The Spine Journal 8 (2008) 96–113

Evidence-informed management of chronic low back pain with lumbar extensor strengthening exercises

John Mayer, DC, PhD[a,b,c,*], Vert Mooney, MD[a,d], Simon Dagenais, DC, PhD[c,e]

[a]School of Physical Therapy and Rehabilitation Sciences, College of Medicine, University of South Florida, Tampa, FL, USA
[b]US Spine & Sport Foundation, 3444 Kearny Villa Rd, Ste 200, San Diego, CA 92123, USA
[c]CAM Research Institute, Irvine, CA, USA
[d]Department of Orthopaedic Surgery, School of Medicine, University of California, San Diego, CA, USA
[e]Division of Orthopaedic Surgery and Department of Epidemiology and Community Medicine, Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada

Received 27 September 2007; accepted 29 September 2007

Abstract **EDITORS' PREFACE:** The management of chronic low back pain (CLBP) has proven very challenging in North America, as evidenced by its mounting socioeconomic burden. Choosing among available nonsurgical therapies can be overwhelming for many stakeholders, including patients, health providers, policy makers, and third-party payers. Although all parties share a common goal and wish to use limited health-care resources to support interventions most likely to result in clinically meaningful improvements, there is often uncertainty about the most appropriate intervention for a particular patient. To help understand and evaluate the various commonly used nonsurgical approaches to CLBP, the North American Spine Society has sponsored this special focus issue of to *The Spine Journal*, titled Evidence-Informed Management of Chronic Low Back Pain Without Surgery. Articles in this supplement were contributed by leading spine practitioners and researchers, who were invited to summarize the best available evidence for a particular intervention and encouraged to make this information accessible to nonexperts. Each of the articles contains five sections (description, theory, evidence of efficacy, harms, and summary) with common subheadings to facilitate comparison across the 24 different interventions profiled in this special focus issue, blending narrative and systematic review methodology as deemed appropriate by the authors. It is hoped that articles in this special focus issue will be informative and aid in decision making for the many stakeholders evaluating nonsurgical interventions for CLBP.

Keywords: Chronic low back pain; Therapeutic exercises; Lumbar extensor strengthening

Description

Terminology

Exercise, loosely translated from Greek, means "freed movement" and describes a wide range of physical activities. Therapeutic exercise implies that the purpose of the prescribed exercise program is for the treatment of a medical condition rather than recreation and includes the following subcategories [1]: 1) activity as usual (eg, recommendations against physical restrictions); 2) aerobic (eg, walking, cycling); 3) aquatic (eg, pool rehabilitation); 4) directional preference (eg, McKenzie); 5) flexibility (eg, Yoga); 6) proprioceptive/coordination (eg, wobble board, stability ball); 7) stabilization (eg, low load exercise targeting abdominal and spinal trunk muscles); and 8) strengthening (eg, lifting weights).

Studies on therapeutic exercises often fail to provide details on the specific exercise techniques used and the exact exercise protocol that was prescribed or followed (eg, dose, timing, intensity). Moreover, guidelines and systematic reviews frequently combine various forms of therapeutic exercise and ignore important differences between the different types of exercise, as well as different protocols for administration. This has resulted in differing conclusions

FDA device/drug status: not applicable.

Nothing of value received from a commercial entity related to this manuscript.

* Corresponding author. University of South Florida, 12901 Bruce B. Downs Blvd, MDC77, Tampa, FL 33612-4766, USA. Tel.: (813) 974-3818; fax: (813) 974-8915.

E-mail address: jmayer2@health.usf.edu (J. Mayer)

1529-9430/08/$ – see front matter
doi:10.1016/j.spinee.2007.09.008

regarding the efficacy and equivalence of different types of exercise for chronic low back pain (CLBP) [2–5].

This review will focus specifically on lumbar extensor strengthening through supervised progressive resistance exercises (PREs) with isolation and intensive loading of the target muscles. Lumbar extensor strengthening exercises are based on standard resistance training principles including overload, specificity, and reversibility, as well as the basic principles of exercise prescription for resistance training, which include frequency, intensity, volume, duration, and mode. These concepts are discussed further below [6,7].

The target muscles for lumbar extensor strengthening programs are the lumbar erector spinae and multifidus. The erector spinae group comprises the iliocostalis lumborum and longissimus thoracis, and is positioned lateral to the multifidus [8]. The erector spinae consists of several multisegmental fascicles, allowing for sagittal rotation (lumbar extension) and posterior translation when the muscles contract bilaterally [9]. The fascicular arrangement of the multifidus suggests that this muscle acts primarily as a sagittal rotator (lumbar extension without posterior translation). Lumbar lateral flexion and axial rotation are also possible for both the multifidus and erector spinae during unilateral contraction [10]. In contrast to lumbar extensor strengthening exercise, lumbar stabilization exercise consists of low load, low intensity, isometric, or restricted range-of-motion (ROM) techniques [11]; that type of exercise is discussed elsewhere in this supplement.

History

Physical exercise has an ancient heritage. Hippocrates noted that lack of exercise led to atrophy, liability for disease, and quicker aging [12]. In 1865, Gustav Zander developed a technique named ‘‘medical mechanical therapy’’ using exercise equipment, including a device to strengthen the back extensors [13]. Although Zander described progressive exercise using equipment in the late 1800s, the idea did not receive much attention in the medical community for treating disease [12]. The first known treatment program for musculoskeletal care that can likely be characterized as therapeutic exercise was by Thomas De Lorme in 1945 for rehabilitation of injured or postsurgical joints [14]. The PREs were founded on the principles of weightlifters and bodybuilders using free weights (barbells and dumbbells) in a progressively demanding approach by increasing the amount of weight and number of repetitions. Today’s athletic training programs continue to use these basic PRE principles.

Exercise equipment specifically designed to treat CLBP by strengthening the lumbar extensors through PREs appeared in the late 1980s. Soon after this, protocols were published for isometric testing and dynamic variable resistance training on dynamometers that isolated the lumbar spine [7,15]. The availability of these measurement-based machines made it possible to more clearly define the dose of exercise during the treatment of CLBP.

Although dynamometers and isokinetic machines effectively administer PREs to strengthen the lumbar extensors, the use of these machines for CLBP has been questioned because of their relatively high cost and inconvenience [16,17]. As a result, less costly protocols were developed including fixed-angle Roman chairs and benches, variable-angle Roman chairs (VARCs), floor exercises, and stability balls. However, it is still unclear if these options provide the overload stimulus necessary to elicit clinically meaningful lumbar extensor strength gains [18,19].

Subtypes

There are four subtypes of lumbar extensor strengthening exercise protocols categorized by the equipment used: 1) machines; 2) benches and Roman chairs; 3) free weights; and 4) floor and stability balls. The characteristics, advantages, and disadvantages of each subtype are highlighted in Table 1 and each is illustrated in Figs. 1–5.

General description

Standard principles for resistance training (overload, specificity, and reversibility) and exercise prescription (frequency, intensity, volume, duration, and mode) [7] are discussed below with respect to lumbar extension strengthening exercise for CLBP using the guidelines of the American College of Sport Medicine [20]. Ideally, as in all evidence-based medical therapies, the dose of treatment should be defined so that the relationship between the treatment applied and outcomes achieved can be determined. Thus, each of these exercise principles plays an important role in lumbar strengthening exercise programs and must be appropriately defined, measured, and delivered to achieve an optimal therapeutic effect.

Overload

Both lumbar muscle strength and endurance can be enhanced through PRE training [7]. In order for resistance exercise programs to produce continued increases in muscular strength and endurance, training must include progressive overload for the target musculature [7]. Intensity must be increased to produce strength gains, whereas volume must be increased to improve endurance. Progressive overload in intensity and volume should be gradual, particularly when treating CLBP [12].

Specificity

Specificity implies that the target muscle must be isolated during loaded movements so that sufficient muscular activation is achieved [7]. To isolate the lumbar spine and enhance specificity, lumbar strengthening exercise equipment and techniques use various strategies. The lumbar dynamometer, for example, incorporates a series of pelvic restraint mechanisms to restrict pelvic and hip rotation

Table 1
Subtypes of lumbar extensor strengthening exercises

Type	Examples	Position/movement	PRE	Measurement	Advantages	Disadvantages
Machines	Variable resistance dynamometers	Seated; Isotonic (with or without variable resistance); Closed-chain exercise for both upper and lower body.	Pin loaded weight stack, pneumatic, electronic/cam system.	Strength: Isometric and dynamic strength tests over full ROM using machine's assessment mechanisms. Endurance: Isometric and dynamic tests over full ROM.	Gradual/incremental progression of exercise load; Standardized protocols for testing and training; Loads in ranges necessary for patients; Visual feedback of performance (computerized devices); High degree of isolation of lumbar spine improves force production from lumbar extensors; Variable resistance allows for consistent load throughout ROM; Safety.	Relatively expensive ($6,000–8,000 US for noncomputerized machines); Large size; Exercise in one plane or one direction only.
Machines	Isokinetic	Standing or seated.	Pin loaded weight stack; Altering rate of motion.	Strength and endurance: isokinetic measurement of work load over full ROM.	Gradual/incremental progression of exercise load; Standardized protocols for testing and training; Loads in ranges necessary for patients; Visual feedback of performance (computerized devices).	Torque overshoot; Acceleration/deceleration may lead to harmful impact forces; Unnatural movement patterns; No known commercial devices are currently manufactured.
Benches and Roman chairs	Prone back extensions on bench; fixed-angle Roman Chair; VARC	Prone; Isotonic; Closed chain for upper or lower body, but not both.	Dependent on gravity's action on upper body or lower body; Alter device angle (VARC); Alter hand position, hip rotation, lumbar posture; Hand-held weights.	Strength: Dynamic strength tests (eg, 1 rep max) using external hand-held weights. Endurance: Dynamic and isometric (eg, Sorensen test).	All: simple; Low cost; Some isolation of lumbar spine; VARC: Able to accommodate loads in ranges necessary for patients; Gradual progression of load; Roman chairs: trunk exercise possible in more than one plane; More natural movement pattern for lumbar musculature (compared with seated machines); Short learning curve for patients and administrators because of simplicity.	Ability to provide the overload necessary to stimulate lumbar extension strength gains is unclear; No safe or standardized protocols to assess strength; Unable to accommodate loads required for patients without assistance from therapist (prone back extension on bench).
Free weights	Barbells and plates: eg, Stiff-legged dead lifts; Good mornings.	Standing; Isotonic; Closed-chain exercise for lower body.	Dependent on gravity's action on upper body or lower body; Increase load with metal barbells and plates.	Strength: Dynamic strength tests (eg, 1 rep max) using external hand-held weights; Endurance: dynamic.	Simple; Relatively low cost; Gradual progression of load	Potentially unsafe; Awkward movements for patients; Unable to accommodate loads necessary for patients; Unable to standardize load (given the contribution of upper body mass); No isolation; Not frequently used for clinical patients.

Floor and stability balls	Floor back extension exercise (eg, "cobra"); Stability ball back extension exercise.	Prone; Isotonic or isometric; Closed-chain exercise for upper and/or lower body.	Dependent on gravity's action on upper or lower body. Increase reps.	Strength: n/a; Endurance: dynamic or isometric.	Simple; Low cost.	Unlikely to provide overload stimulus for strength gains; Restricted ROM; Movement from neutral to extension only (prone floor exercises); Very few, if any, levels of progression within a small range of loads; Loads related to progression are unknown or not standardized; Labile surface of balls decreases safety.

ROM = range of motion; PRE = progressive resistance exercise; VARC = Variable-angle Roman chair.

during dynamic lumbar extension exercise in the seated position [21]. Prone back extensions on Roman chairs and benches improve specificity and isolation of the lumbar extensors during dynamic exercise by aligning the pelvis appropriately on the device, internally rotating the hips, and accentuating lumbar lordosis [22]. Trunk extension is a compound movement of the hip, pelvis, and lumbar spine through the action of the lumbar extensors and hip extensors (gluteals and hamstrings) [15]. The relative contribution of individual muscle groups to force production during compound trunk extension is unknown, but it is assumed that the larger gluteal and hamstring muscles generate the majority of the force [23]. Therefore, it has been suggested that to enhance specificity and optimally activate the lumbar extensors during dynamic resistance exercise, torque production from the gluteals and hamstrings must be eliminated [15].

Reversibility

With all resistance exercise training programs, much of the physiological gains in muscular strength, endurance, and hypertrophy are ultimately lost unless exercise is continued [7]. Thus, it is recommended that lumbar extension PREs should be carried out beyond the initial supervised physical rehabilitation period. Once strength gains are achieved, it is possible to maintain physiological gains with a reduced training frequency as low as once per month [24].

Frequency

The optimal frequency for the treatment of CLBP varies by individual depending on their physical condition, time point in the rehabilitation process, and therapeutic goals of the intervention. Generally, frequencies of 1 to 3 sessions/wk are recommended for most resistance training programs [20]. Given the deconditioned state of the lumbar muscles in individuals with CLBP [25,26], frequencies at the low end of this range may be adequate as a starting point. Studies have reported improved lumbar extensor strength, pain intensity, and psychosocial outcomes in patients with CLBP who trained once per week, whereas 2 sessions/wk produced similar outcomes as 3 sessions/wk [27,28].

Intensity

High-intensity, short-duration (high resistance, low repetitions) exercises are generally prescribed to strengthen muscles, whereas low-intensity, long-duration (low-resistance, high-repetition) exercises are used to improve muscular endurance [7]. Depending on the therapeutic goals, 6 to 25 repetitions per set of exercise at intensities of 30% to 85% of the one repetition maximum intensity can be used for lumbar strengthening programs. In a randomized controlled trial (RCT) by Helmhout et al. [29], no differences were noted in clinical outcomes for CLBP after high and low intensity lumbar extensor strength training.

Fig. 1. Lumbar extension machine (MedX Corp, Ocala, FL).

Repetitions

Each repetition of a particular exercise should be performed in a slow, controlled fashion (2 s for the concentric/shortening phase and 4 s for the eccentric/lengthening phase) throughout the full pain-free ROM in the sagittal plane [30]. It is important to limit lumbosacral flexion, particularly for patients recovering from spinal surgery [1]. Training frequency should be reduced for intense exercise sessions, because additional recovery time is needed [7].

Volume

Although the optimal volume of lumbar extensor exercise for CLBP volume of exercise is unknown, one to three sets of exercise are typically recommended per treatment session [20]. For asymptomatic individuals, lumbar extensor strength gains achieved by one set of exercise have been shown to be equal to those achieved by three sets after an exercise training program on dynamometers [30]. Hypertrophy and more efficient myoelectric activity of the lumbar extensors have been documented after single set exercise in CLBP. In contrast, an RCT demonstrated that increasing the volume of prone back extension exercises on benches improved clinical outcomes for the treatment of CLBP [31].

Duration

To achieve physiological changes in skeletal muscle (eg, hypertrophy), a minimum of 10 to 12 weeks of resistance exercise is needed [7]. Functional gains in the earlier stages of a resistance training program are primarily the result of neurological adaptations, whereas those in the later stages are the result of physiological change [7]. However, compliance with a therapeutic exercise program for the average patient with CLBP decreases over time.

Mode

Mode defines the type of exercise and equipment used [7]. Muscular contractions are either isometric or dynamic. Isometric implies that the muscle contracts without changing length or joint angle, whereas dynamic implies that the muscle shortens (concentric phase) or lengthens (eccentric

Fig. 2. Variable-angle Roman chair (BackStrong International, Brea, CA).

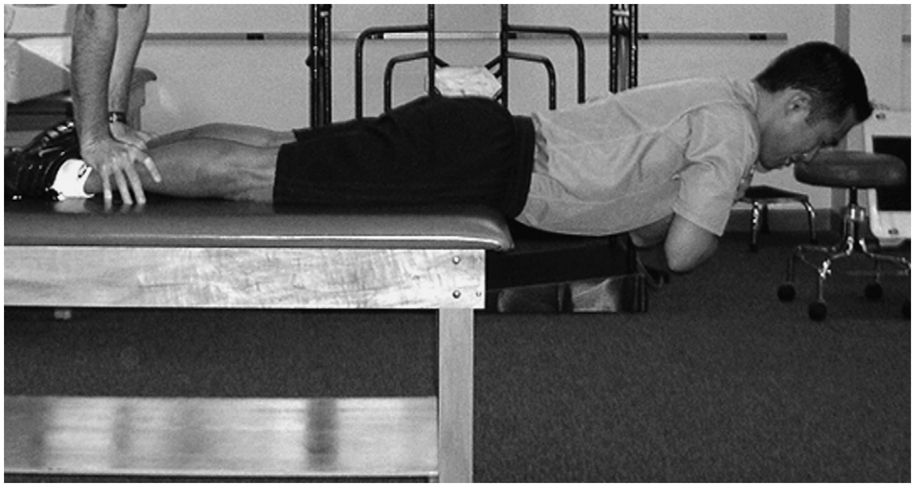

Fig. 3. Prone back extension exercise on bench.

phase) resulting in joint movement. The three categories of dynamic exercise are [7] 1) isotonic—muscle contraction against fixed resistance (constant tension); 2) variable resistance—muscle contraction against variable resistance to mimic strength curve of target muscle (variable tension); and 3) isokinetic—muscle contraction at fixed speed (constant speed).

Lumbar extension dynamometer

The lumbar dynamometer allows for dynamic exercise through a 72° ROM arc in the sagittal plane [15]. On the dynamometer, an adjustable weight stack provides resistance from 9 to 364 kg in 0.5 kg increments, and variable resistance is accomplished by a cam with a flexion:extension ratio of 1.4:1. After securing the pelvic restraint mechanisms, the patient begins exercise in the most flexed position that is pain free and is instructed to perform dynamic exercise by extending their backs to a position near terminal extension in a smooth, controlled manner, taking 2 seconds for the concentric movement (lifting the weight) and 4 seconds for the eccentric movement (lowering the weight). The therapist verbally encourages the patient to perform as many repetitions as possible, and visual feedback of performance is possible through a monitor that graphically displays exercise load and position. When the patient completes 20 or more

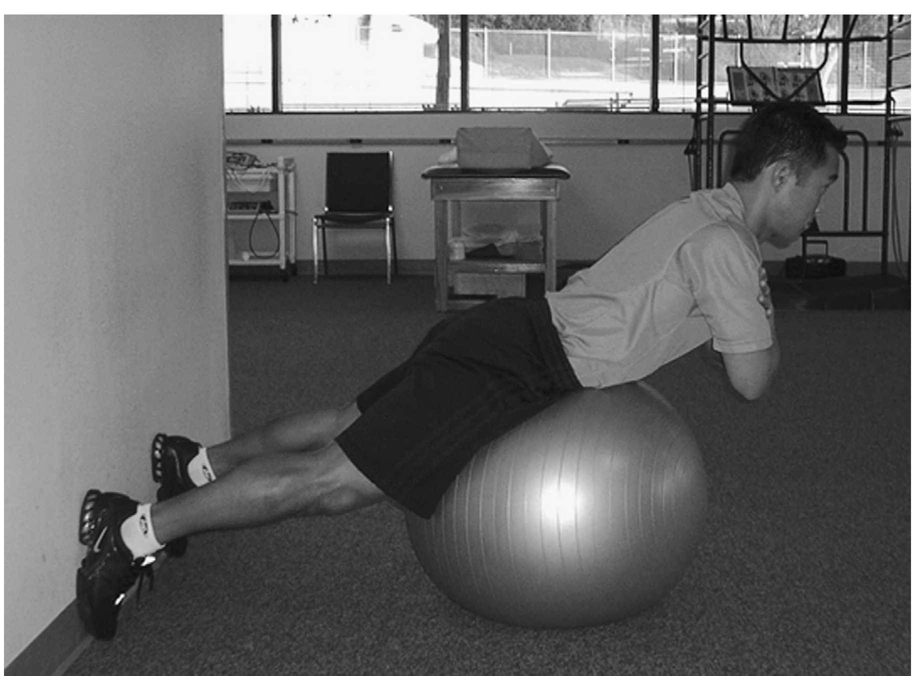

Fig. 4. Stability ball back extension exercise.

Fig. 5. Stiff-legged deadlifts.

repetitions, resistance is increased in 5% increments though pin loaded metal plates on the device at the next training session [1].

Variable-angle Roman chair

The VARC is similar to fixed-angle Roman chairs, except that the VARCs angle setting can be adjusted from 75° (nearly vertical) to 0° (horizontal) in 15° increments [19]. Gradual progressive resistance is achieved by altering the VARCs angle setting and the subject's hand position [18]. Internally, rotating the hips and accentuating lumbar intersegmental extension during lumbar extension exercise on the VARC further optimize lumbar muscle activity [18]. The patient begins the training program at a low resistance level with a VARC angle setting of 60° and hands positioned on the sternum. After positioning the patient on the device (ranging from nearly vertical to prone), the patient starts each repetition of dynamic exercise in the extended position and lowers their trunk in a smooth, controlled fashion, completing the eccentric phase at terminal, pain-free flexion in 4 seconds. Next, the patient raises their torso during the concentric phase of exercise in 2 seconds, and is verbally encouraged to perform as many repetitions as possible. When the patient completes 20 to 25 or more repetitions, resistance is increased by altering the VARC angle setting or hand position at the next training session [32].

Practitioner, setting, and availability

Because this type of exercise is used to treat CLBP, it must be prescribed and monitored by licensed clinicians such as physicians, chiropractors, or physical therapists. The actual treatment, however, can be carried out under the supervision of an athletic trainer, exercise physiologist, or personal trainers who report periodically to the prescribing clinician. Lumbar strengthening exercise protocols could also be self-administered at fitness facilities without a health provider, though this is not recommended. Various training and certification courses are offered for lumbar strengthening exercise protocols. Despite the lack of regulation, any person delivering exercise therapy should be well versed in the basic principles and practice of exercise testing and prescription for the general population and the particular condition being treated. The typical settings for lumbar strengthening programs are outpatient treatment centers, health and fitness facilities, and athletic training centers under the supervision of trained personnel. There are several commercially available home exercise devices that appear to be suitable for unsupervised lumbar strengthening exercise outside of health-care settings. Home exercise may be more appropriate during latter stages of rehabilitation after a formal, supervised exercise program has been completed in a medical facility. This treatment is readily available throughout the United States.

Reimbursement

No specific current procedural code (CPT) codes exist for lumbar extensor strengthening exercise. A general CPT code for therapeutic exercise is frequently used for this treatment: 97110—Therapeutic procedure, one or more areas, each 15 minutes; therapeutic exercises to develop strength and endurance, ROM, and flexibility. Another code can be used to assess lumbar muscle strength and endurance at baseline, during treatment, and at the conclusion of treatment: 97750—Physical performance test or measurement (eg, musculoskeletal, functional capacity) with written report, each 15 minutes.

The typical cost for 97110 is $35–40 per unit, whereas the typical cost for 97750 is $110–120 per unit. Given the need to maintain lumbar muscle strength and endurance gains, and continue improvement beyond the initial supervised physical rehabilitation, gym fitness programs are frequently carried out. The cost for postrehabilitation gym programs that include intensive lumbar strengthening exercises range from $50 to $200 per month depending on the level of supervision provided.

Each third-party payer (eg, Medicare, workers' compensation, private insurance) has its own requirements regarding coverage for therapeutic exercise and exercise testing procedures provided during the initial physical rehabilitation period. Generally, these services are covered to some degree for a predefined period of time or number of sessions. Third-party reimbursement for gym-based maintenance programs is highly variable.

Regulatory status

The more sophisticated lumbar strengthening exercise machines (eg, lumbar dynamometer, isokinetic machines, VARCs) are defined as Class I or II medical devices with classifications such as 980.5370 (nonmeasuring exercise equipment) or 890.1925 (isokinetic testing and evaluation system). There is no regulatory oversight from the FDA for the lumbar strengthening exercises performed on benches, floors, or stability balls.

Theory

Mechanism of action

The mechanism of action of isolated lumbar extensor strengthening exercise programs is likely related to the physiological effects of conditioning the lumbar muscles through progressive tissue loading or enhancing the metabolic exchange of the lumbar discs through repetitive movement [1,33]. Strengthening exercise may also have psychological mechanisms such as improving kinesiophobia and locus of control [27,29].

Progressive tissue loading of the lumbar musculature

The lumbar extensor muscles have been considered the ‘‘weak link’’ in lower trunk function [23]. In CLBP, the lumbar extensors are weak, highly fatigable, atrophied, display abnormal activation patterns, and exhibit excessive fatty infiltration and histopathological changes [26,34–36]. Thus, it is reasonable to focus on conditioning these muscles through PREs during the treatment of CLBP to improve the physiological and structural integrity. Through appropriate resistance training programs, reversal of these muscular dysfunctions and structural abnormalities has been documented in patients with CLBP [27,37].

As previously mentioned, isolation and progressive overload of the lumbar extensors are necessary to achieve the optimal therapeutic benefit from this exercise intervention. Lumbar extensor PREs on machine and prone back extensions on benches and Roman chairs likely provide sufficient isolation and overload stimulus to improve lumbar muscular strength or endurance [19,23,31]. Whether or not appropriate isolation and overload occur from low load floor exercise (eg, lumbar stabilization) or stability ball exercise are unknown. In a recent study by Sung [38], no change in the fatigue status of the lumbar multifidus was noted after a 4-week supervised stabilization exercise program. In an RCT by Danneels et al. [39], the effect of three different exercise training modalities on the cross-sectional area of the lumbar extensor muscles of patients with CLBP was assessed. Stabilization exercise training alone resulted in no change in lumbar muscle cross-sectional area. When this training was combined with dynamic and isometric intensive resistance training, an increase in cross-sectional area of the musculature was noted.

Disc metabolism may also be enhanced through repetitive, full ROM exercise. Modern science supports the concepts and properties of exercise, given that absence of physical activity reduces a healthy metabolism. In regard to spinal pain disorders, the association between biochemical abnormalities in the lumbar discs and CLBP has been documented [40]. Thus, it is possible that repetitive, dynamic, isolated lumbar extensor throughout a full ROM could improve metabolic exchange in the lumbar discs and aid in repair [1].

Diagnostic testing required

Other than a thorough medical history and physical examination to rule out the possibility of serious pathology related to CLBP (eg, red flags), diagnostic testing is not required to implement lumbar strengthening exercise programs and there are no studies assessing how diagnostic testing impacts the efficacy of this intervention. Nevertheless, several diagnostic tests are used clinically to apply the proper and safe dose of exercise, monitor progress throughout treatment, and document that the target muscles are being appropriately activated. These include standardized tests for isometric lumbar extension strength [27] and endurance (eg, Biering-Sorenson test) [41], and assessment of lumbar muscle activity through real-time ultrasound [42] and surface electromyography [38]. More technologically advanced options to assess lumbar muscle cross-sectional area, fatty infiltration, and activation patterns include magnetic resonance imaging [26,43] and computed tomography scanning [44]; these are typically reserved for research settings.

Indications and contraindications

Lumbar extensor strengthening exercises are typically indicated for adults with nonspecific CLBP of mechanical origin [1]. Although these exercises are likely most appropriate for those with suspected or demonstrated deficiencies in muscle strength, endurance, or coordination, lumbar strengthening exercises have been shown to be beneficial for individuals with CLBP with wide ranges of muscular capacities at treatment onset [45,46].

Contraindications to lumbar strengthening exercises are those relevant to any resistance exercise training programs as recommended by the American College of Sport Medicine [47] and include 1) unstable angina, 2) uncontrolled hypertension (systolic blood pressure ≥160 mm Hg and/or diastolic blood pressure ≥100 mm Hg), 3) uncontrolled dysrhythmias, 4) recent history of untreated congestive heart failure, 5) severe stenotic or regurgitant valvular disease, 6) hypertrophic cardiomyopathy, 7) poor left ventricular function, and 8) angina or ischemia at low lumbosacral workloads (<5–6 METs). Other contraindications include acute fracture, possible infection (eg, osteomyelitis), dislocation, and tumor/metastases in the lumbosacral region.

Osteoporosis is frequently listed as an exclusion in RCTs under the assumption that overload because of resistance exercise in patients with bony matrix below normal physiologic levels (eg, osteoporosis/osteomalacia) could result in fractures. However, a cohort study reported that gradually loaded lumbar strength training on machines is safe and improves functional capacity in older adults with CLBP [63]. Controlled studies have also demonstrated that similar training programs significantly improve lumbar vertebral body bone density after heart and lung transplantation [48,49]. With a gradual, controlled, and measured increase in resistance using isolated lumbar extensor strengthening exercises, osteoporosis is not likely a contraindication, and could in fact possibly be improved with this form of therapy.

In our opinion, the ideal CLBP patient for this intervention is one who is in good general health (physically and psychologically) and willing to take responsibility for his or her own self-care in the form of an active exercise program. As is typical of any strenuous exercise activity, lumbar extensor strengthening exercise may be associated with some short-term discomfort. Thus, the recognition of long-term benefit by the patient and subsequent compliance to the program, despite the possibility of short-term discomfort, optimizes chances for positive outcomes.

Evidence of efficacy

Review methods

A systematic review of the literature was undertaken searching MEDLINE, EMBASE, and the Cochrane Library using search strategies developed by the Cochrane Back Review Group, along with additional index and text words (exercise/, physical fitness/, medx.mp, dbc.mp, cybex.mp, backstrong.mp, roman chair.mp, and nautilus.mp).

Only studies that fulfilled the following criteria were included: 1) RCTs; 2) adult patients with CLBP ≥12-week duration; 3) incorporated lumbar extensor strengthening exercises according to our earlier definition; 4) exercise was supervised in clinical facility (ie, not home exercise program); 5) prescription of exercise was clearly defined and reproducible, including frequency, intensity, volume, duration, mode, and progression; 6) if interventions were used in combination, the effects of lumbar strengthening exercise could be partitioned from other interventions; 7) clinical outcome data were available (eg, pain, function, disability); and 8) between-subject data analysis was conducted.

Two of the authors (JM and VM) rated the articles identified from the initial search. A total of 11 RCTs related to lumbar extensor strengthening exercise for CLBP were uncovered. These RCTs are discussed below and summarized in Table 2.

Systematic reviews

Our search uncovered several systematic reviews pertaining to exercise therapy for CLBP [3,50,51]. Many of these reviews were broad in scope and included all forms of exercise (eg, stretching, stabilization, McKenzie, aerobic). Although some of these reviews included studies assessing lumbar strengthening exercise, their conclusions addressed exercise in general and were of limited value to assess the evidence regarding lumbar strengthening exercises. Reviews that made specific conclusions about lumbar strengthening exercise were also of limited value for the following reasons: 1) did not define the inclusion criteria for lumbar strengthening exercise; 2) included RCTs that incorporated exercises (eg, stabilization exercise) that did not fit our criteria for lumbar strengthening exercise; 3) included RCTs that did not clearly define the specific mode of exercise; or 4) included RCTs that combined subacute and chronic cases.

Randomized controlled trials

In an RCT by Manniche et al. [31], 105 individuals with CLBP were randomly assigned to high (n=35) or low (n=35) intensity exercise, or control (n=35). Exercise groups consisted of isotonic prone back extension exercises on a bench and latissimus pull down exercise (plate-loaded cable machine); the high-intensity group performed five times as many sets as the low intensity group. The control group performed light floor exercises. Co-interventions for all groups consisted of thermotherapy and massage. Treatment was administered 2 to 3×/wk for 10 weeks. Outcomes were assessed using the Low Back Pain Rating Scale (LBPRS) composite score for pain, disability, and physical impairment. At 3 and 6 months, the high-intensity exercise group demonstrated significantly greater improvements in LBPRS compared with the low intensity exercise and control groups.

In another RCT by Manniche et al. [52], 62 individuals with CLBP after surgery for lumbar disc protrusion were randomly assigned to receive intensive dynamic back extensor exercise with (n=31) or without (n=31) hyperextension. Back extensor exercises were similar to those used by the high-intensity group in the previous study [31]. The hyperextension group performed dynamic exercise to terminal lumbar extension, whereas the other group stopped at the neutral lumbar position. Co-interventions for both groups were hot packs and abdominal crunches. Treatment was administered 2×/wk for 3 months. Outcomes were assessed with the LBPRS composite score. At 3 and 15 months, there was no difference between the groups. At 6 months, the group that exercised without hyperextension displayed a significantly greater improvement in LBPRS than the hyperextension group.

In an RCT by Risch et al. [27], 54 individuals with CLBP were randomized to receive lumbar extensor strengthening exercise (n=31) or control (n=23). The lumbar strengthening group performed isolated lumbar extensor PREs on a variable resistance dynamometer machine 1 to 2×/wk for 10 weeks. The control group was wait listed and received no intervention. Outcomes included pain intensity, psychosocial function, and lumbar extensor strength. At 10 weeks, the lumbar strengthening exercise group displayed significantly greater improvements in pain intensity, lumbar extensor strength, and psychosocial function on one of several scales.

In an RCT by Timm [53], 250 individuals with CLBP after one-level L5 laminectomy were randomly assigned to lumbar strengthening exercise (n=50), lumbar stabilization and extension ROM exercise (n=50), spinal manipulation (n=50), passive modalities including hot packs, TENS, and ultrasound (n=50), or no treatment control (n=50). The lumbar strengthening exercise group performed lumbar extensor PREs on isokinetic and isotonic machines. Co-interventions for the strengthening exercise group included lumbar flexion and rotation, latissimus dorsi PREs on machines, and bike exercise. Treatments were administered 3×/wk for 8 weeks. Outcomes included self-reported disability, lumbar ROM, and isokinetic lift strength. At 8 weeks, improvements in disability, lumbar flexion, and lift strength for the lumbar extensor exercise and stabilization exercise groups were significantly greater than the spinal manipulation, passive modalities, and control groups. Improvements in lumbar extension for the lumbar extensor exercise, stabilization exercise, and spinal manipulation groups were significantly greater than passive modalities and control.

In an RCT by Johannsen et al. [54], 40 individuals with CLBP were randomly assigned to receive lumbar strengthening exercise (n=20) or control (n=20). The lumbar strengthening exercise group performed prone back extension exercises as described by Manniche et al. [31]. Co-interventions included abdominal crunch exercises. The control group performed group exercises emphasizing balance and stability for the low back, shoulder, and hip. Co-interventions for both groups included flexibility and bike exercise. Treatments were administered 2×/wk for 3 months. Outcomes included pain intensity, self-reported disability, lumbar strength, and ROM. At 3 and 6 months, there were no significant differences between the groups for any of the outcomes.

In an RCT by Kankaanpaa et al. [55], 54 individuals with CLBP were randomly assigned to lumbar strengthening exercise (n=30) or control (n=24). The lumbar strengthening exercise group performed isolated lumbar extensor PREs on machines 2×/wk for 12 weeks. Co-interventions for this group included lumbar flexion, lateral flexion, and rotation PREs on machines, flexibility and relaxation exercises, behavioral support, ergonomic advice, and home back exercises. The control group received no intervention for 9 weeks and massage and thermotherapy for 3 weeks. Outcomes included pain intensity, self-reported disability, and back muscle fatigability. At 3 and 12 months, improvements in each outcome were significantly greater for the lumbar strengthening group than control.

In an RCT by Danneels et al. [39], 59 individuals with CLBP were randomly assigned to dynamic lumbar strengthening exercises with (n=20) and without (n=20) isometric contractions combined with lumbar stabilization exercise or lumbar stabilization exercise alone (n=19). The lumbar strengthening exercise groups performed prone back extension exercises as described by Manniche et al. [31] with or without alternating isometric contractions at terminal extension. Interventions were administered for 10 weeks at an unspecified frequency. At 10 weeks, lumbar extensor muscle cross-sectional area significantly increased for both lumbar strengthening groups, but not the stabilization group. No difference in lumbar muscle hypertrophy was noted between the strengthening groups.

In an RCT by Mannion et al. [56,57], 148 individuals with CLBP were randomly assigned to lumbar strengthening exercise along with co-interventions (n=49), physiotherapy (n=49), or aerobic exercise (n=50). The lumbar strengthening exercise group performed isolated lumbar extensor strengthening PREs as described by Kankaanpaa et al. [55], along with co-interventions consisting of lumbar flexion, lateral flexion, and rotation PREs on machines, as well as bicycle, flexibility, and relaxation exercises. The physiotherapy group performed individual physiotherapy to improve functional capacity using unspecified strengthening, coordination, and aerobic exercise, along with ergonomic instruction and home exercise. The aerobic exercise group performed low impact aerobic classes. Interventions were administered 2×/wk for 3 months. Outcomes included pain intensity, self-reported disability, fear avoidance, psychological disturbance lumbar strength, and lumbar extensor muscle endurance and fatigability. At 3 months, there was no difference in pain intensity, disability, fear avoidance, lumbar extension strength, endurance, and fatigability among the groups. Improvements in lumbar flexion, lateral bend, and rotation strength were significantly greater for the lumbar strengthening group than the physiotherapy and aerobic groups. Improvements in psychological disturbance were significantly greater for the lumbar strengthening and aerobic groups compared with the physiotherapy group. At 12 months, there was no difference in pain intensity, fear avoidance, or psychological disturbance among the groups. Improvements in disability were significantly greater for the lumbar strengthening and aerobic groups compared with physiotherapy.

In an RCT by Rittweger et al. [58], 60 individuals with CLBP were randomly assigned to lumbar strengthening exercise (n=20) or vibration therapy (n=20). The lumbar strengthening exercise group performed isolated lumbar extensor PREs on a variable resistance lumbar dynamometer

Table 2
Summaries of RCTs on lumbar extensor strengthening exercise for chronic low back pain

Reference	Inclusion/exclusion criteria	Number of participants	Interventions	Outcomes	Follow-up	Results	Comments
[31]	Inc: LBP for 6+ mo or 3+ episodes of acute LBP with 6 mo; age 20–70 y; Radiological examination of lumbar spine within 2 y. Exc: clinical signs of lumbar nerve root compression; spondylolysis; pain hip DJD; halisteresis of the spine; joint inflammatory disorder; somatic or psychopathologic disorder; inability to cooperate.	Enrolled— LES-High: n=35 LES-Low: n=35 CON: n=35 3 mo— LES-High: n=29 LES-Low: n=30 CON: n=31 6 mo—unclear	1.LES-High: Isotonic prone back extension on bench—leg lift and trunk lift; latissimus pull down (plate-loaded cable machine) (up to 10 rep/set, up to 10 set, 2–3×/wk, 3 mo, PRE—increase rep and load). 2.LES-Low: Same exercises as LES-High, but 1/5 of the exercise dose/session. 3.CON: Month 1 —Mild floor trunk exercises—isometric prone back extension, isometric trunk curl, dynamic trunk curl (1 set, 10 rep/set, 2×/wk, 8 wk); Months 2–3—no intervention. All groups: hot packs; general flexibility exercises.	Pain intensity, disability, and physical Impairment (LBPRS).	3 mo 6 mo	LBRS: LES-High 14.7, LES-Low 5.7, CON 2.0. LES-High>LES-Low, CON (p<.01). LES-Low>CON (p<.05). LBRS: LES-High 15.0, LES-Low 7.0, CON 5.5, LES-High>LES-Low, CON (p<.01). LES-Low vs. CON (ns).	Intention to treat analysis performed including those who dropped out because of side effects related to back pain aggravation—no difference from analysis of evaluable data set.
[52]	Inc: surgery for lumbar disc protrusion; age 18–74 y; patient global assessment of good, fair, or unchanged. Exc: evidence of lumbar nerve root compression; spondylolysis; malignant disease; joint inflammatory disease; somatic or psychiatric disease.	Enrolled— LES: n=31 LES-EXT: n=31 3 mo— LES: n=21 LES-EXT: n=26 6 mo— LES: n=21 LES-EXT: n=25 15 mo—not reported.	1.LES: Isotonic prone back extension on bench (leg lift and trunk lift—performed to 0-degree lumbar extension); latissimus pull down (plate-loaded cable machine) (up to 10 rep/set, up to 10 set, 2×/wk, 3 mo, PRE—increase rep and load); abdominal crunch (50 rep/set, 1 set). 2.LES-EXT: Same as LES, except prone back extensions performed to greatest possible lumbar extension position. Both groups: Hot packs.	Pain intensity, disability, and physical impairment (LBPRS).	3 mo 6 mo 15 mo	LBRS: LES 10, LES-EXT 7 (ns). LBRS: LES 8, LES-EXT 1 (p=.05). LBRS: LES 3, LES-EXT 0 (p=.08).	Intention to treat analysis performed including those who dropped out because of side effects related to back pain aggravation—no difference from analysis of evaluable data set. High drop out.
[27]	Inc: LBP for 1+ y.Exc: not reported.	Enrolled— LES: n=31 CON: n=23 10 wk—not reported	1.LES: isolated lumbar extension machine, seated, isotonic (8–12 rep/set, 1 set, 1–2×/wk, 10 wk, PRE—increase load). 2.CON: no treatment—waiting list.	Pain intensity (WHYMPI pain), physical function (SIP physical), psychosocial function (SIP psychosocial, MHI stress/well-being, WHYMPI positive/negative support), lumbar extension strength.	10 wk	Pain: LES 0.5, CON −0.4 (p<.002). Physical Function: LES 1.4, CON −4.1 (p<.03). Psychosocial function: SIP-LES 2.0, CON −4.0 (p<.03). MHI (well-being)-LES 0.9, CON 1.3 (ns). MHI (stress)-LES 0.2, CON −1.4 (ns).	

						WHYMPI (positive)-LES 0.2 CON −0.4 (ns). WHYMPI (negative)-LES 0.0, CON −0.4 (ns). Strength: LES 26.8%, CON 3.2% (p<.02).	
[53]	Inc: LBP 6+ mo; manufacturing employee of auto industry; 1-level L5 laminectomy surgery 1+ y before study. Exc: lower extremity pain below knee related to possible lumbar nerve root involvement.	Enrolled— LES: n=50 STAB: n=50 SMT: n=50 PAS: n=50 CON: n=50 8 wk— LES: n=50 STAB: n=50 SMT: n=50 PAS: n=50 CON: n=50	1.LES: lumbar extension, and lumbar flexion, lateral flexion, and rotation machines, isotonic and isokinetic, seated and standing; latissimus pull down (10 rep/set, 1 set, 3×/wk, 8 wk, PRE—increase load); bike (10 min). 2.STAB: lumbar stabilization and McKenzie-type extension exercises (10 rep/set, 2–3 set, 3×/wk, 8 wk); and home exercise daily with same movements. 3.SMT: spinal manipulation —high amplitude, low velocity manipulation to lumbar spine (3×/wk, 8 wk). 4.PAS: passive therapies including hot packs, TENS, ultrasound (3×/wk, 8 wk). 5.CON: no treatment.	Disability (ODI), lumbar ROM, isokinetic lift strength.	8 wk	Disability: LES 18, STAB 21, SMT 4, PAS 0.0, CON 0.0. LES, STAB>SMT, PAS CON (p<.05); LES vs. STAB (ns). ROM ext: LES 2.5, STAB 3.1, SMT 3.1, PAS 0.0, CON 0.0. LES, STAB, SMT>PAS, CON (p<.05). LES vs. STAB vs. SMT (ns). ROM flex: LES 2.8, STAB 2.5, SMT 0.0, PAS 0.0, CON 0.0. LES, STAB>SMT, PAS CON (p<.05); LES vs. STAB (ns). Strength: LES 349, STAB 276, SMT −4, PAS 4, CON 2. LES, STAB>SMT, PAS CON (p<.05); LES vs. STAB (ns).	
[54]	Inc: 1+ y LBP; LBP for >3 mo in the last year; age 18–65 y; employed. Exc: nerve root compression; spondylolisthesis; osteoporosis; lower extremity osteoarthritis; inflammatory joint disease; neoplastic disorders.	Enrolled— LES: n=20 CON: n=20 3 mo— LES: n=13 CON: n=14 6 mo—not reported.	1. LES: Isotonic prone back extension on bench (leg lift and trunk lift—performed to 0-degree lumbar extension); latissimus pull down (plate-loaded cable machine); abdominal crunch (up to 10 rep/set, up to 10 set, 2×/wk, 3 mo, PRE—increase rep or load); bike (10 min); flexibility exercise (10 min). 2.CON: group exercises emphasizing coordination, balance, and stability for the low back, shoulder, and hip (up to 40 reps/set, 1 set); warm-up including jogging (10 min); flexibility exercise (10 min).	Pain intensity (LBPRS), disability (LBPRS); lumbar ROM (derived mobility score), lumbar strength (flex, ext).	3 mo 6 mo	Pain: LES 3, CON 1 (ns). Disability: LES 4, CON 2 (ns). ROM: LES 17, CON 3 (ns). Ext strength: LES 12, CON 1 (ns). Flex strength: LES 1, CON 3 (ns). Pain: LES 2, CON 2 (ns). Disability: LES 5, CON 3 (ns). ROM: LES 15, CON 6 (ns). Ext strength: LES 17, CON 7 (ns). Flex strength: LES 2, CON 3 (ns).	Underpowered considering outcomes used. High drop out. No intention to treat analysis.

(*continued*)

Table 2 (*continued*)

Reference	Inclusion/exclusion criteria	Number of participants	Interventions	Outcomes	Follow-up	Results	Comments
[55]	Inc: nonspecific LBP>3 mo; moderate functional disability with only occasional absences from work. Exc: nerve root compression; disc prolapse; radicular symptoms (radiating pain below knee, loss of sensation, muscle dysfunction, loss of reflexes); severe scoliosis; spondyloarthrosis; spinal surgery.	Enrolled— LES: n=30 CON: n=24 3 mo— LES: n=30 CON: n=24 12 mo— LES: n=27 CON: n=22	1.LES: isolated lumbar extension, and lumbar flexion, lateral flexion, and rotation machines, isotonic, seated (rep/set—not reported, set—not reported, frequency—2×/wk, 12 wk, PRE—increase load); flexibility and relaxation exercises; behavioral support; ergonomic advice; home back exercises. 2.CON: Weeks 1–8—no intervention; Weeks 9–12—massage, thermal therapy (1 session/wk).	Pain intensity (VAS), disability (PDI), back extension fatigability (surface EMG MPF decrease).	3 mo 12 mo	Pain: LES 18.9, CON 3.2 (p=.03). Disability: LES 2.4, CON −1.4 (p=.04). Fatigability: LES 7.6, CON 1.0 (p=.002). Pain: LES 31.3, CON 1.9 (p<.001). Disability: LES 7.5, CON −1.9 (p=.004). Fatigability: LES 6.2, CON 2.0 (p=.09).	
[39]	Inc: LBP>3 mo. Exc: lumbar surgery; spondylolysis; spondylolisthesis; lumbar scoliosis >10 degrees; neuromuscular or joint disease; systemic disease; carcinoma or organ disease; participation in an exercise training program for the lumbar muscles in the previous 3 mo.	Enrolled and 10 wk— LES-DYN: n=20 LES-STATIC: n=20 CON: n=19	1.LES-DYN: Isotonic prone back extension on bench—leg lift and trunk lift; leg lift floor exercise (15–18 rep/set, volume—not reported; frequency—not reported; 10 wk, maintain 70% of 1 rep max; PRE—increase rep and load); lumbar stabilization floor exercises. 2.LES-STATIC: same as LES-DYN, except alternate between isotonic and isometric exercise. 3.CON: lumbar stabilization floor exercises.	Lumbar extensor muscle CSA—upper L3, upper L4l lower L4 levels.	10 wk	CSA-upper L3: LES-DYN 1.4%, LES-STATIC 3.2%, CON −0.5%. CSA-upper L4: LES-DYN 2.2%, LES-STATIC 3.6%, CON 0.0%. CSA-lower L4: LES-DYN 1.6%, LES-STATIC 3.7%, CON −1.0%. All levels: LES-DYN, LES-STATIC>CON (p<.04); LES-DYN vs. LES-STATIC (ns).	Clinical relevance of 2–5% CSA increase compared with control is unclear.
[56,57]	Inc: LBP>3 mo with or without referred or radicular pain, which requires medical attention or work absence; age <65 y. Exc: Constant or persistent severe pain; pregnancy; spinal surgery; lumbar nerve root entrapment with neurological deficit; spinal cord compression; tumor; severe spinal deformity or instability; severe osteoporosis; spinal	Enrolled— LES: n=49 PT: n=49 AER: n=50 3 mo— LES: n=41 PT: n=46 AER: n=45 12 mo— LES: n=38 PT: n=43 AER: n=42	1.LES: isolated lumbar extension, and lumbar flexion, lateral flexion, and rotation machines, isotonic, seated (rep/set—not reported, set—not reported, frequency—2×/wk, 3 mo, PRE—increase load); bike (5–10 min); flexibility and relaxation exercises. 2.PT: individual physiotherapy to improve functional capacity using unspecified	Pain intensity (VAS), disability (RMDQ), fear avoidance (FABQ); psychological disturbance (combined MSPQ and MZQ); lumbar strength (flex, ext, rot, lat bend); trunk extensor muscle endurance, and fatigability (surface EMG).	3 mo 12 mo	Pain: LES 1.1, PT 1.6, AER 0.7 (ns). Disability: LES 1.5, PT 1.3, AER 1.3 (ns). Fear avoidance: LES 2.3, PT 3.0, AER 1.7 (ns). Psychological disturbance: LES 3.5, PT 0.2, AER 1.2. LES, AER>PT (p=.03). LES vs. AER (ns). Strength: Ext—ns among groups. Flex, Rot, Lat	Intention to treat analysis with available data.

	inflammatory disease or infection; severe cardiovascular or metabolic disease; acute infection.		strengthening, coordination, and aerobic exercise (30 min); ergonomic instruction; home exercise. 3.AER: group low impact aerobic classes—aerobics, flexibility exercise, trunk and leg muscle exercise; relaxation exercise (60 min).			bend—LES>PT, AER (p<.03). Endurance: ns among groups. Fatigability: ns among groups. Pain: LES 1.3, PT 1.6, AER 0.9 (ns). Disability: LES 2.5, PT 0.6, AER 1.4. LES, AER>PT (p=.03). LES vs. AER (ns). Fear avoidance: LES 3.8, PT 3.3, AER 2.8 (ns). Psychological disturbance: LES 1.3, PT −0.6, AER −0.5 (ns). Strength, endurance, fatigability—not tested.	
[58]	Inc: continuous LBP for 6+ mo or intermittent LBP for 2+ y, age 40–60 y. Exc: specific underlying disease, tumor, spinal fracture, disc herniation, inflammatory disease, cardiovascular and orthopedic contraindications to resistance of vibration exercise.	Enrolled— LES: n=30 CON: n=30 12 wk— LES: n=25 CON: n=25 9 mo— LES: n=25 CON: n=25	1.LES: isolated lumbar extension machine, seated isotonic (1 set—up to 11 rep, 12 wk, 1–2×/wk, PRE—increase load); resistance exercise for the abdominal and thigh muscles. 2.CON: Whole-body vibration exercise (1–2×/wk).	Pain intensity (VAS), disability (PDI), psychosocial (ADS), lumbar extension strength, lumbar ROM.	12 wk 9 mo	Pain: LES 3.3, CON 2.8 (ns). Disability: LES 9.8, CON 9.1 (ns). Psychosocial: LES 4.3, CON 2.5 (ns). Strength: LES 33%, CON 18.8% (p<.05). ROM: ns. Disability: LES 8.3, CON 5.9 (ns). Psychosocial: LES 4.2, CON −0.5 (ns). Pain, strength, ROM—not reported.	No intention to treat analysis.
[29]	Inc: male; employee of the Royal Netherlands Army; 12+ wk of continuous or recurrent LBP. Exc: spinal surgery; severe LBP that inhibited performance of peak strength tests; herniated disc; ankylosing spondylitis; spondylolysthesis; or relevant neurological diseases.	Enrolled— LES-HIGH: n=41 LES-LOW: n=40 3 mo— LES-HIGH: n=39 LES-LOW: n=36 9 mo— LES-HIGH: n=33 LES-LOW: n=29	1.LES-HIGH (High-intensity training): isolated lumbar extension machine, seated, isotonic (10–20 rep/set, 1 set, 1–2×/wk, 12 wk, start at 35% peak strength, PRE—increase load). 2.LES-LOW (Low intensity training): isolated lumbar extension machine, seated, isotonic (10–20 rep/set, 1 set, 1–2×/wk, 12 wk, start at 20% peak strength, PRE—none).	Pain intensity (Self-assessment improvement of painful back complaint), disability (RMDQ, ODI), kinesiophobia (TSK), HRQOL (SF-36), lumbar extension strength.	3 mo 9 mo	Pain: LES-HIGH 39%, LES-LOW 28% (ns). Disability-RMDQ: LES-HIGH 2.9, LES-LOW 2.4 (ns). Disability-ODI: LES-HIGH 3.1, LES-LOW 3.4 (ns). Kinesiophobia: LES-HIGH 2.0, LES-LOW 2.9 (ns). HRQOL: LES-HIGH 4.2, LES-LOW 6.4 (ns). Strength: LES-HIGH 32, LES-LOW 14 (p<.01). Pain: LES-HIGH 63%, LES-LOW 50% (ns). Disability-RMDQ: LES-HIGH 3.9, LES-LOW 4.7 (ns). Disability-ODI: LES-HIGH 4.9, LES-LOW 5.8 (ns).	No intention to treat analysis, but comparison of baseline characteristics of completed and dropped. Males only.

(*continued*)

Table 2 (*continued*)

Reference	Inclusion/exclusion criteria	Number of participants	Interventions	Outcomes	Follow-up	Results	Comments
						Kinesiophobia: LES-HIGH 2.1, LES-LOW 6.1 (p=.03). HRQOL: LES-HIGH 6.8, LES-LOW 11.8 (ns). Strength: LES-HIGH 37, LES-LOW 14 (p<.01).	
[59]	Inc: failed unspecified conservative care followed by first time lumbar discectomy for 1-level disc herniation. Exc: systemic disease; cardiovascular or orthopedic contraindications to exercise.	Enrolled— LES: n=40 CON: n=40 12 wk and 1 y — LES: n=35 CON: n=40	1.LES: isolated lumbar extension machine, isotonic, seated (rep—not reported, 1 set, frequency—not reported, 12 wk, PRE—increase load); aerobic exercise; limb-strengthening exercise. 2.CON: home-based lumbar conditioning exercise.	Pain intensity (VAS), disability (ODI), RTW, lumbar extension strength, lumbar extensor muscle CSA.	12 wk 1 y	Pain: LES 5.8, CON 3.8 (p<.05). Disability: LES 24.8, CON 30.6 (ns). RTW: LES 87%, CON 24% (p<.05). Strength: LES 52%, CON 18% (p<.01). CSA: LES 29%, CON 7% (p<.05). Pain: LES 6.8, CON 6.8 (ns). Disability, RTW, strength, CSA: not reported.	No intention to treat analysis.

ADS=Allgemeine Depression Scale; CSA=cross-sectional area; FABQ=Fear Avoidance Belief Questionnaire; HRQOL=health-related quality of life; LES=lumbar extensor strengthening exercise; LBPRS=Low Back Pain Rating Scale; MHI=Mental Health Inventory; MSPQ=Modified Somatic Perception Questionnaire; MZQ=Modified Zung Questionnaire; NS=not significant; ODI=Oswestry Disability Index; PDI=Pain Disability Index; PRE=Progressive Resistance Exercise; RMDQ=Roland Morris Disability Questionnaire; RTW=Return to Work; SIP=Sickness Impact Profile; TSK=Tampa Scale for Kinesiophobia; VAS=Visual Analog Scale; WHYMPI=West Haven Yale Multidimensional Pain Inventory. LES-EXT=lumbar extension exercise with hyperextension; STAB=lumbar stabilization exercise; SMT=spinal manipulative therapy; PAS=passive therapies; CON=control; EMG MPF=electromyographic mean power frequency; LES-DYN=lumbar extension exercise-dynamic; LES-STATIC=lumbar extension exercise-static; SF-36=Short-Form 36.

Results: Change (improvement) scores from treatment initiation, unless otherwise noted.

Follow-up: Time from onset of intervention.

machine as described by Risch et al. [27], along with co-interventions of resistance exercise for the abdominal and thigh muscles. Interventions were administered 1 to 2×/wk for 12 weeks. Outcomes included pain intensity, self-reported disability, psychosocial function, lumbar extension strengthen, and ROM. At 12 weeks, there were no differences in improvement in pain intensity, disability, psychosocial function, and ROM between the groups. Lumbar extensor strength improvement for the lumbar strengthening group was significantly greater than the vibration therapy group. At 12 months, there were no differences in disability and psychosocial function; pain, strength, and ROM outcomes were not reported for this time point.

In an RCT by Helmhout et al. [29], 81 individuals with CLBP were randomly assigned to high (n=41) or low (n=40) intensity lumbar strengthening exercise. Both groups performed isolated lumbar extensor strengthening exercises on machines 1 to 2×/wk for 12 weeks. The high-intensity group performed PREs by increasing exercise load, whereas the low intensity group performed the same low load (20% peak strength from baseline measurement) throughout the entire exercise program. Outcomes included pain intensity, disability, kinesiophobia, quality of life, and lumbar strength. At 3 and 9 months, lumbar strength improvements were significantly greater for the high-intensity group than the low intensity group. There were no differences between the groups in pain intensity, disability, kinesiophobia, and quality of life. At 9 months, improvements in kinesiophobia were significantly greater for the low intensity group than the high-intensity group, whereas there was no difference between the groups at 3 months.

In an RCT by Choi et al. [59], 80 individuals with CLBP after lumbar discectomy surgery were randomly assigned to lumbar extensor strengthening exercise (n=40) or home exercise (n=40). The lumbar extensor strengthening group performed isolated lumbar extensor PREs on a variable resistance lumbar dynamometer machine as described by Risch et al. [27], along with co-interventions of aerobic and limb-strengthening exercise for 12 weeks at an unspecified frequency. Outcomes included pain intensity, self-reported disability, return to work, lumbar extensor strength, and lumbar muscle cross-sectional area. At 12 weeks, improvements in pain intensity, return to work, lumbar extensor strength, and cross-sectional area were significantly greater for the lumbar strengthening group than the home exercise group; there was no difference in disability between the groups. At 12 months, there was no difference between the groups in pain intensity; self-reported disability, return to work, lumbar extensor strength, and cross-sectional area were not reported for this time point.

Ongoing studies

Prospective studies are currently underway to assess the optimal mode of lumbar strengthening exercise. Some of these studies are evaluating the myoelectric activity of the lumbar extensor muscles during exercise on newly developed lower-tech and home exercise machines. An ongoing RCT is designed to assess the efficacy of a muscle-specific strengthening exercise program using the VARC compared with an educational program after lumbar microdiscectomy [60].

Harms

Performance of intensive lumbar extensor strengthening exercise may result in delayed onset muscle soreness (DOMS) of the lumbar muscles [61]. DOMS occurs as a consequence of unfamiliar strenuous physical activity, especially during the first few days or weeks of performance. Typically, symptoms of lumbar DOMS include mild increase in pain and stiffness, which peaks at approximately 24 to 72 hours after initial exercise sessions and rapidly attenuates [62]. This is a normal response to vigorous exercise and is not associated with any long-term adverse effects when exercise is appropriately administered under supervision. Temporary side effects were reported in 3 of the 11 RCTs that we reviewed, including increased LBP [31,52,54] and dizziness [52].

Every physical activity is associated with some risk of rare adverse events. Intensive lumbar extensor strengthening exercise performed under load is associated with a small risk of musculoskeletal injury, including lumbar disc herniation and fracture. Individuals with cardiovascular disease may also be at risk of an untoward cardiovascular event during strenuous exercise.

Noncompliance is probably the most significant predictor of negative outcomes for lumbar strengthening exercise interventions. This treatment requires active patient participation for many exercise sessions, lasting from several weeks to a few months. Thus, motivation and willingness to participate for an extended period of time are necessary to gain the physiologic benefit of improved function by way of an active exercise program. Predictors of negative outcome for other conservative therapies for CLBP (eg, yellow flags) likely apply to this intervention also.

Summary

Lumbar extensor strengthening exercise describes a system of supervised physical exercises designed to provide isolated and gradual PREs for the lumbar musculature. Several types of lumbar extensor strengthening devices and protocols exist including high-tech machines and lower-tech prone back extensions on benches and Roman chairs. The theoretical mechanism of action of this intervention is that it enhances the structural integrity of the lumbar spine through progressive loading and improves the metabolic exchange of the lumbar discs through repetitive motion.

The current evidence suggests that in the short-term, lumbar extensor strengthening exercise administered alone or with co-interventions is more effective than no treatment and most passive modalities in improving pain, disability, and other patient-reported outcomes in CLBP. There is no clear benefit of lumbar extensor strengthening exercises compared with other exercise programs. In the long-term, some of the relative benefits in pain and disability of lumbar extensor strengthening exercise versus other interventions are lost. The effect of exercise intensity during lumbar extension strengthening programs is unclear. Hyperextension during dynamic lumbar strengthening exercise does not appear to offer additional benefit compared with extension movements to a neutral lumbar posture.

Lumbar extensor strengthening exercise administered with co-interventions also appears more effective than stabilization exercise and home exercise in improving lumbar paraspinal muscle cross-sectional area. Lumbar extensor strengthening exercise administered alone or with co-interventions is more effective than no treatment and passive modalities in improving lumbar muscle strength and endurance. There is no clear benefit of lumbar extensor strengthening exercises compared with other exercise programs in improving muscular strength and endurance. High-intensity lumbar strengthening exercise appears to be superior to low intensity in improving muscular strength and endurance.

To improve the strength and endurance of the isolated lumbar extensor muscles in CLBP through safe, gradually loaded, and measurable PREs, lumbar dynamometer machines appear to be the best option. Roman chairs and benches are viable alternatives, whereas floor, stability ball, and free weight exercises are not recommended. The relative efficacy of the various exercise subtypes for the treatment of CLBP, however, has not been assessed in RCTs.

Higher-quality RCTs with larger sample sizes, well-defined patient groups, and long-term outcomes are needed to assess the efficacy of lumbar extensor strengthening exercise for CLBP versus other interventions of particular interest are RCTs comparing different exercise programs, administered alone or with co-interventions. Future research is needed to develop and test classification systems to distinguish responders from nonresponders regarding lumbar extensor strengthening exercise for CLBP. The optimal dose of strengthening exercise needs to be clarified, including exercise intensity, frequency, volume, and duration. Similarly, the optimal mode needs to be established (eg, costly machines vs. low-cost options), and supervised versus unsupervised exercise programs. Future studies on the mechanisms of action of lumbar strengthening exercise would be useful to determine if tissue loading, repetitive movement, psychological factors, or a combination of these is responsible for the intervention's beneficial effects.

References

[1] Mooney V, Verna J, Morris C. Clinical management of chronic, disabling low back syndromes. In: Morris C, ed. Rehabilitation of the spine: a practitioner's manual. New York: McGraw-Hill, 2006.

[2] Ferreira P, Ferreira M, Maher C, Herbert R, Refshauge K. Specific stabilisation exercise for spinal and pelvic pain: a systematic review. Aust J Physiother 2006;52:79–88.

[3] Hayden JA, van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev 2005;3. CD000335.

[4] Liddle SD, Baxter GD, Gracey JH. Exercise and chronic low back pain: what works? Pain 2004;107:176–90.

[5] Smeets R, Wade D, Hidding A, Van Leeuwen P, Vlaeyen J, Knottnerus J. The association of physical deconditioning and chronic low back pain: a hypothesis-oriented systematic review. Disabil Rehabil 2006;28:673–93.

[6] ACSM. ACSM's resource manual for guidelines for exercise testing and prescription. New York: Lippincott Williams & Wilkins, 2005.

[7] Pollock M, Graves J, Carpenter D, Foster D, Leggett S, Fulton M. Muscle. In: Hochschuler S, Cotler H, eds. Rehabilitation of the spine: science and practice. Philadelphia, PA: Mosby, 1993.

[8] Bogduk N. A reappraisal of the anatomy of the human lumbar erector spinae. J Anat 1980;131:525–40.

[9] MacIntosh J, Bogduk N. The attachments of the lumbar erector spinae. Spine 1991;16:783–92.

[10] Bogduk N, Twomey L. Clinical anatomy of the lumbar spine. New York: Churchill Livingstone, 1990.

[11] Rackwitz B, de BR, Limm H, von GK, Ewert T, Stucki G. Segmental stabilizing exercises and low back pain. What is the evidence? A systematic review of randomized controlled trials. Clin Rehabil 2006;20:553–67.

[12] Mooney V. The unguarded moment. A surgeon's discovery of the barriers to the prescription of inexpensive, effective heath care in the form of therapuetic exercise. New York: Vantage Press, 2007.

[13] Zander G. OM Medico-Mekaniska Instituteti Stockholm. J Nord Med Arch 1872;Band IV.

[14] De Lorme T. Restoration of muscle power by heavy-resistance exercises. J Bone Joint Surg Am 1945;27.

[15] Graves J, Pollock M, Carpenter D, et al. Quantitative assessment of full range-of-motion isometric lumbar extension strength. Spine 1990;15:289–94.

[16] Alaranta H, Hurri H, Heliovaara M, Soukka A, Harju R. Non-dynamometric trunk performance tests: reliability and normative data. Scand J Rehabil Med 1994;26:211–5.

[17] Ostelo R, de Vet H, Waddell G, Kerckhoffs M, Leffers P, van Tulder M. Rehabilitation following first-time lumbar disc surgery: a systematic review within the framework of the cochrane collaboration. Spine 2003;28:209–18.

[18] Mayer J, Graves J, Robertson V, Verna J, Pierra E, Ploutz-Snyder L. Electromyographic activity of the lumbar extensor muscles: effect of angle and hand position during Roman chair exercise. Arch Phys Med Rehabil 1999;80:751–5.

[19] Verna J, Mayer J, Mooney V, Pierra E, Robertson V, Graves J. Back extension endurance and strength: effect of variable angle Roman chair exercise training. Spine 2002;27:1772–7.

[20] ACSM. ACSM's guidelines for exercise testing and prescription. New York: Lippincott Williams & Wilkins, 2005.

[21] Graves J, Webb D, Pollock M, et al. Pelvic stabilization during resistance training: its effect on the development of lumbar extension strength. Arch Phys Med Rehabil 1994;75:210–5.

[22] Mayer J, Verna J, Manini T, Mooney V, Graves J. Electromyographic activity of the trunk extensor muscles: effect of varying hip position and lumbar posture during Roman chair exercise. Arch Phys Med Rehabil 2002;83:1543–6.

[23] Pollock M, Leggett S, Graves J, Jones A, Fulton M, Cirulli J. Effect of resistance training on lumbar extension strength. Am J Sports Med 1989;17:624–9.

[24] Tucci J, Carpenter D, Pollock M, Graves J, Leggett S. Effect of reduced frequency of training and detraining on lumbar extension strength. Spine 1992;17:1497–501.

[25] Kumar S, Dufresne R, Van Schoor T. Human trunk strength profile in flexion and extension. Spine 1995;20:160–8.

[26] Mooney V, Gulick J, Perlman M, et al. Relationships between myoelectric activity, strength, and MRI of the lumbar extensor muscles in back pain patients and normal subjects. J Spinal Disord 1997;10:348–56.

[27] Risch S, Norvell N, Pollock M, et al. Lumbar strengthening in chronic low back pain patients: physiological and psychosocial benefits. Spine 1993;18:232–8.

[28] Rainville J, Jouve C, Hartigan C, Martinez E, Hipona M. Comparison of short- and long-term outcomes for aggressive spine rehabilitation delivered two versus three times per week. Spine J 2002;2:402–7.

[29] Helmhout P, Harts C, Staal J, Candel M, de Bie R. Comparison of a high-intensity and a low-intensity lumbar extensor training program as minimal intervention treatment in low back pain: a randomized trial. Eur Spine J 2004;13:537–47.

[30] Graves J, Pollock M, Foster D, et al. Effect of training frequency and specificity on isometric lumbar extension strength. Spine 1990;15:504–9.

[31] Manniche C, Lundberg E, Christiansen I, Bentzen L, Hesselsoe G. Intensive dynamic back exercises for chronic low back pain. Pain 1991;47:53–63.

[32] Singh B, Liu X, Trapp L, et al. The effect of lumbar extension exercise using a variable angle Roman chair on low back pain. Top Clin Chiropr 2002;9:54–9.

[33] Slade S, Keating J. Trunk-strengthening exercises for chronic low back pain: a systematic review. J Manipulative Physiol Ther 2006;29:163–73.

[34] Cassisi J, Robinson M, O'Conner P, MacMillan M. Trunk strength and lumbar paraspinal muscle activity during isometric exercise in chronic low back pain patients and controls. Spine 1993;18:245–51.

[35] Hakkinen A, Kuukkanen T, Tarvainen U, et al. Trunk muscle strength in flexion, extension, and axial rotation in patients managed with lumbar disc herniation surgery and in healthy control subjects. Spine 2003;28:1068–73.

[36] Kankaanpaa M, Taimela S, Laaksonen D, Hnninen O, Airaksinen O. Back and hip extensor fatigability in chronic low back pain patients and controls. Arch Phys Med Rehabil 1998;79:412–7.

[37] Parkkola R, Kukala U, Rytokoski U. Response of the trunk muscles to training assessed by magnetic resonance imaging and muscle strength. Eur J Appl Physiol 1992;65:383–7.

[38] Sung P. Multifidi muscles median frequency before and after spinal stabilization exercises. Arch Phys Med Rehabil 2003;84:1313–8.

[39] Danneels L, Cools A, Vanderstraeten C, et al. The effects of three different training modalities on the cross-sectional area of the paravertebral muscles. Scand J Med Sci Sports 2001;11:335–41.

[40] Kitano T, Zerwekh J, Usui Y, Edwards M, Flicker P, Mooney V. Biochemical changes associated with the symptomatic human intervertebral disk. Clin Orthop Relat Res 1993;293:372–7.

[41] Biering-Sorensen F. Physical measurements as risk indicators for low back trouble over a one-year period. Spine 1984;9:106–19.

[42] Hides J, Richardson C, Jull G. Multifidus recovery is not automatic after resolution of acute, first episode low back pain. Spine 1996;21:2763–9.

[43] Flicker P, Fleckenstein J, Ferry K, et al. Lumbar muscle usage in chronic low back pain. Spine 1993;18:582–6.

[44] Danneels L, Vanderstraeten G, Cambier D, Witvrouw E, de Cuyper H. CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. Eur Spine J 2000;9:266–72.

[45] Leggett S, Mooney V, Matheson L, et al. Restorative exercise for clinical low back pain: a prospective two-center study with 1-year follow-up. Spine 1999;24:889–98.

[46] Nelson B, O'Reilly E, Miller M, Hogan M, Wegner J, Kelly C. The clinical effects of intensive, specific exercise on chronic low back pain: a controlled study of 895 consecutive patients with 1-year follow up. Orthopedics 1995;18:971–81.

[47] Pollock M, Franklin B, Balady G, et alAHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: an advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. Circulation 2000;101:828–33.

[48] Braith R, Conner JA, Fulton M, et al. Comparison of alendronate vs alendronate plus mechanical loading as prophylaxis for osteoporosis in lung transplant recipients: a pilot study. J Heart Lung Transplant 2007;26:132–7.

[49] Braith R, Mills R, Welsch M, Keller J, Pollock M. Resistance exercise training restores bone mineral density in heart transplant recipients. J Am Coll Cardiol 1996;28:1471–7.

[50] Hayden JA, van Tulder MW, Tomlinson G. Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain. Ann Intern Med 2005;142:776–85.

[51] Hayden J, van Tulder M, Malmivaara A, Koes B. Meta-analysis: exercise therapy for nonspecific low back pain. Ann Intern Med 2005;142:765–75.

[52] Manniche C, Asmussen K, Lauritsen B, et al. Intensive dynamic back exercises with or without hyperextension in chronic back pain after surgery for lumbar disc protrusion. A clinical trial. Spine 1993;18:560–7.

[53] Timm KE. A randomized-control study of active and passive treatments for chronic low back pain following L5 laminectomy. J Orthop Sports Phys Ther 1994;20:276–86.

[54] Johannsen F, Remvig L, Kryger P, et al. Exercises for chronic low back pain: a clinical trial. J Orthop Sports Phys Ther 1995;22:52–9.

[55] Kankaanpaa M, Taimela S, Airaksinen O, Hnninen O. The efficacy of active rehabilitation in chronic low back pain. Effect on pain intensity, self-experienced disability, and lumbar fatigability. Spine 1999;24:1034–42.

[56] Mannion AF, Muntener M, Taimela S, Dvorak J. Comparison of three active therapies for chronic low back pain: results of a randomized clinical trial with one-year follow-up. Rheumatology (Oxford) 2001;40:772–8.

[57] Mannion A, Taimela S, Mntener M, Dvorak J. Active therapy for chronic low back pain part 1. Effects on back muscle activation, fatigability, and strength. Spine 2001;26:897–908.

[58] Rittweger J, Just K, Kautzsch K, Reeg P, Felsenberg D. Treatment of chronic lower back pain with lumbar extension and whole-body vibration exercise: a randomized controlled trial. Spine 2002;27:1829–34.

[59] Choi G, Raiturker P, Kim M, Chung D, Chae Y, Lee S. The effect of early isolated lumbar extension exercise program for patients with herniated disc undergoing lumbar discectomy. Neurosurgery 2005;57:764–72.

[60] Selkowitz D, Kulig K, Poppert E, et al. The immediate and long-term effects of exercise and patient education on physical, functional, and quality-of-life outcome measures after single-level lumbar microdiscectomy: a randomized controlled trial protocol. BMC Musculoskelet Disord 2006;7:70.

[61] Mayer J, Mooney V, Matheson L, et al. Continuous low-level heat wrap therapy for the prevention and early phase treatment of delayed onset muscle soreness of the low back: a randomized controlled trial. Arch Phys Med Rehabil 2006;87:1310–7.

[62] Szymanski D. Recommendations for the avoidance of delayed onset muscle soreness. Strength Cond J 2001;23:7–13.

[63] Holmes B, Leggett S, Mooney V, Nichols J, Negri S, Hoeyberghs A. Comparison of female geriatric lumbar-extension strength: asymptotic versus chronic low back pain patients and their response to active rehabilitation. J Spinal Disord 1996;9:17–22.