CHAPTER 4

What effect do core strength and stability have on injury prevention and recovery?

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Introduction

Over the past decade, the focus in sports rehabilitation and performance training has been on core strengthening and stability. Despite the recent gain in popularity, the concept of core strength is not new. As early as the 1920s, Joseph Pilates talked about developing a girdle of strength by recruiting the deep trunk muscles. Additionally, educational programs of various rehabilitation professions have historically taught the concept that stability of proximal segments is required for effective mobility of distal segments (e.g., a stable pelvis and trunk are needed for controlled movement at the knee and ankle).

Hodges and Richardson[1] popularized the term *core stability* in the late 1990s. They described the spine as inherently unstable and requiring active support from intra-abdominal pressure and tensioning of the thoracolumbar fascia and deep lumbar stabilizers. Thus, core strength is considered to be the muscular support about the lumbar spine necessary to achieve and maintain functional stability.[2] More recently, this has been expanded by some to include muscles of the hip[3] and even the scapulothoracic musculature as well.[4] Good core strength contributing to adequate core stability has been suggested to be necessary in maintaining the correct lumbar and pelvic posture and alignment during movement and sport, allowing for powerful extremity movements. Similarly, inadequate core strength leading to poor core stability may decrease biomechanical efficiency and increase the risk for injury.

With the incorporation of core strengthening exercises into injury prevention and rehabilitation programs, scientific investigation of its effects is beginning to grow. In this chapter, we will review the clinical and scientific evidence pertaining to core strengthening as it relates to two specific questions:

- Does core strength prevent injury?
- Does core strengthening enhance recovery from injury?

Methods

A comprehensive search of the peer-reviewed literature was conducted using the following databases: MEDLINE on PubMed (1966–May 2005), Cumulative Index to Nursing and Allied Health (CINAHL) on Ovid (1982–May 2005), SportDiscus on Ovid (1830–May 2005), Science Citation Index (1970–May 2005), HealthSTAR on Ovid (1975–May 2005),

Table 4.1 Search strategy of text words and subject headings for the MEDLINE (1966–2005) and CINAHL (1982–2005) databases. MEDLINE was accessed using the PubMed search engine. All searches (limited to human studies) were conducted in February 2005

Item	Search	Results					
		MEDLINE	CINAHL	SportDiscus	Cochrane reviews	Science Citation Index	HealthSTAR
1	Core OR lumbar OR trunk	156993	8351	3804	461	> 100,000	49645
2	Strength OR stability OR stabilization	243574	12342	24815	802	> 100,000	83318
3	Injury	571250	21321	34163	670	> 100,000	84240
4	1 AND 2 AND 3	722	47	23	52	98	130

and the Cochrane Database of Systematic Reviews on Ovid (volume 2, 2005) (Table 4.1). Due to the variety of terms that are used synonymously with *core strengthening* and *stability*, a comprehensive search strategy was developed (Table 4.1). Identified articles that used strengthening of core muscles as an intervention, involved a comparison group and assessed either risk of injury or recovery from injury were included for this analysis. Finally, reference lists of relevant articles were reviewed to identify any additional citations not found in our search of the databases.

Results

Of the identified references (Table 4.1), the majority investigated the effect of core strengthening and stabilization exercises on specific aspects of muscle physiology and function. As these studies were unrelated to injury prevention or recovery, they were excluded. Only 16 articles were directly related to injury prevention or rehabilitation and were therefore included in this review.

Does core strength prevent injury?

Several correlational studies have been conducted to establish a relationship between core muscle weakness and the likelihood of injury. In their frequently cited paper, Hodges and Richardson[1] observed a significant delay in the activation of the transversus abdominis muscle among individuals with low back pain (LBP) when performing simple reaching tasks while standing. The authors suggested that this delay was a motor control deficit resulting in inefficient muscular stabilization of the lumbar spine, possibly preceding the onset of LBP. A similar delay in activation of the obliquus internus abdominis, multifidus and gluteus maximus was observed on the symptomatic side of individuals with sacroiliac joint pain.[5] Further, Iwai and colleagues[6] demonstrated that trunk extensor isokinetic strength was significantly correlated to the disability level of LBP among collegiate wrestlers without radiological abnormalities in the lumbar region. With regard to lower extremity injury, Ireland *et al.*[7] identified a positive correlation between hip muscle weakness and patellofemoral pain in females. Subjects with patellofemoral pain demonstrated 26% less hip abduction isometric strength and 36% less hip external rotation isometric strength in comparison with age-matched women who were not symptomatic. Unfortunately, the study design utilized by the four investigations cited above does not allow one to determine if the delayed timing or muscle weakness was present prior to symptom onset.

The prospective design employed by two of the identified studies does allow such conclusions to be made. Over a 5-year prospective study, Lee *et al.*[8] identified trunk muscle weakness as a risk factor for LBP. On the basis of isokinetic strength testing (60°/s) performed at the start of the investigation, individuals who developed LBP displayed an imbalance between trunk extensor and flexor strength. Specifically, the trunk extension/flexion strength ratio was approximately 25% less in females who developed LBP in comparison with those who did not. Similar findings were present for males, in whom a 20% deficit was noted.

Using a 1-year prospective design, Nadler *et al.*[9] demonstrated a bilateral imbalance in isometric strength of the hip extensors was related to the development of LBP among females. This relationship did not exist among males, as no significant change in side-to-side strength was evident in males who developed LBP. Further, no significant association was noted between the development of LBP and hip abductor strength for either gender. Although this study involved 163 collegiate athletes (100 males and 63 females), only 13 developed LBP (eight males and five females) over the subsequent year, indicating that caution is necessary in generalizing these findings.

On the contrary, Leetun *et al.*[3] prospectively determined that athletes with greater hip abduction and external rotation strength were less likely to experience LBP or injury to the lower extremities. Core muscle strength and performance (isometric strength of hip abduction and external rotation, endurance of back extension and side-bridging and abdominal performance) was assessed in 139 college basketball and cross-country athletes (79 females and 60 males). After which, they were monitored for injury throughout their respective season. Of the 139 athletes, a total of 41 sustained back or lower extremity injuries. The injured athletes displayed significantly less hip abduction and external rotation strength in comparison with those who did not incur an injury. On the basis of a regression analysis, hip external rotation weakness was the only useful predictor of lower extremity or low back injury over the course of an athletic season.

While the findings from this article are important, it should be noted that the muscle groups traditionally considered as compromising the core (i.e., the abdominals and trunk extensors) were consistent between athletes whether they did or did not sustain an injury. Further, the authors equate core strength to that of core stability. The ability of the lumbopelvic region to resist perturbations (core stability) is not accurately represented through isometric strength testing of associated musculature. Although isometric testing does provide a measure of muscle strength, it does not reflect how or if that strength is used in a stabilizing manner. Thus, conclusions regarding the relationship between core stability and injury may be limited. Testing procedures utilized to measure core strength and stability need continued development in relationship to dynamic movements and sport specific positions. These developments could potentially bolster the early results found in this study.

On the basis of the correlational evidence that activation delay or weakness of the core muscles is related to LBP and lower extremity injury, interventions aimed at restoring core strength should therefore reduce the risk of injury. One study was identified that prospectively determined the effects of core strengthening and injury prevention. Nadler *et al.*[10]

concluded that the incorporation of a core strengthening program among Division I college athletes did not reduce the incidence of LBP. Injury incidence data among these athletes were compared between two academic years, 1998–1999 and 1999–2000. A core strengthening program was instituted at the start of the 1999–2000 academic year, with the injury data from the 1998–1999 academic year used as the control comparison. The incidence of LBP did not differ with the inclusion of the core strengthening program, as 8.5% of the athletes (14 of 164) developed LBP during the 1998–1999 year in comparison with 6% (14 of 236) during the 1999–2000 year. Additionally, the strengthening program had a similar response across genders, as neither the male or female athletes displayed a reduction in LBP incidence.

However, given the study design, caution should be used when considering the results. Of most concern is the lack of reporting of statistical power or sample size estimation. In addition, the inconsistent subject pools between academic years may have confounded the results. Although all athletes participated in core strengthening as it became part of each sport's conditioning program, subject participation in the study remained voluntary, with the number of subjects from the different sports not controlled. Thus, sports having a greater incidence of LBP may have been unequally represented between academic years. Confounding variables such as weather, game and practice schedules, game and practice planning and strategy, or other strength and conditioning programs instituted by the coaching staff may also limit the strength of the findings. Finally, there is some question as to whether the selected exercises constitute a core strengthening program. Only two of the seven exercises focused on strengthening the abdominal and back muscles, with all seven exercises limited to movement in the sagittal plane.

Two additional articles that investigate the effects of core strengthening and stabilization exercises in preventing injury recurrence were identified.[11,12] While likely having implications for injury prevention, these two articles will be discussed in the next section of this chapter.

Summary of key points

- Delay in activation of core muscles, especially the transversus abdominis, has been retrospectively correlated with LBP.
- Imbalance of the trunk flexors/extensors and/or bilateral hip extensors has been prospectively correlated with LBP.
- Weakness of the hip external rotators has been prospectively correlated with lower extremity injury.
- The use of a core strengthening exercise program to prevent LBP in college athletes was not supported.

Does core strengthening enhance recovery from injury?

Most of the evidence available for the use of core strength and stabilization during rehabilitation is related to the treatment of acute and chronic LBP. As the multifidus muscle weakness and inhibition has a known relationship to LBP, Hides *et al.*[13] employed a prospective experimental design to determine if the recovery of the multifidus muscle can be enhanced with core stabilizing exercises. Subjects experiencing acute, first-episode LBP were randomized into either a medical management group or a group receiving medical management and exercise therapy. The medical management included advice on bed rest, absence from work and prescription of medication, while the exercise therapy involved stabilization exercises designed to reeducate the multifidus muscle in combination with the transversus abdominis. While both groups achieved symptom remission in a similar time period, the multifidus muscle recovery was more rapid and complete in the exercise therapy group. Even with a return to full activity, the medical management group continued to show decreased multifidus muscle size at 10 weeks after the onset of symptoms.

The authors[13] suggested that persistent muscle atrophy was related to the high recurrence rate of LBP. Through continued monitoring of subjects over the subsequent 3 years, Hides *et al.*[12] demonstrated that the LBP recurrence rate was 30% in subjects receiving the core stabilization therapy, in comparison with 84% of those who only received the medical management. On the basis of the experimental design, the use of core stabilization exercise is certainly more beneficial in the management of acute LBP than without exercise. However, the relative effectiveness of core stabilization exercise in comparison with other commonly prescribed exercise therapies was not determined.

O'Sullivan *et al.*[14] performed such a comparison in the management of patients with chronic LBP secondary to spondylosis and spondylolisthesis. Subjects were randomized into either a core stabilization exercise group or a group receiving general exercise treatment. The core stabilization exercises involved contraction of the deep abdominal muscles and facilitation of co-activation of the lumbar multifidus muscle above the level of the pars interarticularis defect. Initially, these exercises were performed statically and then progressively incorporated into postures and activities previously known to aggravate the patient's symptoms. The general exercise treatment involved walking, swimming, and care under other medical providers, such as pain-relieving interventions (e.g., heat, massage, ultrasound) and supervised exercise programs.

In comparison with the general exercise treatment group, the core stabilization exercise group had a significant reduction in pain intensity and functional disability immediately after the 10-week intervention. More importantly, this group was able to maintain these levels over a 30-month follow-up period. The general exercise treatment group did not show a significant reduction in these factors at either the 10-week or 30-week follow-ups. The authors concluded that even when the basic morphology of the lumbar spine is compromised, as is the case with spondylosis and spondylolisthesis, the neuromuscular system can be trained to create dynamic stability.[14]

In another investigation comparing exercise programs among individuals with chronic LBP, Danneels *et al.*[15] suggested that a 10-week core stabilization exercise program offered no advantage over a more traditional progressive resistive exercise program of the same duration in increasing the cross-sectional area of the multifidus muscle. However, concern has been raised with both the performance of the core stabilization exercises and the technique employed to characterize the multifidus cross-sectional area.[16] Unfortunately, Danneels and colleagues[15] did not report the recurrence rate of LBP or the changes in either symptoms or functional disability levels, as improvement in all is the ultimate purpose of increasing the size of the multifidus muscle.

On the basis of data from Yilmaz *et al.*,[17] lumbar stabilization exercises were more effective in reducing pain and functional disability levels than traditional flexion–extension exercises among patients following lumbar microdiscectomy. However, it is important to note that the stabilization exercises were supervised by a physiotherapist, while the flexion–extension exercises were performed as an unmonitored home exercise program. Thus, observed differences may not be secondary to the specific exercises, but rather to the level of supervision and compliance.

In comparison to manual therapy alone, a 6-week stabilization exercise program was found to be more effective in reducing low back pain and improving function in patients with either acute or chronic LBP.[18] As others have noted,[12] the recurrence rate of LBP among those receiving core stabilization exercises was also lower.

With regard to the treatment of lower extremity injuries, core strengthening and stabilization was involved in two articles. Holmich *et al.*[19] demonstrated that individuals with long-standing adductor pain had less pain and improved sports performance after undergoing an active rehabilitation program that aimed at improving strength and coordination of the muscles acting on the pelvis, in comparison with individuals who completed a rehabilitation program consisting of modalities and stretching.

Sherry and Best[11] employed a prospective randomized clinical trial to compare two rehabilitation programs in the treatment of acute hamstring strain injuries. The rehabilitation program incorporating core stabilization exercises was found to be protective against the recurrence of hamstring strain injury. In the first 2 weeks after return to sports, none of the 13 athletes (0%) who had received the progressive agility and trunk stabilization exercises during the rehabilitation of their initial injury experienced a hamstring injury recurrence, in comparison with six of the 11 athletes (54.5%) who received isolated hamstring stretching and strengthening exercises. One year after the return to sports, the re-injury rate remained significantly lower.

While this study supports the view that the incorporation of core strengthening and stability can be effective in preventing recurrent hamstring strain, the mechanism for this reduction is not known. As measurements related to the assessment of trunk stabilization and neuromuscular control were not made, it is not possible to conclude that the results were due to changes in trunk stability, coordination, or other aspects of motor control. More research is needed to quantify changes in muscle activation and response times of the trunk and pelvis that may occur from these types of rehabilitation programs.

Summary of key points

- Core stabilization exercises are effective in restoring the size and activation of the multifidus muscles in patients with acute LBP.
- Treatment programs including core stabilization were found to be more effective than manual therapy alone, medical management alone, and other common exercise programs in reducing pain and improving functional disability associated with acute and chronic LBP.
- Core stabilization exercises are more effective in reducing the recurrence of LBP and hamstring strain injuries in comparison with other exercise programs.

Discussion

The objective of this chapter was to review the clinical and scientific evidence pertaining to core strengthening as it relates to injury prevention and recovery. On the basis of our search strategies, 16 articles were identified and discussed, with seven of the 16 comparing core strengthening and stabilization exercises with other common types of exercise. Given our search of multiple databases, we believe it to be unlikely that we missed any prominent articles that would have significantly added to our findings. However, relevant articles not referenced in these databases may have been excluded from our review.

On the basis of the reviewed articles, LBP was the primary injury of concern with respect to core strengthening and stabilization. This is certainly not surprising, given the muscular control deficits observed with LBP and the related focus of these exercises. The clinical trials show strong promise for rehabilitation programs incorporating core strengthening exercise, both from an injury recovery and recurrence perspective. However, the studies investigating the use of these exercises in *preventing* LBP were predominantly observational in design and did not directly involve an intervention. Instead, subjects with known injuries were descriptively compared with control subjects with regard to specific strength and performance measures in the lumbar spine, pelvis and lower extremities. While such designs are useful in directing future studies, they do not allow for conclusions to be made regarding cause and effect.

As stated in the introduction to this chapter, the arguable success these exercises have had in treating LBP has led many to expand their use to treating injuries of the extremities. On the basis of the fact that biomechanically correct and efficient extremity movement cannot exist in the presence of an unstable pelvis and spine, core stabilization has been advocated for the treatment of such injuries as patellofemoral pain, iliotibial band syndrome, hamstring strain and postoperative rehabilitation of ligamentous reconstruction. While this appears to have theoretical merit, evidence addressing this application of core strengthening exercises was limited to two randomized controlled trials, both of which showed favorable results in treating acute hamstring strain[11] and hip adductor muscle pain.[19] Investigations involving the effects of core strengthening exercises on injuries more distal to the lumbopelvic region (e.g., patellofemoral pain) need to be conducted.

Certainly, it stands to reason that specific interventions may be more effective with specific patient types. It has been suggested that the equivocal or conflicting results observed in various investigations of exercise programs for nonspecific LBP may be related to the assumed homogeneity of the subjects. This has led others to investigate exercise treatment efficacy in defined subgroups within a particular diagnosis.[20,21] That is, not all patients with LBP can be grouped and treated uniformly. A patient experiencing LBP secondary to lumbar instability will likely respond favorably to different interventions than one with LBP secondary to hypomobility. It would be somewhat naïve to expect all individuals with LBP and lower extremity injury to require and benefit from a core strengthening and stabilization program. Thus, future studies may wish to identify the characteristics of those most likely to respond to core strengthening exercises.

The overall evidence either for or against the use of core strengthening exercises for injury prevention or rehabilitation is rather limited. While clinical experience appears to be providing motivation for the continued use of such exercises, systematically designed investigations are paramount in order to determine their effectiveness. In the end, this will allow the development of successful and efficient rehabilitation, injury prevention, and sports performance programs.

Sample examination questions

Multiple-choice questions (answers on page 602)

1 The primary injury investigated with respected to core strengthening and stabilization exercises is:
  A Iliotibial band syndrome
  B Patellofemoral pain syndrome
  C Low back pain
  D Hamstring strain injury

Table 4.2 Summary of clinical investigations involving core strength and injury prevention

Study	Design	Sample	Intervention	Results
Hodges and Richardson[1]	Case–control	Case: 15 patients with LBP Control: 15 age- and sex-matched healthy subjects	Not applicable	Transversus abdominis muscle activation was significantly delayed in patients with LBP
Hungerford *et al.*[5]	Case–control	Case: 14 males with sacroiliac joint pain Control: 14 age-matched healthy males	Not applicable	Activation onset of obliquus internus abdominis, multifidus and gluteus maximus was delayed on the symptomatic side of subjects with sacroiliac joint pain
Ireland *et al.*[7]	Case–control	Case: 15 females with patellofemoral pain Control: 15 asymptomatic age-matched females	Not applicable	Subjects with patellofemoral pain demonstrated 26% less hip abduction strength and 36% less hip external rotation strength
Iwai *et al.*[6]	Case–control	53 college wrestlers with LBP Case: 35 with radiologic abnormality Control: 18 without radiologic abnormality	Not applicable	Trunk extensor strength characteristics were correlated ($r = 0.28$–0.73) with the level of disability in the group of wrestlers without radiologic abnormality

Lee *et al.*[8]	5-yr prospective cohort	67 subjects without history of LBP	Not applicable	The 18 subjects that developed LBP had significantly reduced trunk extension/flexion strength ratio at baseline
Leetun *et al.*[3]	Prospective cohort	139 college basketball and cross-country athletes (79 females; 60 males)	Not applicable	Hip external rotation weakness was the only useful predictor for lower extremity or spine injury (OR 0.86)
Nadler *et al.*[9]	1-yr prospective cohort	163 Division I college athletes (63 females; 100 males)	Not applicable	13 athletes developed LBP. Bilateral asymmetry of hip extensor strength was predictive of LBP in females
Nadler *et al.*[10]	2-yr prospective cohort	164 Division I college athletes as a control group and 236 Division I college athletes the following year as an intervention group	Strengthening program performed 4–5 x/week (pre-season) and 2–3 x/ week (season). Exercises included: abdominal crunches, pelvic tilts, squats, lunges, leg press, hang cleans, dead lifts, isolated back extensions	No statistically significant reduction in the incidence of LBP among those participating in the core strengthening program (14/236) in comparison with those that did not (14/164)

LBP, low back pain.

Table 4.3 Summary of clinical investigations using core strengthening and stabilization exercises as part of the recovery from injury

Study	Design	Sample	Intervention	Results
Danneels *et al.*[15]	RCT	59 patients with chronic LBP	Subjects randomly assigned to: 1–10 weeks of stabilization exercises 2–10 weeks of stabilization exercises combined with dynamic resistance training 3–10 weeks of stabilization exercises combined with dynamic–static resistance training	Cross-sectional area of the multifidus muscle at L3 and L4 vertebral levels was significantly increased in group 3 only
Hides *et al.*[13]	RCT	39 patients with acute, first-episode, unilateral LBP and unilateral segmental inhibition of the multifidus	Subjects randomly assigned to: 1 medical management only 2 medical management and exercise therapy group involving stabilization exercises designed to re-educate the multifidus muscle in combination with the transversus abdominis muscle	Symptom remission occurred in a similar time period between groups, but the multifidus muscle recovery was more rapid and complete in the exercise therapy group
Hides *et al.*[12] (follow-up to Hides *et al.*[13])	3-yr prospective cohort	Case: subjects with LBP who received medical management and exercise therapy Control: subjects with LBP who were medically managed only	Same as Hides *et al.*[13]	LBP recurrence rate was 30% in subjects receiving the stabilization exercise therapy in comparison with 84% in the medical management only group

Holmich *et al.*[19]	RCT with blinded investigator	68 male athletes aged 18–50 with long-standing adductor pain	Subjects randomly assigned to: 1, active rehabilitation program aimed at improving strength and coordination of the muscles acting on the pelvis 2, rehabilitation program consisting of modalities and stretching	23/34 patients in the active rehabilitation group returned to sport without groin pain in comparison with 4/34 patients in the group receiving modalities and stretching
O'Sullivan *et al.*[14]	RCT with blinded investigator	44 subjects aged 16–49 with LBP secondary to spondylosis and spondylolisthesis greater than 3 months' duration	Subjects randomly assigned to: 1, core stabilization exercise group (abdominal and multifidus co-contraction) 2, general exercise treatment (swimming, walking, modalities and home exercise program)	Statistically significant reduction in pain intensity and functional disability levels, maintained up to a 30-month follow-up, in the core stabilization group
Sherry and Best[11]	RCT	24 athletes with an acute hamstring strain (6 females; 18 males)	Subjects randomly assigned to: 1, progressive agility and trunk stabilization program (n = 11) 2, isolated hamstring stretching and strengthening program (n = 13)	Significant decrease in hamstring injury recurrence at 2 weeks (0% vs. 54.5%) and 1 y (7.7% vs. 70%) following return to sport for subjects that received the progressive agility and trunk stabilization exercises. Early return to sport in the progressive agility and trunk stabilization group was not statistically significant
Yilmaz *et al.*[17]	RCT	42 patients aged 20–60 who had undergone first-time micro-discectomy for unisegmental lumbar disc herniation	Subjects randomly assigned to: 1, physical therapist–supervised dynamic lumbar stabilization exercises 2, written home exercise program of range-of-motion and trunk/abdominal strengthening exercises 3, no-exercise control group	Both exercise groups demonstrated improvements in pain, functional capacity, body strength, mobility and weight-lifting capacity. However, the gains were greater in those performing the lumbar stabilization exercise program.

LBP, low back pain; RCT, randomized controlled trial.

2 In the treatment of patients with low back pain, which muscle(s) is (are) frequently targeted through core stabilization exercises?
   A Multifidus
   B Erector spinae
   C Transversus abdominis
   D Both A and B
   E Both A and C
3 Which of the following statements is true concerning the evidence for core strength and lower extremity injury?
   A Weakness of the hip external rotators may be a useful predictor of lower extremity injury.
   B Females with patellofemoral pain often demonstrate hip abductor and external rotator weakness.
   C Incorporation of core stabilization exercises into the rehabilitation of acute hamstring strain injuries may significantly reduce the likelihood of re-injury.
   D All of the above.

Essay questions

1 Discuss the limitations associated with case–control design studies in determining the contribution of core strength to low back or lower extremity injury.
2 Create a list of exercises that would be considered core stabilization exercises. Each exercise must involve a stabilization component and not merely strengthening. Place in order of easiest to most difficult.
3 When considering the mechanism by which core stabilization exercises are beneficial, theorize whether it is predominantly due to gains in muscle force output or improved activation and coordination between muscles.

Case study 4.1

Joe Smith is a 16-year-old male diagnosed with plica syndrome of the left knee, who presented to physical therapy for evaluation and treatment. He is 1.93 m tall, weighs 117.5 kg, and has a body mass index of 31.5 kg/m^2. He reports that he gradually developed medial knee pain during the past basketball season. He denies any trauma, instability, swelling or locking episodes in his left knee. Magnetic resonance imaging (MRI) performed by the referring physician was read as normal. He does complain of some clicking/snapping medially, but very intermittent. On physical examination, he had a full knee range of motion, with 12° of hyperextension with tenderness to palpation over the superior medial plica. The ligament examination was negative, with mild patellar hypermobility without apprehension noted. Although he was well-developed for his age, manual muscle testing revealed slight weakness of the medial and lateral hip rotators and hip abductors. A McGill side-bridge position with proper alignment was maintained for 10 s. Mild to moderate medial deviation at the knee was observed in an attempt to stabilize his posture during single leg balance, single leg squat, and single leg landing.

After his initial evaluation, a rehabilitation program was initiated, emphasizing static core strength and stabilization, along with static balance exercises. This program included the McGill side bridge, supine bridging with hip external rotation resistance, four-point multifidus leg lift, prone planks, and single leg balance with the knee and hip slightly flexed.

When Joe was re-evaluated after 2 weeks he had improved his core strength and endurance. He could now hold the side bridge position for 20 s, his hip external and internal rotation strength was normal on single repetition testing but still fatigued quickly. He could control a single leg balance position for 20 s with minimal postural sway. The program was progressed to include single-leg half-squats, single-leg balance on an uneven surface, alternate leg lifting with his prone planks and side bridges, and trunk rotations in standing with band resistance.

After 3½ weeks of therapy, Joe was able to easily maintain the plank and side bridge alignment with alternate leg lifting for greater than 20 s. He had also significantly improved his alignment control with his single-leg squats, and now demonstrated good strength and endurance of the hip rotators. At this time, his program was transitioned to more dynamic sport-specific core strengthening and stabilization exercises, such as medicine-ball rotation throw and catch off the wall, medicine-ball lunge chops with trunk rotation, medicine-ball figure of eight, medicine-ball rotations in a half-squat and multiplanar leap–land balance drills.

After 5 weeks of therapy, Joe was not experiencing pain with his activities of daily living, rehabilitation exercises, or limited basketball shooting drills. He demonstrated excellent postural control with single-leg activities, along with improved timing and speed in the medicine-ball core drills. He was gradually returned to team practices over the next week, with eventual return to competitive basketball without medial knee pain. He continues to incorporate principles of core strengthening and stabilization into his independent strength and conditioning program for basketball.

Summarizing the evidence

Comparison	Results	Level of evidence
Core strength deficits and injury occurrence	6 case–control or cohort studies, 4 of moderate size, 3 prospective, core muscle weakness present in individuals who currently had or developed LBP or lower extremity injury	B
Core deficits and LBP prevention	1 prospective cohort study, moderate size, exercises did not reduce incidence of LBP	B
Core strengthening exercises and LBP rehabilitation	5 RCTs, 1 of moderate size, results in favor of exercises	A3
Core strengthening exercises and lower extremity injury rehabilitation	2 RCTs, 1 of moderate size, results in favor of exercises.	A3

LBP, low back pain; RCT, randomized controlled trial.
* A1: evidence from large randomized controlled trials (RCTs) or systematic review (including meta-analysis).†
A2: evidence from at least one high-quality cohort.
A3: evidence from at least one moderate-sized RCT or systematic review.†
A4: evidence from at least one RCT.
B: evidence from at least one high-quality study of nonrandomized cohorts.
C: expert opinions.
† Arbitrarily, the following cut-off points have been used: large study size: ≥ 100 patients per intervention group; moderate study size ≥ 50 patients per intervention group.

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Second Edition

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