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Effects of Stabilization Exercise on Lower Limb Functions: A Scoping Review of the Literature

Stabilizasyon Egzersizinin Alt Ekstremite Fonksiyonları Üzerindeki Etkileri: Literatürün Kapsamlı Bir İncelemesi

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ABSTRACT

We performed a scoping review of the literature to examine the effects of stabilization exercises on lower limb functions. We searched Cochrane Library (trials), PubMed, Web of Science, and Google Scholar electronic databases (from 2010 to 2023) for randomised controlled trials to determine the effects of stabilization exercises on the lower extremity functions. Fourteen studies met the inclusion criteria. Stabilization exercises were effective in improving lower limb functions, biomechanics, and balance ability, as well as preventing sport-related injuries. The results suggest that the level of evidence regarding the effects of stabilization exercise on lower limb functions is good. Stabilization exercises should be used as part of rehabilitation programs for patients or individuals with lower extremity issues.

Anahtar Kelimeler: Stabilization, exercise, rehabilitation, lower extremity.

ÖZ

Stabilizasyon egzersizlerinin alt ekstremite fonksiyonları üzerinde etkilerini değerlendirmek amacıyla literatürde kapsamlı bir inceleme gerçekleştirdik. Stabilizasyon egzersizlerinin alt ekstremite fonksiyonları üzerinde etkilerini belirlemek için Cochrane Library (trials), PubMed, Web of Science ve Google Scholar elektronik veri tabanlarında (2010'dan 2023'e kadar) randomize kontrollü çalışmaları araştırdık. On dört çalışma dahil etme kriterlerini karşıladı. Stabilizasyon egzersizleri alt ekstremite fonksiyonları, biyomekaniği ve denge yeteneğini geliştirmede ve sporla ilgili yaralanmaları önlemede etkili oldu. Sonuçlar, stabilizasyon egzersizinin alt ekstremite fonksiyonları üzerindeki etkilerine ilişkin kanıt düzeyinin iyi olduğunu göstermektedir. Stabilizasyon egzersizleri, alt ekstremite problemleri olan hastalar veya bireyler için rehabilitasyon programlarının bir parçası olarak kullanılmalıdır.

Keywords: Stabilizasyon, egzersiz, rehabilitasyon, alt ekstremite.

Introduction

The lumbo-pelvic-hip complex, referred to as the "lumbar core," consists of muscle groups positioned three-dimensionally to stabilize the trunk and spine, functioning much like a corset (Huxel Bliven & Anderson, 2013). This core stability is essential for force transmission and serves as a vital connection between the lower and upper limbs (Akuthota et al., 2008).

Core stability and strengthening are becoming increasingly important in the rehabilitation and fitness sectors. In addition to being integrated for performance optimization and strengthening, core stability has gained significance in injury prevention (Hartigan et al., 2010). However, few studies have investigated the impact of core stability on various functional impairments, such as pain, activity limitations, and range of motion (ROM) (Yılmaz Yelvar et al., 2015).

Inefficient core muscle activation can lead to the development of maladaptive compensatory movement patterns over time, complicating trunk control. For instance, abnormalities in the ankles, knees, or hips may result in the increased use of the hip strategy (Francis & Song, 2011). Proper core muscle activation is essential for maintaining the quality of movement during walking (Bassoe Gjelsvik & Syre, 2016, Kalron & Givon, 2016). Impairments in core activation can lead to reduced walking

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speed (Cameron & Lord, 2010) and a greater cognitive attention required for walking (Wajda & Sosnoff, 2015).

Stabilization exercises have become a key focus in enhancing lower extremity function and addressing musculoskeletal issues. This review examines studies that investigate the effects of stabilization exercises on lower limb functions. Given the essential role of lower limb mobility and stability in both daily activities and athletic performance, understanding the outcomes of these exercises is crucial for guiding evidence-based practices and rehabilitation programs. The objectives of this review are to: 1) outline the characteristics of studies on stabilization exercises, and 2) assess the impact of stabilization exercises on lower extremity functions.

Methods

Search Methods for Identification of Studies

Scoping reviews, or mapping reviews, are used to define the conceptual boundaries and working definitions of a subject, especially when the literature is too complex or heterogeneous for systematic reviews or has not been thoroughly examined (Peters et al., 2015). An independent researcher reviewed relevant published articles on stabilization exercises. The researcher independently screened the search results by reading the titles and abstracts. The results were first checked for duplicates. Full texts of the potentially relevant studies were obtained and independently assessed for inclusion. The Cochrane Library (trials), PubMed, Web of Science, and Google Scholar electronic databases were used to search for published articles from 2010 to 2023. All the searches included English language studies. Keywords were determined as “stabilization” or “exercise,” or “rehabilitation,” or “lower extremity,” or “stabilization and exercise and lower extremity,” or “stabilization and rehabilitation and lower extremity.” Two of the authors completed the study selection and data extraction. In cases of disagreement, studies were reassessed until consensus was reached. The process used to select the articles for this review follows figure 1.

Eligibility criteria

- This review included all randomised controlled trials (RCTs) that investigated the efficacy of stabilization exercises in patients or general individuals that had an effect on lower limb functions.
- Studies that compared a stabilization exercises group with a general exercises group or any kind of intervention.
- Studies were considered regardless of publication status or size.

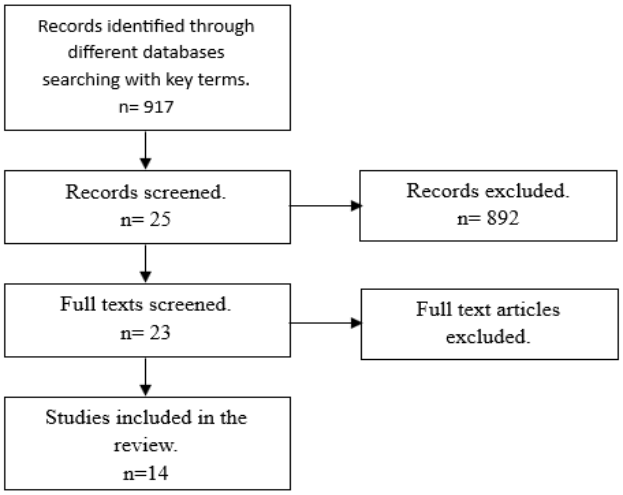

Figure 1: Flow chart of study evaluation and selection process.

Table 1: Study quality on the PEDro scale.

	Study	1	2	3	4	5	6	7	8	9	10	11	Total
1	Sasaki et al. 2019	-	+	-	+	-	-	-	+	+	+	+	6
2	Baldon et al. 2014	+	+	+	+	+	+	-	+	+	+	+	9
3	Jeong et al. 2021	+	+	-	+	-	+	-	+	+	+	+	7
4	Silder et al. 2013	+	+	+	+	-	+	+	+	-	+	+	8
5	Baldon et al. 2015	+	+	+	+	+	-	-	+	+	+	+	8
6	Güngör et al. 2022	+	+	-	+	-	-	-	+	+	+	+	6
7	Yılmaz et al. 2015	+	+	-	+	-	+	-	+	+	+	+	7
8	Develi et al. 2021	+	+	+	+	+	-	-	+	+	+	+	8
9	Arntzen et al. 2019	+	+	+	+	-	-	+	+	+	+	+	8
10	Min et al. 2020	+	+	-	+	-	-	+	+	+	+	+	7
11	Elshafey et al. 2022	+	+	-	+	-	-	+	+	+	+	+	7
12	Priyanka et al. 2017	+	+	-	+	-	-	+	+	+	+	+	7
13	Kim et al. 2011	+	+	-	+	-	-	-	+	+	+	+	6
14	Rasika et al. 2020	+	+	-	+	-	-	-	+	+	+	+	6

1: eligibility criteria; **2:** random allocation; **3:** concealed allocation; **4:** baseline comparability; **5:** blinded participants; **6:** blinded therapists; **7:** blind assessors; **8:** adequate follow-up; **9:** intention-to-treat analysis; **10:** between-group comparisons; **11:** point estimates and variability. Item 1 does not contribute to the total score.

Exclusion criteria

- Studies not available in English.
- Conference abstracts and theses.
- Case report studies.
- Articles inaccessible in full text.

Quality Assessment

The quality of evidence was independently scored by one researcher based on the PEDro scale, which consisted of 11 items. The PEDro scale is a useful tool for evaluating the quality of physical therapy and rehabilitation trials. The method score is often determined by excluding one item from the PEDro scale (eligibility criteria) that relates to external validity, leaving a score range of 0–10 (Olivo et al., 2008, Verhagen et al., 1998, Maher et al., 2003).

Results

Descriptive Data

The researcher identified 917 potentially relevant articles through different electronic databases (Fig. 1). After evaluating titles and abstracts, 892 articles were excluded. Eighteen full texts were reviewed, and the researcher could not reach the full text of two articles (Saleem et al., 2023). Effects of Routine Physical Therapy with and without Pilates-based Core Stability Exercises on Gait, Function and Balance in Patients with Multiple Sclerosis: Pilates-based Core Stability Exercises in Multiple Sclerosis. The Healer Journal of Physiotherapy and Rehabilitation Sciences, 3(7), 651-658; and Lyons et al., Core and Whole-Body Vibration Exercise Improve Military Foot March Performance in Novice Trainees: A Randomized Controlled Trial. Mil Med. 2023 Jan 4;188 (1-2): e254-e259. doi: 10.1093/milmed/usab294). Fourteen studies were included in this scoping review. Each was scored using the PEDro scale. Table 1 presents the results of individual assessments by the PEDro scale. The study characteristics are summarized in Table 2. The studies, published between 2011 and 2023, were all randomized controlled studies. The results section clarifies the effect of stabilization exercises on lower extremity functions by analyzing a variety of research studies.

Interventions

Functional Stabilization Training (FST)

Three studies (Baldon Rde et al., 2014, Baldon Rde et al., 2015) evaluated the effects of FST on different groups. In one study (Baldon Rde et al., 2014), thirty-one women were randomly assigned to either an FST group or a standard training (ST) group. Both groups followed their respective training programs three times a week for eight weeks, with at least twenty-four hours between each session. The sessions for the FST group lasted between 90 and 120 minutes, while those for the ST group were between 75 and 90 minutes long. Additionally, all participants received instruction on how dynamic lower limb misalignment could lead to increased patellofemoral stress and knee pain.

Another controlled laboratory study (Baldon Rde et al., 2015) conducted by Baldon et al. examined the effects of FST in women with patellofemoral pain. Thirty-one female athletes were randomly assigned to either an FST group, which focused on strengthening the trunk and hip muscles, or ST group, which focused on stretching and quadriceps strengthening. Treatment began three to five days after baseline isokinetic testing. Both groups followed their respective training programs three times a week for eight weeks, ensuring a minimum of twenty-four hours between each session. The FST program included both weight-bearing and non-weight-bearing exercises to strengthen the hip and trunk muscles. During phase 1, which lasted the first two weeks, the primary goal was to enhance motor control of the trunk and hip muscles through non-weight-bearing exercises. Phase 2, which spanned the following three weeks, focused on strengthening the hip and trunk muscles using weight-bearing exercises. In phase 3, the final three weeks of the program, patients were educated on performing functional exercises with their lower limbs in a neutral frontal alignment and on leaning forward with their hips to reduce quadriceps dominance.

Pilates-Based Core Stability Training (PBCST)

PBCST is a controlled form of exercise designed to enhance the stabilization of the trunk muscles (Freeman et al., 2012). By incorporating fundamental Pilates principles into core stabilization exercises and utilizing the activating influence of breathing on deep muscles, PBCST aims to train the core muscles more effectively. Activation of the Transversus Abdominis (TrA) is crucial for this type of exercise. The TrA facilitates postural adaptation by being activated through a feedforward mechanism of neuromuscular control before sudden spinal loads or limb movements occur. Thus, efficient TrA activation enhances trunk stability, which in turn supports both distal movement and postural control (Borghuis et al., 2008).

In a study conducted by Güngör et al. (2022), PBCST was administered to one group under supervision at a clinic twice a week for eight weeks, while another group performed the PBCST at home. For the first four weeks, the exercises were performed with 10 repetitions, increasing to 15 repetitions for the subsequent four weeks, with progressions made every two weeks for both groups. By the end of the eight-week period, each session had increased in length from sixty to seventy-five minutes, with five minutes added at each progression step.

Postural Stabilization Exercises

Forty-two volunteers with patellofemoral pain syndrome (PFPS) participated in a study conducted by Yılmaz et al. (2015). The subjects were randomly assigned to two groups: Group 1 performed postural stabilization exercises in addition to therapeutic knee exercises, while Group 2 performed only therapeutic knee exercises. In group 1, the stabilization exercises were carried out three days a week for six weeks. These exercises incorporated concepts such as maintaining a neutral spine, core activation, and diaphragmatic breathing to enhance core muscle activation, support movement, improve mobility, increase lung capacity, and enhance focus. During the first two weeks, participants performed the exercises using only their body weight, completing five repetitions of each exercise in the prescribed order. In the subsequent four weeks, the exercises were performed using appropriate elastic resistance band to increase the intensity. All participants received instructions for an at-home exercise regimen, which included the therapeutic knee exercises. They were instructed to perform each exercise in the home program three times a day, with ten repetitions for each exercise.

Trunk Stability Robot (using a trunk stabilization training robot (3DBT-33)) Training

The Trunk Stability Rehabilitation Robot Trainer (3DBT-33) is a piece of medical equipment approved by the Ministry of Food and Drug Safety for use in postural control and leg function rehabilitation training. This robotic rehabilitation tool is designed to enhance muscle strength training. A chair has been incorporated into the commercialized version of this postural control trainer, which previous studies have shown to have positive effects on gait and functional postural control (Lee et al., 2012).

In a RCT by Min et al. (2020), participants were assigned to either a conventional rehabilitation group (CRG) or a robot-assisted group. Both groups underwent 30 minutes of traditional physical therapy five days a week for four weeks. The traditional physical therapy was part of a standard neurorehabilitation program aimed at improving symmetrical static and dynamic standing balance function in hemiplegic stroke patients during walking. In addition to the conventional physical therapy, the robot-assisted group also received 30 minutes of training using a trunk stability robot. The trunk stability robot training consisted of three different ten-minute exercises, each incorporated into a game format. The first exercise was a standing balance activity using a balloon popping game. The second involved a seated balance exercise using a fruit collecting game. The final exercise was a sit-to-stand workout, conducted using a basketball game. Both the CRG and the robot-assisted group followed the conventional physical therapy regimen.

Dynamic Neuromuscular Stabilization (DNS) Technique

The DNS technique is a relatively recent approach that achieves enhanced functional outcomes by transitioning from locomotor activities to an "integrated stabilizing system" (Norberg, 2015, Song et al., 2013). This technique aims to achieve postural stability by using each movement to enhance the coordinated activity of every spinal segment (Race Walking, 2007).

In a comparative study by Pawar et al. (2020), all participants were race walkers and were divided into two groups of 20 participants each. Group A underwent the DNS method, while Group B participated in a parachute resistance training program. The DNS conditioning program (Palamarchuk, 1980) lasted 20 minutes and included the following exercises: Participants started in the Shavasana pose (lying supine with the chin tucked in and palms open) and performed a series of Breathing exercises. These included lifting one leg up with the hip fully flexed and externally rotated–knee flexed, and then repeating with the other leg. This was followed by lifting both hands up with palms open. Participants then returned to a relaxed position. Next, participants moved to a prone position, with their head up, chin tucked in, elbows flexed, palms open, and fingers flexed as if catching a ball. They practiced breathing exercises by rotating their head three times, inhaling and exhaling, and then moved their head up and down, followed by relaxation. The Parachute resistance training program also lasted 20 minutes conditioning

program and involved five laps of 50 meters each, with each lap lasting four minutes. Resistance training using a parachute was applied to race walkers. Air is the source of the resistance that has been imposed at right to the rear of the athlete's body center of gravity.

Outcome measurements

The studies included in this review used a wide variety of outcome measures. Sasaki et al. (2019) reported that for the drop-jump test, the maximal trunk-flexion angle increased and peak knee-valgus moment decreased in the training group. Additionally, during the single-legged squat, the peak trunk-flexion angle increased, and the total amount of trunk lateral-inclination angle and peak knee-valgus moment decreased in the training group. No changes were observed in the control group.

According to Baldon et al. (2014), patients in the FST group showed greater overall improvement and better physical function by the end of the intervention compared to those in the STG. They also reported less pain at the 3-month follow-up. Only in the FST group did the single-leg squat result in reduced ipsilateral trunk inclination, pelvic contralateral depression, hip adduction, and knee abduction, as well as increased pelvis anteversion and hip flexion movement excursions. Following training, only the FST group exhibited increased eccentric hip abductor and knee flexor strength and increased anterior, posterior, and lateral trunk muscle endurance.

According to Jeong et al. (2021), following training, the trunk endurance scores of the intervention group significantly improved. This group demonstrated a higher trunk flexion angle, increased rectus abdominis to erector spinae coactivation ratio, higher hamstring to quadriceps coactivation ratio, and an increased vastus medialis to vastus lateralis (VM:VL) activation ratio, while showing reduced knee valgus and hip adduction angles. Additionally, a positive correlation was observed between the hip adduction angle and the knee valgus angle at initial contact, but a negative correlation was found between the hip adduction angle and the VM:VL activity ratio during the precontact phase. In contrast, the control group showed no statistically significant differences in kinematics, muscle activations, or trunk endurance scores.

In addition to physical tests, such as the return-to-sport time (days), which measures the duration from the original injury to the end of rehabilitation, Silder et al. (2013) also assessed the mediolateral width and anterior/posterior depth of the affected area using magnetic resonance imaging (MRI). Clinical and morphological outcome indicators did not show significant differences between the rehabilitation groups over time, and both groups had low rates of reinjury following their return to sports. A longer time to return to sport was positively correlated with a greater craniocaudal duration of injury as determined by MRI before the start of rehabilitation. Although all participants experienced nearly complete pain relief and regained muscle strength upon resuming sports activities, none achieved complete resolution of the injury as assessed by MRI.

Güngör et al. (2022) reported that among groups in multiple sclerosis, the supervised PBCST group was mostly superior to the home PBCST group. A significant improvement was noted in all parameters in both groups, except some sub-parameters of postural sway in home PBCST. In another study, Develi et al. (2021) investigated the effectiveness of combining core stabilization exercises with an asthma education program and breathing exercises in patients with asthma. They reported that the Training Group (TG) showed more significant improvements in Maximum Inspiratory Pressure (MIP), the International Physical Activity Questionnaire Short Form (IPAQ), the six-minute walking test (6MWT), and dynamic balance sub-parameters. These improvements were measured as the mean difference between the initial assessment and after a 6-week intervention program, which included twelve exercise sessions.

In a study conducted by Arntzen et al. (2020), several outcome measures were used, including the 2-minute walk test (2MWT), the 10-minute walk test (10MWT) at preferred/fast/slow speeds, the Multiple Sclerosis Walking Scale-12 (MSWS-12), the Patient Global Impression of Change-walking (PGIC-walking), the Rivermead Visual Gait Assessment (RVGA), and the ActiGraph Wgt3X-BT activity monitors. The study found that the group-based, individualized, comprehensive core stability and balance intervention (GroupCoreDIST) led to significant improvements in walking ability immediately following the intervention, with continued benefits up to 24 weeks of follow-up, compared to standard treatment.

In a study by Min et al. (2020), participants were assessed using several measures, including the Berg Balance Scale (BBS), the Korean Modified Barthel Index (K-MBI), the Functional Ambulation Categories (FAC), the Timed Up and Go (TUG) test, and the Fugl-Meyer Assessment of Lower Extremity (FMA-LE). Statistically significant differences were found between the

robot-assisted and control groups for the FMA-LE, K-MBI, and BBS. Among these, the FMA-LE and BBS demonstrated a more substantial minimal detectable change compared to the FAC, TUG, and K-MBI. The results indicated that trunk stabilization rehabilitation training with a rehabilitation robot led to improvements in balance and lower limb functions in individuals with chronic stroke.

Elshafey et al. (2022) investigated the effects of a core stability exercise program in children with cerebral palsy. Both groups were evaluated by using the Scale for the Assessment and Rating of Ataxia, the Balance Error Scoring Systems scale, Bruininks-Oseretsky tests of motor proficiency, and HUMAC balance system scores. The study found statistically significant reductions in the severity of ataxia, as well as improved balance and coordination in both groups, with stronger effects observed in the intervention group.

To measure upper/lower extremity muscle strength and endurance, Kim et al. (2011) used the Biodex System 3 Pro for both the resistance exercise group (REG) and the resistance and stabilization exercise group (RSEG). Both groups demonstrated significant increases throughout the trial. Lumbar resistance and stabilization complex exercises enhanced muscle strength and endurance in both the upper and lower extremities, with the RSEG showing more pronounced effects compared to the REG.

The Cooper test and sprint test were used in a study by Pawar et al. (2020) to determine VO2 max and speed prior to treatment. Following treatment, all the parameters were assessed. Participants in group A received dynamic neuromuscular stabilization (DNS) technique, whereas group B participated in a Parachute resistance training program. The results showed that race walkers in group A, who received DNS therapy, experienced a significantly greater improvement in performance compared to those in group B.

Yılmaz et al. (2015) assessed pain, hamstring flexibility, function, lower extremity strength, and postural control of every patient before and after therapy, and at the 12-week follow-up. They found statistically significant differences between the groups in terms of pain, flexibility, function, strength, endurance, postural control, and the characteristics of the Kujala patellofemoral pain scale. Group 1, which participated in therapeutic knee and postural stabilization exercises, achieved the most significant improvements across all parameters after treatment.

Conclusion

This scoping review study aimed to summarize the available literature to determine the effects of stabilization exercise on lower limb functions. A total of 14 original research studies, including randomized controlled trials (RCTs) were included and analyzed. Eleven studies demonstrated that stabilization exercises effectively improved lower limb functions and biomechanics, as well as helped prevent sport-related injuries (Pawar, 2020, Baldon Rde et al., 2014, Baldon Rde et al., 2015, Güngör et al., 2022, Yılmaz Yelvar et al., 2015, Arntzen et al., 2020, Min et al., 2020, Kim et al., 2011, Priyanka et al., 2017, Sasaki et al., 2019, Jeong et al., 2021).

Two studies focused on individuals with multiple sclerosis (MS) (Güngör et al., 2022, Arntzen et al., 2020). Güngör et al. found that patients who received supervised Pilates-Based Core Stability Training (PBCST) showed significant improvements in strength, postural control, core stability, physical capacity, and fatigue compared to those who performed PBCST at home. Arntzen et al. reported that walking ability improved significantly immediately after the GroupCoreDIST intervention and continued to show benefits up to 24 weeks of follow-up, compared to conventional care.

Additionally, two studies (Yılmaz Yelvar et al., 2015, Baldon Rde et al., 2014) demonstrated that stabilization exercises were efficacious in decreasing pain and improving physical function and strength.

One study (Develi et al., 2021) found that incorporating core stabilization exercises into a pulmonary rehabilitation program significantly improved inspiratory muscle strength, physical activity levels, functional exercise capacity, and dynamic balance after a 6-week intervention program.

Two additional studies (Jeong et al., 2021, Priyanka et al., 2017) reported that core stability exercise programs are effective in improving function and post-anterior cruciate ligament (ACL) reconstruction. According to Jeong et al. core strength training may be taken into account in programs aimed at preventing ACL injuries in order to modify the lower extremity alignment in the frontal plane and the activation of muscles during sports-related tasks. In contrast, Priyanka et al. found that a conventional institutional exercise regimen effectively reduced pain and

Table 2: Characteristis of the studies in this review.

Study	Methodology	Participants Stabilization exercise	Intervention	Outcomes	Conclusions
Sasaki et al. 2019	Controlled laboratory study	Female collegiate basketball players (n = 9)	Core-muscle-training program + daily practice	Three-dimensional hip, knee, and trunk kinematics; Knee kinetics; Isokinetic muscle strength	Improved lower limb and trunk biomechanics. These altered biomechanical patterns could be favorable to preventing sport-related injuries.
Baldon et al. 2014	Randomized clinical trial (RCT) Level of evidence: Therapy, level 2b–	Women with patellofemoral pain (n = 15)	Functional stabilization training (FST)	10-cm visual analog scale, The Lower Extremity Functional Scale, The single-leg triple-hop test. A global rating of change scale was used to measure perceived improvement. Trunk endurance and eccentric hip and knee muscle strength assessment.	An intervention program consisting of hip muscle strengthening and lower-limb and trunk movement control exercises was more beneficial in improving pain, physical function, kinematics, and muscle strength compared to a program of quadriceps-strengthening exercises alone.
Jeong et al. 2021	Controlled laboratory study	Male participants (n = 32)	Core strength training program	Three-dimensional trunk, hip, knee, and ankle kinematic data and muscle activations of selected trunk and lower extremity muscles were obtained while the participants performed side-step cutting. The core endurance scores were measured before and after training.	Modify the biomechanics associated with ACL injuries in a side-step cutting task. Alter the lower extremity alignment in the frontal plane and muscle activations during sports-related tasks.
Silder et al. 2013	Randomized, double-blind, parallel-group clinical trial Level of evidence: Therapy, level 1b-	Individuals who sustained a recent hamstring strain injury (n = 13)	Progressive agility and trunk stabilization (PATS) rehabilitation program	Primary Outcome Measures—return-to-sport time (days), defined as the period from initial injury to completion of rehabilitation; Secondary Outcome Measures—Mediolateral width and anterior/posterior depth of the total injured area were also measured on *MRI*.	Hamstring muscle recovery and function at the time of return to sport.

Study	Methodology	Participants Stabilization exercise	Intervention	Outcomes	Conclusions
Baldon et al. 2015	Controlled laboratory study	Female recreational athletes with patellofemoral pain (PFP) (n = 15)	Functional stabilization training	The potential mediators that were evaluated included eccentric torque of hip muscles and endurance of the trunk muscles. The outcome variables were the lower limb and trunk kinematics in the frontal plane assessed during a single-legged squat task.	Improvements in the strength of the gluteus muscles can influence the frontal plane movement patterns of the lower limb and trunk in women with PFP. Patients with PFP might benefit from strengthening of the hip muscles to improve frontal plane lower limb and trunk kinematics during functional tasks.
Güngör et al. 2022	RCT	Individuals with multiple sclerosis (n = 19)	Pilates-based core stability training (PBCST)	Knee muscle strength; Postural sway in different conditions.	Improving strength, postural control, core stability, physical capacity, and fatigue.
Yılmaz et al. 2015	RCT	Females with patellofemoral pain (n = 22)	Therapeutic knee exercises +postural stabilization exercises	Pain, Hamstring flexibility, Function, Lower extremity strength Postural control.	Improve strength and function and reduce pain
Develi et al. 2021	RCT	Patients with asthma (n = 20)	Core stabilization exercises + Asthma Education Program + Breathing exercises	Respiratory muscle strength (maximum inspiratory and expiratory pressures), Physical activity level (International Physical Activity Questionnaire Short Form (IPAQ)), Health-related quality of life (Asthma Quality of Life Questionnaire (AQOL)), Functional exercise capacity (six-minute walking test (6MWT)), Dynamic balance (Prokin PK200).	Improvements in inspiratory muscle strength, physical activity level, functional exercise capacity, and dynamic balance.
Arntzen et al. 2020	RCT	Individuals with multiple sclerosis (n = 39)	Group-based, individualized, comprehensive core stability + balance intervention	The 2-min walk test (2MWT), 10-m walk test-preferred/fast/slow speed (10MWT), Multiple Sclerosis Walking Scale-12 (MSWS-12), Patient Global Impression of Change-walking (PGIC-walking), Rivermead Visual Gait Assessment (RVGA), Actigraphswgt3x-BT activity monitors (ActiGraph).	Improved walking immediately.

Study	Methodology	Participants Stabilization exercise	Intervention	Outcomes	Conclusions
Min et al. 2020	RCT	Patients with chronic stroke (n = 19)	Trunk stability robot (using a trunk stabilization training robot (3DBT-33)) training + conventional physical therapy	Functional Ambulation Categories (FAC), Timed up and go (TUG) test, Berg Balance Scale (BBS), Korean Modified Barthel Index (K-MBI), Fugl-Meyer Assessment of Lower Extremity (FMA-LE).	Improving the balance and functions in the lower extremities.
Elshafey et al. 2022	A pretest-posttest RCT	Children with cerebellar ataxic cerebral palsy (n = 18)	Core stability program + selected physical therapy program	Scale for the Assessment and Rating of Ataxia, Balance Error Scoring Systems scale, Bruininks-Oseretsky tests of motor proficiency, HUMAC balance system scores.	Improve balance and coordination.
Priyanka et al. 2017	RCT	Patients with ACL reconstruction (n = 30)	Institutional rehabilitation protocol+ additional lumbar core stability exercise	Pain on VAS, Range of motion (ROM), Function using Modified Lysholm Scoring Scale (MLSS), Tegner Activity Level (TAL).	Lumbar core stability exercise programme is effective in improving function, post ACL reconstruction.
Kim et al. 2011	RCT	Male adults (n = 7)	Resistance and stabilization exercise group (RSEG)	Biodex System 3 Pro (USA), D2 diagonal flexion patterns, D2 diagonal extension patterns, Knee joint flextion and extension.	More effective for rehabilitation of the upper/lower extremities.
Rasika et al. 2020	Experimental research-based study (a stratified sampling technique)	Race walkers (n = 20)	Dynamic Neuromuscular Stabilization Technique	Assessment of VO2MAX, and speed was done using the Cooper test and sprint test.	DNS therapy and Parachute resistance training exercises are equally effective in improving the performance level in race walkers.

enhanced range of motion (ROM) and activity levels. These findings may be attributed to the prescribed and encouraged home exercise regimens and the relatively short 4-week intervention period.

Two studies (Min et al., 2020, Elshafey et al., 2022) indicated that the stabilization exercise program was effective in improving balance. Elshafey et al. demonstrated that the core stability program can improve balance and coordination in children with ataxic cerebellar palsy when incorporated with a standard physical therapy program. The study found statistically significant reductions in the severity of ataxia, as well as improved balance and coordination in both groups, with stronger effects observed in the intervention group. According to Min et al., balance and lower limb functions improved in patients with chronic stroke by trunk stabilization rehabilitation training with a rehabilitation robot.

Given the considerable heterogeneity in the investigation, it is important to consider this variability when interpreting the current results. Differences in assessment tools and intervention plans may affect the comparability of the findings. The studies employed various scales for evaluating lower limb and trunk kinematics, knee kinetics, and both primary and secondary outcome measures. Additionally, the interventions differed in duration, therapy combinations, and follow-up time points.

In contrast to other findings, the study by Silder et al. (2013) showed that, in terms of muscle recovery and function following a hamstring strain injury, a modified progressive agility and trunk stabilization (PATS) rehabilitation program and a progressive running and eccentric strengthening (PRES) program produced similar results. Despite receiving clinical approval to resume sports, athletes in both therapy groups showed signs of injury on their MRIs even after their recovery was over. Thus, once an athlete has clinical clearance to resume sports, the physical therapist should take into account that the athlete's hamstring muscle recovery continues. It should be highlighted that any findings about the efficacy of any rehabilitation program in reducing the likelihood of reinjury are limited by the study's small sample size.

Limitations

In this scoping review, most of the included studies (13 out of 14) were of good methodological quality, with PEDro scale scores ranging from 6 to 8 out of 10 (Cashin & McAuley, 2020). This generally reduced the risk of high bias. However, further research is needed to identify the critical attributes of stabilization exercises, including mode, intensity, frequency, duration, and timing. In conclusion, stabilization exercises should be integrated into rehabilitation programs for patients/individuals with lower extremities issues.

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