveness of intervention for low back pain in female caregivers in nursing homes: a pilot trial based on multicenter randomization. Objective: Although the importance of stretching exercise for pain-relieving and patient education is well documented for chronic lumbago patients, it is uncertain how effective on-the-job training (OJT) is for female caregivers in nursing homes. In the present pilot trial based on multicenter randomization, we evaluated the intervention effect of a lecture and stretching exercise on caregivers in nursing homes. METHODS: Eighty-eight female caregivers (four nursing homes) volunteered to participate in this study, and they were separated into two groups randomly. For the intervention group, guidance by an orthopedist and an exercise instructor were provided as one OJT, and stretching exercises for only 6 min every day were recommended for low back pain prevention to the caregivers. Low back pain visual analogue scale (VAS), physical fitness, and mental and physical health were compared at baseline and
immediately after the intervention. RESULTS: A total of 29 (33%) participants withdrew by 12 weeks. Regarding the reasons for withdrawal, 28 participants resigned, and one took a leave of absence due to exacerbation of lumbago. Adherence to the stretching exercises was 2.3 ± 1.3 (mean ± SD) times per week. No significant differences were seen for any outcome measurements. The high adherence group (≧3 times per week) did not show a change in the VAS, but the low adherence group (<3 times per week) and control group showed a tendency towards an increased score (p = 0.068). CONCLUSIONS: Even with the conduct of one OJT, and exercises of only 6 min every day, the adherence of caregivers was low, and there appeared to be few effects of the OJT.

Shirado O et al. (2010)\textsuperscript{37} evaluated the effect of home-based exercise on patients with chronic low back pain. STUDY DESIGN: Prospective, randomized, controlled trial. OBJECTIVE: To investigate the effectiveness of home-based exercise on pain, dysfunction, and quality of life (QOL) in Japanese individuals with chronic low back pain (CLBP). SUMMARY OF BACKGROUND DATA: Exercise therapy is a widely used treatment for CLBP in many countries. The studies on its effectiveness have been performed only in Western industrialized countries. The existence of cross-cultural differences and heterogeneity of patients in each country may influence the outcome of interventions for CLBP. Data that would enable researchers to compare the effectiveness of interventions between widely different societies is lacking. METHODS: A total of 201 patients with nonspecific CLBP were randomly assigned to either the control or exercise therapy group: 89 men and 112 women with a mean age of 42.2 years. The control group was treated with nonsteroidal anti-inflammatory drugs (NSAIDs), and the exercise group performed trunk muscle strengthening and stretching exercises. The primary outcome measures were pain intensity (visual analogue scale) and dysfunction level (Japan Low back pain Evaluation Questionnaire [JLEQ] and Roland-Morris Disability Questionnaire [RDQ]) over 12 months. The secondary outcome measure was FFD (Finger-floor distance). Statistical analysis was performed using Wilcoxon signed-ranks and Mann-Whitney U tests, and estimation of the median with 95% CI was calculated. RESULTS: In both groups, significant improvement was found at all points of follow-up assessment. However, JLEQ and RDQ were significantly more improved in the exercise group compared to the control group (P = 0.021 in JLEQ, P = 0.023 in RDQ). The 95% CI for the difference of medians of the change ratio between exercise and
NSAID groups, [Exercise]- [NSAID], was -0.25 to -0.02 in JLEQ, -0.33 to 0.00 in RDQ, and -0.20 to 0.06 in visual analogue scale. CONCLUSION: The home-based exercise prescribed and monitored by board-certified orthopedic surgeons was more effective than NSAIDs for Japanese patients with CLBP.

Yozbatiran N et al. (2004)\textsuperscript{38} studied the Effects of fitness and aquafitness exercises on physical fitness in patients with chronic low back pain. The Pain Clinic randomized 30 patients to: 1) aquatic exercise (n=15) or; 2) land-based exercise (n=15). Both groups followed similar programs, which included warm-up, stretching, a circuit of 15 progressive exercises, cool down with light stretching and light aerobic exercise. Sessions were conducted 3 times a week for 4 weeks. In both groups pain disability was decreased and motor fitness was increased, but no significant differences were found between the groups with regards to aerobic fitness, motor fitness (single leg balance test with eyes open or closed), and musculoskeletal fitness, pain reports, Sorensen and Oswestry low back pain disability index scores.

Ferreira ML et al. (2007)\textsuperscript{39} compared general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain. Practice guidelines recommend various types of exercise and manipulative therapy for chronic back pain but there have been few head-to-head comparisons of these interventions. Two hundred and forty adults with non-specific low back pain 3 months were allocated to groups that received 8 weeks of general exercise, motor control exercise or spinal manipulative therapy. General exercise included strengthening, stretching and aerobic exercises. Motor control exercise involved retraining specific trunk muscles using ultrasound feedback. Spinal manipulative therapy included joint mobilization and manipulation. Primary outcomes were patient-specific function (PSFS, 3-30) and global perceived effect (GPE, -5 to 5) at 8 weeks. These outcomes were also measured at 6 and 12 months. Follow-up was 93% at 8 weeks and 88% at 6 and 12 months. The motor control exercise group had slightly better outcomes than the general exercise group at 8 weeks (between-group difference: PSFS 2.9, 95% CI: 0.9-4.8; GPE 1.7, 95% CI: 0.9-2.4), as did the spinal manipulative therapy group (PSFS 2.3, 95% CI: 0.4-4.2; GPE 1.2, 95% CI: 0.4-2.0). The groups had similar outcomes at 6 and 12 months. Motor control exercise and spinal manipulative therapy produce slightly better short-term function and perceptions of effect than general exercise, but not better medium or long-term effects, in patients with chronic non-specific back pain.
Sebnem, K and Birkan, S. T (2007)\textsuperscript{40} investigated the effects of three therapeutic approaches in the chronic low back pain on pain, spinal mobility, disability, psychological state, and aerobic capacity. Sixty patients with chronic low back pain were randomized to three groups: group 1, aerobic exercise + home exercise (Stretching); group 2, physical therapy (hot pack, ultrasound, TENS) + home exercise; group 3, home exercise only. Spinal mobility, pain severity, disability, and psychological disturbance of the patients were assessed before and after the treatment and at 1-month follow-up. Aerobic capacities of the patients were measured before and after treatment. All of the groups showed similar decrease in pain after the treatment and at 1-month follow-up, and there was no significant difference between the groups. In group 2, a significant decrease in Beck Depression Inventory scores was observed with treatment. At 1-month follow-up, group 1 and 2 showed significant decreases in General Health Assessment Questionnaire scores. In group 2, there was also a significant improvement in Roland Morris Disability scores. There were similar improvements in exercise test duration and the MET levels in all the three groups. All of the three therapeutic approaches were found to be effective in diminishing pain and thus increasing aerobic capacity in patients with chronic low back pain. On the other hand, physical therapy + home exercise was found to be more effective regarding disability and psychological disturbance.

Ayse K et al. (1999)\textsuperscript{41} investigated and compared the efficacy of aerobic exercises versus strengthening, stretching and mobilization exercises in patients with sub acute or chronic low back pain. Forty patients were recruited for the study and randomly allocated to two groups. All patients were evaluated at admission, mid-treatment and termination of the program by visual analog scale (VAS), face scale, weekly analgesic intake and Million visual analog scales for pain. They were also scored by Roland-Morris scale and Oswestry scale for functional impairment. Beck depression inventory was used to evaluate depression and lumbar range of motion was measured by inclinometry, Schober, finger tip to floor distance. The aerobic exercise group was also evaluated for VO2\textsubscript{max} and anaerobic threshold levels. Both groups showed significant improvement in all parameters at termination. Comparison between groups showed a higher significant improvement in depression and functional improvement parameters in the group given strengthening, stretching and mobilization exercises by physiatrist.
2.4 Reviews Related to research reliability of the measurement tools used for this study

Koppenhaver SL et al. (2009) investigated Reliability of rehabilitative ultrasound imaging of the transversus abdominis and lumbar multifidus muscles. Objective: To evaluate the intraexaminer and interexaminer reliability of rehabilitative ultrasound imaging (RUSI) in obtaining thickness measurements of the transversus abdominis (TrA) and lumbar multifidus muscles at rest and during contractions. DESIGN: Single-group repeated-measures reliability study. SETTING: University and orthopedic physical therapy clinic. PARTICIPANTS: A volunteer sample of adults (N=30) with current nonspecific low back pain (LBP) was examined by 2 clinicians with minimal RUSI experience. INTERVENTIONS: Not applicable. MAIN OUTCOME MEASURES: Thickness measurements of the TrA and lumbar multifidus muscles at rest and during contractions were obtained by using RUSI during 2 sessions 1 to 3 days apart. Percent thickness change was calculated as thickness (contracted)-thickness (rest)/thickness (rest). Intraclass correlation coefficients (ICC) were used to estimate reliability. RESULTS: By using the mean of 2 measures, intraexaminer reliability point estimates (ICC (3, 2)) ranged from 0.96 to 0.99 for same-day comparisons and from 0.87 to 0.98 for between-day comparisons. Inter examiner reliability estimates (ICC (2, 2)) ranged from 0.88 to 0.94 for within-day comparisons and from 0.80 to 0.92 for between-day comparisons. Reliability estimates comparing measurements by the 2 examiners of the same image (ICC (2,2)) ranged from 0.96 to 0.98. Reliability estimates were lower for percent thickness change measures than the corresponding single thickness measures for all conditions. CONCLUSIONS: RUSI thickness measurements of the TrA and lumbar multifidus muscles in patients with LBP, when based on the mean of 2 measures, are highly reliable when taken by a single examiner and adequately reliable when taken by different examiners.

Koppenhaver SL et al. (2009) investigated the effect of averaging multiple trials on measurement error during ultrasound imaging of transversus abdominis and lumbar multifidus muscles in individuals with low back pain. Study design: Clinical measurement, reliability study. OBJECTIVES: To investigate the improvements in precision when averaging multiple measurements of percent change in muscle thickness of the transversus abdominis (TrA) and lumbar multifidus (LM) muscles. BACKGROUND: Although the reliability of TrA and LM muscle thickness measurements
using rehabilitative ultrasound imaging (RUSI) is good, measurement error is often large relative to mean muscle thickness. Additionally, percent thickness change measures incorporate measurement error from both resting and contracted conditions. METHODS: Thirty volunteers with nonspecific low back pain participated. Thickness measurements of the TrA and LM muscles were obtained using RUSI at rest and during standardized tasks. Percent thickness change was calculated with the formula thickness(contracteds) - thickness(rest)/thickness(rest). Standard error of measurement (SEM) quantified precision when using 1 or a mean of 2 to 6 consecutive measurements. RESULTS: Compared to when using a single measurement, SEM of both the TrA and LM decreased by nearly 25% when using a mean of 2 measures, and by 50% when using the mean of 3 measures. Little precision was gained by averaging more than 3 measurements. CONCLUSION: When using RUSI to determine percent change in TrA and LM muscle thickness, intra examiner measurement precision appears to be optimized by using an average of 3 consecutive measurements.

Wallwork TL et al. (2007) investigated Intrarater and interrater reliability of assessment of lumbar multifidus muscle thickness using rehabilitative ultrasound imaging. Study design: Within-session intrarater and interrater reliability study. OBJECTIVE: To establish the intrarater and interrater reliability of thickness measurements of the multifidus muscle in a parasagittal plane, conducted by an experienced ultrasound operator and a novice assessor. BACKGROUND: There is considerable evidence for the important role of the multifidus muscle in segmental stabilization of the lumbar spine. The cross-sectional area of the multifidus muscle has been assessed in healthy subjects and patients with low back pain using real-time ultrasound imaging. However, few studies have measured the thickness of the multifidus muscle using a parasagittal view. METHODS AND MEASURES: The thickness of the multifidus muscle was measured at rest, using real-time ultrasound imaging, in 10 subjects without a history of low back pain, at the levels of the L2-3 and L4-5 zygapophyseal joints. The measure was carried out 3 times at each level by 2 assessors (1 experienced, 1 novice). Intrarater (model 3) and interrater (model 2) reliability was assessed by calculation of an F statistic (analysis of variance), the intraclass correlation coefficient (ICC), and the standard error of measurement (SEM). RESULTS: On the basis of an average of 3 trials, the 2 operators showed very high interrater agreement on the measurement of thicknesses at the L2-3 level (ICC2,3 ==
Interrater reliability was relatively lower for the L2-3 level (ICC2,1 = 0.85; 95% CI: 0.51 to 0.96) than the L4-5 level (ICC2,1 = 0.87; 95% CI: 0.52 to 0.97) when a single trial per rater was used, but these values still indicated a high level of agreement. In addition, the novice and experienced operator produced reliable intrarater measurements at L2-3 (ICC3,1 = 0.89; 95% CI: 0.72 to 0.97 and 0.94; 95% CI: 0.86 to 0.99) and at L4-5 (ICC3,1 = 0.88; 95% CI: 0.68 to 0.97 and 0.95; 95% CI: 0.86 to 0.99), with no systematic differences in muscle size across trials (P > .05). The consistently low SEM values also indicate low measurement error. CONCLUSION: A novice and an experienced assessor were both able to reliably perform this measure at rest for 2 vertebral levels using real-time ultrasound imaging. An average of 3 trials produced higher interrater reliability scores, though using a single trial per rater was also reliable.

Cliona O’Sullivan et al. (2009) did the study; The purpose of the study was to establish the validity of Rehabilitative Ultrasound Imaging (RUSI) against Magnetic Resonance Imaging (MRI) for measuring trapezius muscle thickness. Participants were asymptomatic subjects recruited from Trinity College Dublin and associated teaching hospitals. Four MRI axial slices were made through each of the C6, T1, T5 and T8 spinous processes, with the subject supine. RUSI was performed immediately after MRI at the same vertebral levels, with the subject prone. Linear measurements of trapezius muscle thickness were made off-line on both the MRI and Ultrasound scans, in three regions: lower, middle and upper trapezius. Bland and Altman limits of agreement and Pearson's correlation coefficient were used to analyse the relationship between thickness measures taken from MRI and RUSI. Eighteen subjects (9 women) participated, (age-range 21–42 years). Results demonstrated good agreement between MRI and RUSI measurements of the lower trapezius muscle at T8 (r = 0.77) and moderate agreement at T5, (r = 0.62). Results were poor for the middle (T1) and upper (C6) trapezius muscles, (r = −0.22 to 0.52) but may be explained by differences in both positioning and imaging planes between the 2 modalities. It was concluded that RUSI is a valid method of measuring lower trapezius muscle thickness.

Barbara Cagnie et al. (2009) investigated Validity and reliability of ultrasonography for the longus colli in asymptomatic subjects. The purposes of this study were to evaluate the reliability and validity of ultrasound (US) for measuring the cross-sectional
area (CSA) of the longus colli (LC) as compared with magnetic resonance imaging (MRI), and to determine the change in CSA of the LC during contraction. 27 healthy volunteers participated in the study. In order to assess the validity of US, the US measurements of the CSA of the LC were compared to those determined with MRI. Two testers established the measurements to ascertain intra- and interrater reliability. The widely spaced limits of agreement (2SD = ±0.45) reflect the large variability between the measurements by US and MRI. The ICC for the intra- and interrater reliability for the CSA of the LC was respectively 0.71 (95% CI, 0.57–0.81; SEM, 0.17; SDD, 0.48) and 0.68 (95% CI, 0.48–0.81; SEM, 0.18; SDD, 0.50). The CSA of the LC increased significantly during contraction of the LC (p = 0.006). Results from this study show that the validity and reliability of US to evaluate the CSA of the LC is questionable, which may be due to both anatomical characteristics and methodological limitations.

Leila Ghamkhar et al. (2010) have done a literature review about Application of rehabilitative ultrasound for the assessment of low back pain. Low back pain (LBP) is one of the most common work-related conditions affecting all populations both in industrialized and non-industrialized countries, with reported high prevalence and incidence rates and huge direct and indirect costs. Among various suggested causes of LBP, dysfunction of back muscles, particularly lumbar multifidus and transverse abdominis, has been the subject of considerable research during last decades. Of the available imaging techniques, ultrasound (US) imaging technique is increasingly used to assess muscle dimensions and function as a valid, reliable and non-invasive approach. The purpose of the present study was to review the previously published studies (1990e2009) concerning the merit of US imaging of lumbar and abdominal muscles with particular attention to its clinical application in patients with LBP. Studies showed wide variation in terms of methodology, sample size, procedure, definition of LBP, heterogeneous sample, method of analyzing US imaging, US imaging parameters, etc. However, a convincing body of evidence was identified that supports US imaging as a reliable and valid tool both to differentiate patients with LBP from normal subjects and to monitor the effect of rehabilitation programs.

J.M. McMeeken et al. (2004) investigated the relationship between EMG and change in thickness of transversus abdominis. Objective: To investigate the relationship between changes in thickness and EMG activity in the transversus abdominis muscle of healthy subjects and the reliability of ultrasound measurements using different modes
and transducers. Design: Convenience sampling. Background: Chronic low back pain is associated with transversus abdominis dysfunction but EMG studies of this muscle are restricted to invasive techniques. Since the thickness of transversus abdominis changes with activity, such changes measured from ultrasound images might provide insight into this muscle's function non-invasively. In addition, little is known about the comparability of ultrasound measurements from different modes and transducers, nor the reliability of transversus abdominis measurements. Methods: In 9 healthy subjects (aged 29–52 years, four male) transversus abdominis was studied at rest and during activity (5–80% max) with simultaneous EMG and ultrasound (M mode, 5 MHz curvilinear transducer) measurements. Intra-rater reliability for thickness measurements was studied on 13 subjects using 7.5 MHz linear and 5 MHz curvilinear transducers in B and M modes. Results: Muscle thickness changes correlated well with EMG activity (P < 0.001, R² = 0.87) and there were no significant differences between subjects (P > 0.05). Using 7.5 MHz head, the ICC for B mode was 0.989 and for M mode was 0.981 for between days reliability. The ICC for between transducer reliability was 0.817. Conclusions: Changes in thickness of transversus abdominis can be used to indicate changes in the electrical activity in this muscle.

M Tousignant et al. (2005) investigated The Modified–Modified Schober Test for range of motion assessment of lumbar flexion in patients with low back pain: A study of criterion validity, intra- and inter-rater reliability and minimum metrically detectable change. Purpose: The objective was to estimate the psychometric properties of the Modified–Modified Schober Test (MMST). Design: This study compared range of motion measurements of lumbar flexion in low back pain (LBP) patients using the MMST with measurements calculated on X-rays as the gold standard, and compared the measurements taken by two independent examiners. Method: This study was conducted at the main hospital in the Outaouais area, Quebéc, Canada. Thirty-one subjects with LBP from private and public clinics participated in the study. After a warm-up session, measurements with the MMST were taken in neutral position and an X-ray technician took an exposure in the same position. Results: Pearson's correlation test (r) between measurements made with the MMST and the gold standard, intra-class correlation coefficient (ICC), minimum metrically detectable change (MMDC) and confidence interval (CI) were used to analyze the data. The MMST demonstrated moderate validity (r=0.67; 95%CI 0.44–0.84), excellent reliability (intra: ICC=0.95; 95%CI 0.89–0.97;
inter: ICC = 0.91; 95% CI 0.83–0.96) and a MMDC of 1 cm. Conclusions: In our sample of LBP patients, the MMST showed moderate validity but excellent reliability and MMDC.

Renee Williams et al. (1993)\textsuperscript{50} investigated Reliability of the Modified-Modified Schober and Double Inclinometer Methods for Measuring Lumbar Flexion and Extension. Background and Purpose: The primary purpose of this study was to determine the reliability of lumbar flexion and extension range-of motion measurements obtained with the modified-modified Schober and the double inclinometer methods on subjects with low back pain. Subjects: Fifteen patients (8 women, 7 men), aged 25 to 53 years (X = 35.7, SD = 99), with chronic low back pain were measured by three physical therapists with 3 to 12 years (0.1 = 8.3, SD = 4.7) of clinical experience. Methods: The therapists used the modified-modified Schober and double inclinometer techniques to measure, in random order and on two occasions, the subjects' lumbar flexion and extension. Results: Pearson Product Moment Correlation Coefficients for test-retest reliability for the modified-modified Schober technique varied from .78 to .89 for lumbar flexion and from .69 to .91 for extension; for the double inclinometer method, Pearson correlation coefficients varied from .13 to .87 for lumbar flexion and from .28 to .66 for extension. Analysis of variance-derived intraclass correlation coefficients for interrater reliability for the modified-modified Schober technique were .72 for flexion and .76 for extension; for the double inclinometer technique, they were .60 for flexion and .48 for extension. Conclusion and Discussion: The modified-modified Schober method thus appears to be a reliable method for measuring lumbar flexion and extension for patients with low back pain, whereas the double inclinometer technique needs improvement.

Boonstra AM et al. (2008)\textsuperscript{51} investigated Reliability and validity of the visual analogue scale for disability in patients with chronic musculoskeletal pain. To determine the reliability and concurrent validity of a visual analogue scale (VAS) for disability as a single-item instrument measuring disability in chronic pain patients was the objective of the study. For the reliability study a test-retest design and for the validity study a cross-sectional design was used. A general rehabilitation centre and a university rehabilitation centre was the setting for the study. The study population consisted of patients over 18 years of age, suffering from chronic musculoskeletal pain; 52 patients in the reliability study, 344 patients in the validity study. Main outcome measures were as follows. Reliability study: Spearman's correlation coefficients (rho values) of the test and retest data of the VAS for disability; validity study: rho values of the VAS disability scores with
the scores on four domains of the Short-Form Health Survey (SF-36) and VAS pain scores, and with Roland-Morris Disability Questionnaire scores in chronic low back pain patients. Results were as follows: in the reliability study rho values varied from 0.60 to 0.77; and in the validity study rho values of VAS disability scores with SF-36 domain scores varied from 0.16 to 0.51, with Roland-Morris Disability Questionnaire scores from 0.38 to 0.43 and with VAS pain scores from 0.76 to 0.84. The conclusion of the study was that the reliability of the VAS for disability is moderate to good. Because of a weak correlation with other disability instruments and a strong correlation with the VAS for pain, however, its validity is questionable.

Bayar et al. (2003)\(^{52}\) investigated Reliability and construct validity of the Oswestry Low Back Pain Disability Questionnaire in the elderly with low back pain. The purpose of this study was to examine the validity and reliability of the Oswestry Low Back Pain Disability Questionnaire (ODQ) in the elderly with low back pain (LBP). Design: Validation of the ODQ in the elderly with LBP. Subjects: Twenty-nine elderly with LBP were included in the study. Methods: ODQ, Roland-Morris Disability Questionnaire (RMQ), lumbar mobility testing and visual analogue scale (VAS) were used as validity study for each elder and tests were repeated seven days later. Results: Scores of the two ODQ were 48.76 (SD = 17.02) on day one and 51.24 (SD = 15.20) on day seven, respectively, with an intraclass correlation coefficient of 0.93 (\(p = 0.000\)). Cronbach's was 0.722 on day one and 0.717 on day seven. Concurrent validity was measured by comparing ODQ responses with the result of VAS and flexibility were \(r = 0.53, p = 0.003\) and \(r = 0.03, p > 0.05\) for day one, and \(r = 0.48, p = 0.002, r = -0.03, p > 0.05\) for day seven respectively. Construct validity, tested by the correlation between the Turkish ODQ and the Turkish adaptation of the RMQ yielded \(r = 0.66, p = 0.000\) on day one and \(r = 0.78, p = 0.000\) on day seven. Conclusion: The ODQ seems to be a reliable and valid questionnaire for assessing the disability of elderly patients with LBP.

Tousignant M et al. (2005)\(^{53}\) investigated The Modified-Modified Schober Test for range of motion assessment of lumbar flexion in patients with low back pain. Purpose: The objective was to estimate the psychometric properties of the Modified-Modified Schober Test (MMST). DESIGN: This study compared range of motion measurements of lumbar flexion in low back pain (LBP) patients using the MMST with measurements calculated on X-rays as the gold standard, and compared the measurements taken by two independent examiners. METHOD: This study was
conducted at the main hospital in the Outaouais area, Quebéc, Canada. Thirty-one subjects with LBP from private and public clinics participated in the study. After a warm-up session, measurements with the MMST were taken in neutral position and an X-ray technician took an exposure in the same position. RESULTS: Pearson's correlation test (r) between measurements made with the MMST and the gold standard, intra-class correlation coefficient (ICC), minimum metrically detectable change (MMDC) and confidence interval (CI) were used to analyze the data. The MMST demonstrated moderate validity (r=0.67; 95%CI 0.44-0.84), excellent reliability (intra: ICC=0.95; 95%CI 0.89-0.97; inter: ICC=0.91; 95%CI 0.83-0.96) and a MMDC of 1 cm. CONCLUSIONS: In our sample of LBP patients, the MMST showed moderate validity but excellent reliability and MMDC.
Reference


