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Updates on core stabilization exercise and strengthening exercise: A review article

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Abstract

Nowadays, core stabilization exercise (CSE) and strengthening exercise (STE) are widely used in clinical practice to treat lower back pain. CSE focuses on the transversus abdominis (TrA) and lumbar multifidus (LM) muscles, is based on a motor relearning approach, and retrains the function of the local trunk muscles, whereas STE emphasizes the global muscles. Both exercises reduce pain and functional disability, provide neuromuscular control, and enhance the stability of the spine. Although a variety of previous studies have compared the effectiveness of these two forms of exercise, the heterogeneity of treatment procedures and participants produced conflicting results. The aim of this article is to compare and contrast CSE and STE in four different categories: exercise performance, neuromuscular activation and muscle involvement, intensity and duration, and exercise adherence. Most previous research has concluded that there is no significant difference in effectiveness between the two forms of exercise because both utilize a similar approach. Therefore, both exercises can help to reduce lower back pain problems, and we suggest that therapies should be chosen according to which exercise is the most appropriate for the problems presented by each individual patient in terms of the severity and pathology of the lower back pain. Further studies need to explore the effects of CSE and STE in terms of motor control-proprioceptive sense, balance, and muscle thickness-in the early stages of lower back pain.

Keywords: Exercise, Core stabilization, Local muscles, Strengthening, Global muscles

1. Introduction

Globally, lower back pain (LBP) is one of the most common musculoskeletal disorders causing disability and a reduction in quality of life. In addition, LBP is the leading cause of activity limitation and work absence and represents a major socioeconomic problem worldwide, with a prevalence of 11% in Spain [1], 20% in the Netherlands [2], 25.4% in Brazil [3], and 30% in Thailand [4]. Patients with LBP suffer pain in the area between the costal margin and gluteal fold. More than 85% of LBP incidences have not been attributed to a specific cause or pathology and are hence termed nonspecific LBP. A previous epidemiological study by Candotti and colleagues concluded that the prevalence of back pain was 82.9% [5]. Among these cases, 27.7% suffered functional disability, with postural changes of the spine present in 22.7%, which may pose serious implications for public health [5].

Therapeutic exercise is the methodical performance of planned physical movements, postures, or activities [6]. Several forms of therapeutic exercise are utilized in clinical practice for strengthening muscle, improving stability, restoring range of motion, improving cardiovascular conditioning, enhancing proprioception, and decreasing fear of movement in patients with LBP. However, it is difficult to conclude which exercise approach is better. Core stabilization exercise and strengthening exercise are two commonly used forms of therapeutic exercise for improving muscle strength and endurance and reducing pain and functional disability in patients with LBP.

Core stabilization exercise (CSE) is also identified as a specific stabilization exercise or motor control exercise and constitutes a skill training that is widely used in clinical practices related to LBP [7,8]. The aim of CSE is to improve neuromuscular control, increase the strength and endurance of the local trunk muscles, especially the transversus abdominis (TrA) and lumbar multifidus (LM), and relearn normal function to maintain segmental stability of the spine [9,10]. Local deep stabilization muscles attach to the thoracolumbar fascia, deliver a stiffening effect on the lumbar spine by increasing intra-abdominal pressure, and provide segmental stability of the spine in patients with lumbar instability [7-11].

Strengthening exercise (STE) is a methodical performance of lifting, lowering, or controlling heavy loads (resistance) by a muscle or group of muscles over a short period of time. This may be achieved by isometric, static, concentric, or eccentric muscle contraction. Strengthening exercise aims to increase the strength and control of the global trunk muscles in order to improve the general stability of the spine. In addition, the strengthening of the global muscles may generate a significant reduction of pain and functional disability [12].

Therapeutic exercises are aimed at remediating or preventing impairments and enhancing function, fitness, and well-being [6]. Previous systematic reviews reported that CSE and STE exercise programs have no significantly different effect, as they utilize a similar approach. The purpose of this review article is to compare and contrast CSE and STE with respect to four different categories.

2. Exercise performance

Complex components of functional movement are known as exercise performance, and the key elements include strength, power, and endurance [5]. Impairment in any one of these areas of performance may lead to activity limitations (functional) and participation restriction (disability) or increased risk of dysfunction.

2.1 Core stabilization exercise program

The stabilization exercise program is based on the principles of motor learning control. Firstly, it is important to develop awareness of the contraction of the muscle and position of the spine by kinesthetic training. To reeducate the stabilizing role of TrA and LM, a simultaneous isometric co-contraction of these muscles is performed while maintaining a static, neutral position of the spine. This co-contraction is progressively incorporated in various positions. Then, limb movements are added to the exercise program to coordinate segmental muscle activity with the global stabilizing musculature. Moreover, limb movement repetitions are increased, and resistance is applied to the limbs. Finally, spinal stability can be controlled and maintained automatically, and a progression from easy functional activities (walking) to complex and unplanned situations can be achieved. The segmental stabilization model of Richardson and Jull [9] comprises local segmental control, closed chain segmental control, and open chain segmental control (Figure 1) for the management of LBP.

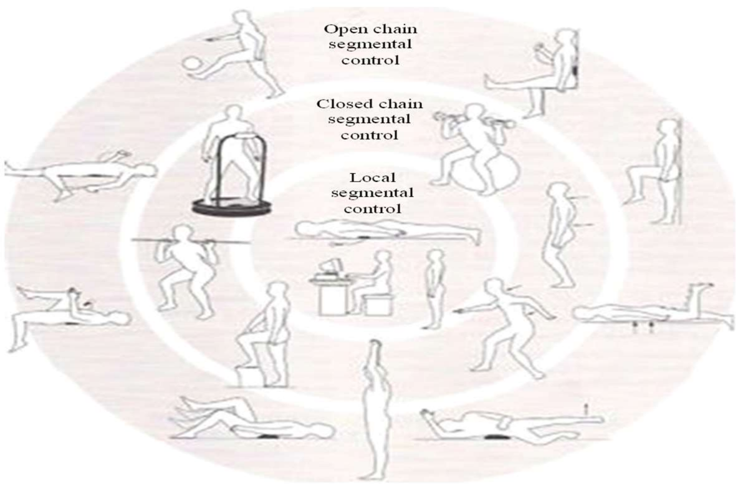

Figure 1 The segmental stabilization model of Richardson and Jull. [9]

The exercise procedure of the core stabilization exercise program for patients with LBP, modified in the study of Puntumetakul et al. [13], is based on the motor learning theory and skill acquisition described by Fitts and Posner. The exercise program is divided into three stages: the cognitive stage, the associative stage, and the autonomous stage [2]. In the first stage of the exercise training, the isolated co-contraction of the TrA and LM muscles is taught cognitively to the patients in order to improve the skill and precision of their contractions. This isometric co-activation of the TrA and LM muscles should be done in a low-load position without lumbo-pelvic movement. The patients are asked to gently draw the lower abdomen in and up towards their spine without lumbo-pelvic movement and accentuate the activations of the TrA and LM muscles while maintaining a static, neutral spine position by using pelvic floor contraction during normal respiration. Progression in the first stage consists of increasing the holding time of the contraction.

The second stage of CSE starts when the patient achieves the first stage. The number of repetitions of co-activation of the TrA and LM muscles and its precision are increased during this stage. The integration of local and global trunk muscles is also trained, in addition to co-activation of the two muscles. Controlled movements of the upper and lower limbs are performed in a low-load position while maintaining co-contraction. Moreover, the exercise performances progress to a heavier loading position: bridging and four-point kneeling position together with limb movement. Normal respiration and the co-activation of the TrA and LM muscles in a neutral spine position are maintained during training [8]. In the last stage of CSE, physical therapists analyze the need for situations or positions of "unstable" experience or anticipated pain in patients. Furthermore, the patients are trained to be able to perform co-activation of the TrA and LM muscles automatically in an unstable position and during functional activities of daily living in various environments and contexts [8].

2.2 Strengthening exercise program

The strengthening exercise program trains the muscle in a range wherein the muscle contracts isometrically, concentrically or eccentrically. For applying resistance in strength training, movements against gravity are used. Moreover, exercises are designed specifically for the task required; the involved muscle group, the type of contraction, the range and velocity of movement, and the type of equipment are chosen accordingly.

Strengthening exercises for the rectus abdominis (RA) muscles can be conducted by trunk flexion as well as hip flexion in a supine position with flexed knees. Similarly, exercises for the rectus abdominis (RA), external and internal obliquus (EO and IO), and trunk flexion and rotation movements are performed in a supine position with semi-flexed knees. Strengthening exercises for abdominal muscles will be done in a supine position with flexed knees to prevent tilting of the pelvis and hyperextension of the lumbar spine. Participants are asked to raise their trunk until their elbows touch their knees [14].

All aspects of resistance training can be integrated into various rehabilitation programs. Loading must be increased progressively to develop sufficient strength gains for a muscle or muscle group [10]. The exercise program can be graded from easy to difficult according to the muscular effort needed. For sit-ups, it is necessary to start with the hands under the thighs to help pull the body up, with progression to hands resting lightly on thighs, to fingertips on shoulders and elbows reaching forward, to holding weight, to sitting-up on an inclined board.

Strengthening exercises for the erector spinae (back extensors) can be performed in a prone position. The participant lifts the trunk, gently holds, and then slowly lowers the trunk back to the starting position. While performing the exercise, progression can be applied in the form of arms outstretched in front of the head, abducted, and crossed over the back or the head. In addition, a prone trunk extension on the elbow can be done by the participant lying prone on an exercise mat. This can be progressed by advancing to a prone extension on the hand, during which the participant lies prone and raises the chest off the mat by pressing with the arms. The range of movement increases gradually as the exercise progresses [14].

Strengthening exercises for the superficial muscles of the abdomen, trunk, and hip can be conducted in supine or bridging positions. The participant lies on the back with the hips and knees bent 90°, with the feet flat on the floor, gradually raising the pelvis off the mat by using the hip extensor muscles until the trunk is in line with the thighs [14]. The therapist monitors and makes decisions about the progression of the exercises in every session for each subject based on correct performance of the previous exercise stage [8].

In terms of exercise performance, CSE marks milestones with a focus on deep trunk muscles. New stages of the exercise are indicated when patients achieve an effective contraction of the TrA and LM muscles. In contrast, STE emphasizes the global trunk muscles, with progression achieved by increasing the load and number of repetitions. Both exercises are performed under the consideration of therapists [8].

3. Neuromuscular activation and muscles being involved

The muscles of the trunk show great variability in several characteristics: size, arrangement, types of muscle fibers, and role of function. Bergmark [15] described the local and global muscle systems of the trunk based on the control of load transfer across the lumbar spine (Figure 2). The smaller, local, deep muscles comprise the transversus abdominis (TrA), lumbar multifidus (LM), internal oblique (IO), medial fibers of the external oblique (EO), the quadratus lumborum, the diaphragm, and the pelvic floor muscle [16] attached directly to the spine. These muscles act as stabilizers to control inter-segmental motion of the spine and are essential for maintaining a neutral curve of the lumbar spine. The local muscles consist of tonic type I muscle fibers, and responses to postural changes are continuously active throughout the movement with low load contraction, independent from the direction of the movement [17]. In addition, these muscles pre-activate before global muscles and provide anticipatory control after unexpected perturbation [17].

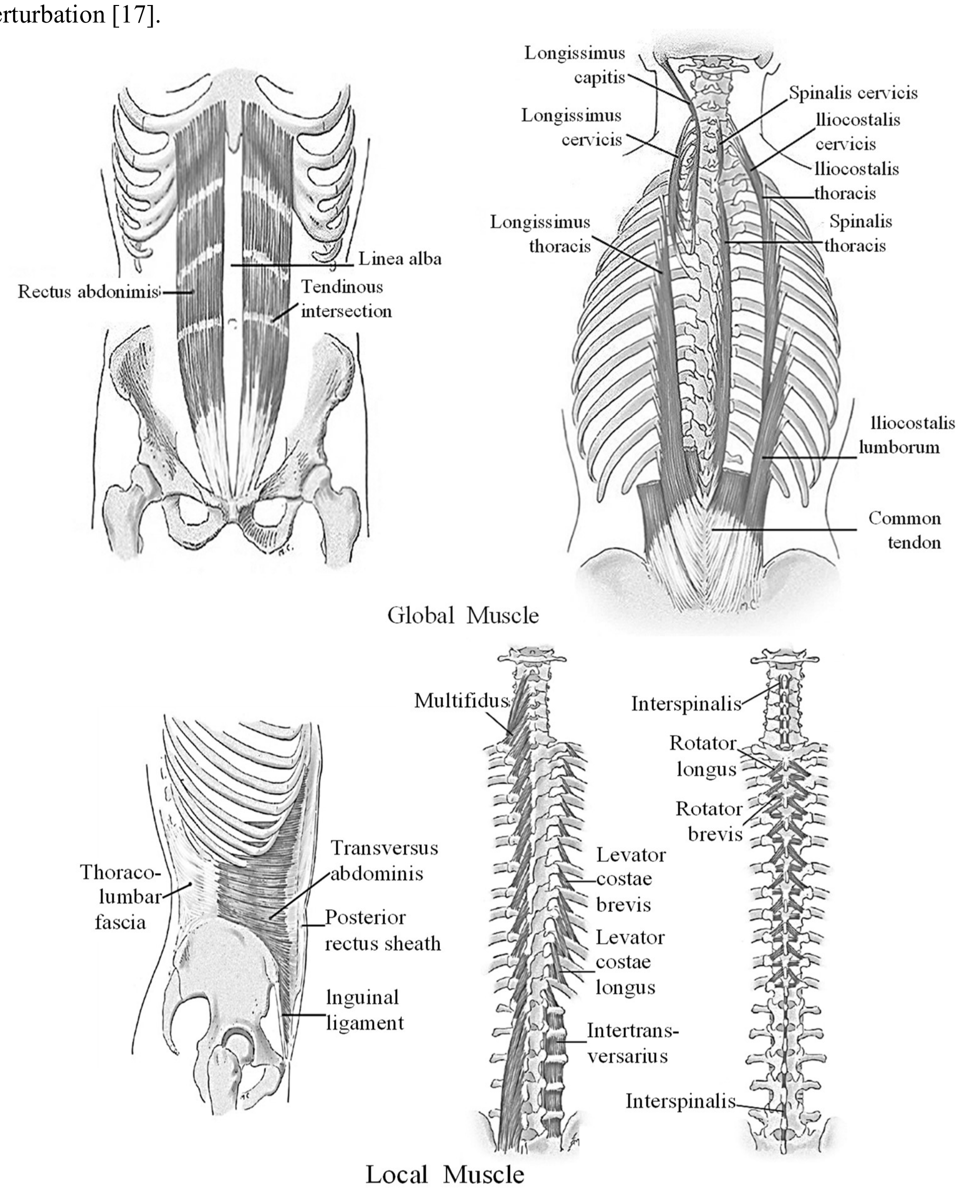

Figure 2 Local and global muscles of the lumbar spine. (modified from Neumann [18]).

The larger, global muscles comprise the rectus abdominis, external oblique, psoas major, erector spinae, and iliocostalis lumborum pars thoracis muscles [19]. These muscles have large moment arms, do not attach directly to the spine, consist of phasic type II muscle fibers, generate large torque for trunk movement in addition to spinal compression, and, as a result, provide overall stability of the spine. They diffuse loads from the thorax to the pelvis and play an important role in the shock absorption of the loads [8]. During states of "pain, injury, fatigue and stress," inhibition, hypotonia, atrophy, and delayed activity of local muscle occur, whereas over-activity of global muscle, tightness, and shortness dominate in movement [8].

3.1 Core stabilization exercise

Core stabilization exercise retrains the function of the local trunk muscles, increases the activity of the lumbar segmental muscles, and improves coordination between local and global muscle activities, which is important for neuromuscular control of the stability of the spine. Cholewicki and McGill [20] explored the importance of local muscle activity for motor control to achieve coordination between large muscles and small, intrinsic muscles of the trunk in performing specific functions. In addition, Gardner-Morse and Stokes [21] also proposed that the deep abdominal muscles are essential in providing spinal stability. According to the result of the study of Puntumetakul et al. [13], 10 weeks of CSE training significantly increased the activation ratio of the abdominal muscles (TrA and IO/RA). This improvement of local muscle activities occurs by increasing intra-abdominal pressure through generating tension in the thoracolumbar fascia and provides potential stabilization of the lumbar spine.

3.2 Strengthening exercise

General trunk-strengthening exercise emphasizes the global muscles-RA, OI, OE, and ES-reduces pain and physical disability, improves trunk muscle activity, and provides general trunk stabilization in patients with nonspecific LBP [7]. The neuromuscular system shows a remarkable ability to accommodate different external demands. After strength training, plasticity is evident in the robust and almost immediate changes in the structure and function of the neuromuscular system. Some previous research has explored whether resistance training may improve the excitability and recruitment of spinal motor neurons [22]. Increased protein synthesis within muscle fibers causes hypertrophy of the muscles and increases the physiologic cross-sectional area of the whole muscle (hyperplasia). Staron and colleagues showed that the cross-sectional area of muscles increases by as much as 30% in young adults after 20 weeks of high-resistance strength training, with increases in fiber size detected after only 6 weeks [18]. Ultimately, the most effective method of strengthening a weakened muscle involves specific and adequate progressive overload to evoke changes not only in the nervous system, but also in the structure of the muscle.

One previous study [23] investigated the effect of single sessions of cognitively activated training of LM with minimal activity of superficial muscles (CSE/skilled training), with no attention to any specific muscles (STE/simple extension training) in patients with recurrent LBP. Electromyographic (EMG) activity of the deep multifidus (DM) and superficial multifidus (SM) muscles was recorded to assess motor coordination during rapid arm movements. Interestingly, EMG activity of the superficial trunk muscles was reduced only after skilled training [23], and the activity of the lumbar multifidus muscles was reduced after simple extension training. According to the results of this study, it can be proposed that training-induced changes in motor coordination are not simply related to muscle activation and may be related to the type of task.

Tsao and colleagues found that earlier postural activation of the lumbar multifidus muscles can be regained immediately after a single session of skilled motor training in patients with recurrent LBP and postulated that it may be associated with greater reorganization of the motor cortex [24]. Motor behavior is complex and highly adaptable, and changes in motor performance after specific training occur due to changes in the function of the motor system. Furthermore, the nature of the plasticity within the motor system may be altered according to the nature of the change in motor performance. Skill training can decrease the activity of superficial muscles, increase the activity of deep muscles, and improve the coordination of muscles in patients with recurrent LBP.

In conclusion, CSE focuses on TrA and LM muscles, which are mainly tonic type I muscles, whereas STE emphasizes predominantly phasic type II muscles. Although there is evidence supporting the fact that neuromuscular activation is changed in both exercise groups according to EMG assessment, according to the study of Taso et al. [23] improvement in motor coordination can be achieved only after CSE.

4. Intensity and duration

Core stabilization exercise is a specific exercise program that emphasizes co-contraction of the deep trunk muscles, mainly the TrA and LM, to improve spinal stability in individuals with LBP [9]. This exercise can increase the strength and endurance of muscles, as well as improve the neuromuscular control and stability of the spine. This exercise uses only a low level of maximum voluntary contraction to exhibit co-contraction of the deep local segmental muscles, TrA and LM. This co-contraction is progressively integrated in various positions, and exercise is performed with increasing complexity from open chain to closed chain segmental control and the addition of different functional elements. Moreover, exercises progress gradually to avoid replacements of global muscle and compensations (e.g., pelvic movements, loss of controlled respiration) [9]. Settings typically vary among studies, and it is hard to depict a “usual” course of treatment; however, 6-12 sessions of exercise is rather common in clinical practice. This exercise program prescribes 10 contractions with 10-second holds in 20-min sessions for two sessions per week under supervision and a daily home program for 10 weeks [13].

Strengthening exercises, also recognized as progressive resistance exercises (PRE), are based on the principles of overload, specificity, reversibility, frequency, intensity, repetition, volume, duration, and mode. The intensity of PRE is determined not only by the number of repetitions but also by the amount of resistance used. High-intensity PRE with higher resistance and fewer repetitions is used to increase muscle strength, whereas low-intensity PRE with lower resistance and more repetitions is used to improve muscular endurance [25]. While performing PRE, intensity ranges between 30% and 85% of maximum intensity, and six to 25 repetitions of the exercise can be applied depending on the therapeutic goals (i.e., strength or endurance).

The duration of the exercise refers to the total length of the exercise program in the context of PRE. Although clinical improvement can be seen after only a few weeks of a resistance training program due to changes in specific physical function, a minimum of 10 to 12 weeks of PRE is requisite to attain physiologic changes (hypertrophy) in skeletal muscles [25].

The two forms of exercise differ in intensity and duration. In the case of the strengthening exercise, progression is achieved by increasing either the number of exercise sessions (e.g., from six sessions to 12 sessions) or the number of contractions (e.g., from five contractions to 10 contractions). In contrast, CSE progresses by either integrating performance in different positions or by combining the performance of more difficult functional activities. Furthermore, the longest period of CSE training is 10 weeks [26]. Table 1 shows a summary of the comparison of CSE and STE exercises on intensity and duration prescribed in previous studies.

Table 1 Summary of previous studies of CSE and STE exercises on intensity and duration.

Author, Year	Participants	Intensity and duration		Results
		CSE	STE	
Hwangbo et al. [28]	30 patients with CLBP Age 30-40 years	60 min, 3 times per week for 6 weeks	NA	Decreased pain and disability Significantly decreased sway length and sway area ($p < 0.05$)
Aly et al. [15]	30 patients with CLBP	7- 8 seconds hold for 10 repetitions, 3 times per week for 8 weeks	8 seconds hold for 10 repetitions, 3 times per week for 8 weeks	Core stabilization exercises more effective in improving strength and endurance ($p < 0.001$)
Bhadauria et al. [29]	44 patients with CLBP Age 20-60 years	10 seconds hold for 10 contractions 10 sessions of exercises for 3 weeks	10 seconds hold for 10 contractions 10 sessions of exercises for 3 weeks	Stabilization exercise superior to strengthening exercise in reducing pain and functional disability ($p = 0.001$)
Shamsi et al. [30]	51 patients with NSCLBP	20 min in each session, 3 times per week, total 16 sessions	14 min in each session, 3 times per week, total 16 sessions	Significant reduction in disability level, pain intensity and stability index in both groups ($p < 0.001$)
Nabavi et al. [31]	41 patients with NSCLBP	10 seconds hold for 10 contractions, 3 times per week for 4 weeks	10 seconds hold for 10 contractions, 3 times per week for 4 weeks	Both groups show reduced pain intensity and improved muscle measurement ($p < 0.01$)
Puntumetakul et al. [27]	38 patients with CLI Age 20-60 years	10 seconds hold for 10 contractions low levels of MVC 20 min twice per week for 10 weeks	10 seconds hold for 10 contractions 20 min twice per week for 10 weeks	Improvement of balance and reduction of pain intensity in both groups Significant improvement of deep abdominal muscle activation ratio in CSE group ($p = 0.001$)

CSE= core stabilization exercise; STE= strengthening exercise; SE= stabilization exercise; CLBP= chronic low back pain; NSCLBP= nonspecific chronic low back pain; CLI= clinical lumbar instability; MCV= maximum voluntary contraction; NA= Not applicable.

5. Exercise adherence

Adherence is "the extent to which a person's behavior corresponds with agreed recommendations from a healthcare provider" [31]. A patient's participation in more than 75% of the exercise sessions is considered high adherence to the exercise program, and this can reduce the disability level of the subject. However, adherence to any therapeutic exercise program tends to decline over time, and it is demanding to retain patient participation for the whole period to achieve functional progress.

Exercise programs may be moderately effective in reducing pain and improving function in chronic LBP. Most effective exercise programs comprise individually designed exercises that use a supervised format, such as home exercise with regular follow-up [12]. Good adherence is essential to improving the effectiveness of exercise programs. In contrast, poor adherence to treatment is common and may adversely affect outcomes and efficiency, can cause recurrence, and increases healthcare cost [31]. It is, however, worth noting that previous studies reported no adverse effects from either CSE or STE exercises [32]. Meta-analysis was used to identify five RCTs that compared core stabilization exercise and strengthening exercise for chronic LBP, and no serious complications were reported in any of the five articles that investigated adverse events [32]. During and after exercise, serotonin synthesis tends to increase, which may be related to improved mood and enhanced exercise adherence. In addition, the age and sex of the patients also influence exercise adherence, and men have higher adherence rates than women [33].

Factors that influence adherence to an exercise program include a patient's characteristics (poor self-efficacy, fear of pain, inability to fit exercises into daily life), a patient's health state or impairments (severity or stability of state), program-related variables (lack of supervision during learning sessions, complex design of program, large number of exercises), and style of care providers (absence of monitoring or feedback) [33].

A prospective, observational study explored adherence to the stabilization exercise program in patients with chronic LBP and concluded that all patients experienced a significant reduction of pain and improvement of function, while the adherence to exercise was 82–84% during the three trimesters [34]. One key finding of this study was that high adherence to the routine of exercises for lumbar stabilization resulted in a decrease in pain and more rapid functional progress. Moreover, strengthening exercises also improved pain, functional performance, and adherence to exercise in older adults with chronic LBP [35]. Therefore, it may be assumed that the strongest predictor of functional progress could be therapeutic exercise adherence.

One qualitative study evaluated barriers to adherence to home-based exercise programs by questioning the views of patients with chronic LBP [36]. The results of this study determined that barriers associated with adherence to exercise programs comprised number, efficiency, difficulty, and load of exercises, interruption among supervised sessions and home exercise, absence of follow-up and difficulties in contacting care providers, patient illness, mood and exercise perception, unhappiness, depression and lack of inspiration, attitudes of others, and problems in planning exercise. In addition, the author also reported that exercise adherence could be enhanced by developing the attractiveness of training programs, improving the performance of patients by using a model or providing feedback, and increasing the feeling of being supported by care providers [36].

For patients with chronic low back pain, CSE follows a spinal stabilization model, provides feedback while performing low-load isometric co-contraction, and uses a facilitation technique to enhance the exercise performance of patients. In addition, the exercise is explained clearly, and sessions are completed under supervision with suitable intensity and duration of exercise, further including 10-15 min of a daily home exercises program. Moreover, the daily home exercise program is recorded in an exercise diary, and the exercise progresses according to the individual's achievement in order to improve exercise adherence.

Generally, no difference in terms of exercise adherence between the CSE and STE exercises could be identified. Both exercise programs were successful in increasing both the strength and endurance of muscles, reducing disability level and pain intensity, and improving the stability index [34]. Table 2 compares CSE and STE with respect to factors concerned with exercise adherence.

Table 2 Comparison of CSE and STE exercises on factors of exercise adherence.

Factors concern with adherence	CSE	STE
Attractiveness of exercise programs	Attractive	Attractive
Model, Feedback	US, pressure biofeedback	Manual
Duration	6 to 12 sessions 4 weeks- 12 weeks	6 to 25 repetitions 8 weeks- 4 months
Supervision	Provide	Provide
Motivation, support	Provide	Provide
Effectiveness	Effective	Effective

6. Conclusion

The aim of this article was to compare and contrast CSE and STE exercise with respect to four different criteria: exercise performance, neuromuscular activation and muscle involvement, intensity and duration, and exercise adherence. In terms of exercise performance, CSE relies on the co-contraction of TrA and LM, which are activated first, followed by allowing coordinated segmental muscle activity of superficial muscles. In contrast, STE emphasizes the training of trunk muscles in the range of isometric, concentric, or eccentric muscle contraction. While CSE focuses on local muscles, which consist of tonic type I muscle fibers, and responds to postural changes, STE emphasizes global muscles, consisting of phasic type II muscle fibers. These generate a large torque in trunk movement, resulting in over-activity of the global muscles. The intensity and duration of CSE and STE were found to be fundamentally different. CSE uses a milestone progress model with a focus on deep local trunk muscles and requires very gentle and slow exercise performance in order to make sure that the deep muscles are properly activated. The typical duration of CSE was 20 min per session. In contrast, STE is recognized as progressive resistance exercise (PRE) based on the principles of either higher resistance and lower repetition or lower resistance and higher repetition. Concerning adherence, no difference between the two exercises could be identified, and both are effective in increasing strength and endurance, reducing disability level and pain intensity, and improving stability index.

Clinical practitioners can apply both exercises to reduce LBP problems. Hence, we suggest that therapies should be chosen in accordance with which exercise (CSE or STE) is the most appropriate for the problems presented by each patient. For example, CSE is recommended for LBP patients with clinical lumbar instability, as this exercise can improve neuromuscular control, specifically of the local trunk muscles, which play an important role in lumbar segmental stabilization. On the other hand, STE is commonly used in LBP patients to improve pain, physical disability, and trunk muscle activity.

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8. Conflicts of interest

All of the authors declare that there is no conflicts of interests.

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