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PILATES-BASED STABILITY TRAINING VERSUS ECCENTRIC TRAINING IN PATIENTS WITH MULTIPLE SCLEROSIS SUFFERING FROM CHRONIC NON-SPECIFIC LOW BACK PAIN

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ABSTRACT

Introduction: Back pain is the most prominent comorbidity and a major barrier to daily functioning in patients with multiple sclerosis. Exercise programs can help reduce key disease-related symptoms like fatigue and motor impairments, promoting greater functional independence and better quality of life.

Objective: To determine the impact of Pilates training versus eccentric training in patients with multiple sclerosis suffering from chronic non-specific low back pain on: pain, static, dynamic sitting balance and trunk coordination, and isometric strength of trunk flexors and extensors.

Method: This randomized clinical trial involved 36 adults with multiple sclerosis, chronic non-specific low back pain, and expanded disability status scale between 2-4.5. Participants were assigned to Pilates-based core stability training or eccentric trunk training, performed for six weeks, three times a week. The study assessed trunk flexor and extensor isometric strength, pain, seated balance, and trunk coordination.

Results: Both groups significantly improved in pain and trunk performance. No major differences were identified between groups for pain reduction and trunk control. The Pilates group showed greater improvements in isometric trunk flexor strength with hips extended ($p = 0.03$) and isometric trunk extensor strength with hips flexed 30° ($p = 0.021$) compared to the eccentric group. No significant differences were found between groups for trunk flexor strength with hips flexed 30° ($p = 0.086$) or trunk extensor strength with hip extension ($p = 0.08$).

Conclusion: Pilates-based stability training led to greater improvements in trunk flexor and extensor strength compared to eccentric training in some testing positions; both therapies were successful in relieving pain and improving trunk performance.

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KEYWORDS
Eccentric, low back pain, multiple sclerosis, Pilates

INTRODUCTION

Multiple sclerosis (MS) is a chronic, progressive, and inflammatory illness that causes degeneration in the nervous system, mainly affecting young people. Its exact cause is unknown, but various external factors are thought to contribute[1]. Symptoms depend on the quantity and place of lesions in the central nervous system. They may include motor impairments like paresis and spasticity, sensory changes, visual disturbances, cranial nerve damage, and issues like sphincter dysfunction and sexual problems[1–3].

Pain is common in patients with multiple sclerosis (PWMS), affecting 29% to 86% of patients. While neuropathic pain is most frequent, MS patients also often experience musculoskeletal (MSK) pain, especially low back pain (LBP)[4]. LBP, worsened by prolonged sitting or lying down, is linked to spasticity, muscle weakness, disability, and reduced mobility[5]. It is also a major cause of comorbidities and daily activity limitations in this population[6].

Physical exercise has been proposed as a valuable non-pharmacological therapy for PWMS due to its low cost and positive effects on both mental and physical health[7–9]. Although exercise was once discouraged for PWMS over concerns that it might exacerbate the disease[10], current research supports its benefits for symptom management, functional restoration, improved quality of life, and enhanced performance of daily activities[2,11].

Pilates is a form of exercise that emphasizes breathing, alignment, muscle control, strength, flexibility, core stability, and the mind-body connection[12]. Today, Pilates is recognized as an effective rehabilitation tool, and it has been shown to improve physical function, pain management, and quality of life across various areas of physiotherapy[13,14]. This Pilates-based treatment approach may help PWMS to improve their functional impairment.

On the other hand, eccentric training (ECC) is known to lead to the improvement of function and reduction of pain in the context of various pathologies/structures, such as tendinopathies[15], and prevention of hamstring injuries[16]. From a clinical perspective, ECC appears to be particularly beneficial because of its efficiency regarding superior strength gains, strong relevance to activities of daily living, time efficiency, lower metabolic demands, and possible post-exercise anti-inflammatory reactions[17]. Accordingly, the clinical application of ECC seems to be promising in neurologic diseases, such as MS[18].

Both Pilates and ECC improve muscle strength, functional ability, and quality of life, and reduce fatigue in PWMS. Pilates uniquely includes a respiratory component. A meta-analysis showed Pilates enhances dynamic balance and flexibility and moderately improves muscular endurance in healthy individuals[13]. Core stabilization, essential for functional independence in MS, is a major focus of clinical Pilates exercises[19].

It was hypothesized that there would be no significant difference between the effect of Pilates-based stability training versus ECC training in PWMS suffering from CNSLBP on pain severity, quality of trunk movement and performance, and isometric strength of trunk flexors and extensors.

METHODS

This research is a parallel randomized clinical trial carried out in the physical therapy department of El Sheikh Zayed Alnahyan Hospital. Ethical approval for the study was secured from the Ethics Committee of the Faculty of Physical Therapy at Cairo University, Egypt. The study protocol has been registered on ClinicalTrials.gov. Website.

Male and female individuals with MS and CNSLBP, diagnosed by a specialist, according to specific inclusion criteria: PWMS diagnosed according to the McDonald criteria (2010)[20], age range 18 to 40 years, expanded disability status scale (EDSS) score of 2.0 to 4.5[21], and relapsing-remitting free for at least ninety days before testing. Exclusion criteria: having a neurologic condition other than MS, a relapse within three months, cognitive challenges that could hinder the ability to provide informed consent or to fully engage in the exercise program, orthopedic issues including arthritis, severe back pain (BP) attributed mostly to other reasons (e.g., spinal stenosis, lumbar disc degeneration, etc.).

The sample size was 36 patients, 18 in each study group, as calculated by G-power software V. 3.1 (Heinrich-Heine-University, Düsseldorf, Germany). The calculation was based on the following parameters: power (0.8), effect size (0.2), and alpha level (<0.05) to compare pain intensity between the two groups. Patients were randomly assigned to either the ECC or Pilates group using opaque, sealed envelopes selected by an independent investigator. Group allocation occurred after the initial assessment but before the first therapy session *(Fig. 1)*.

PROCEDURES

Evaluation procedures

Informed consent was obtained from every participant after they received complete details regarding the study's objectives, procedures, potential advantages, and confidentiality. All individuals in both groups underwent assessments before and following a 6-week treatment program.

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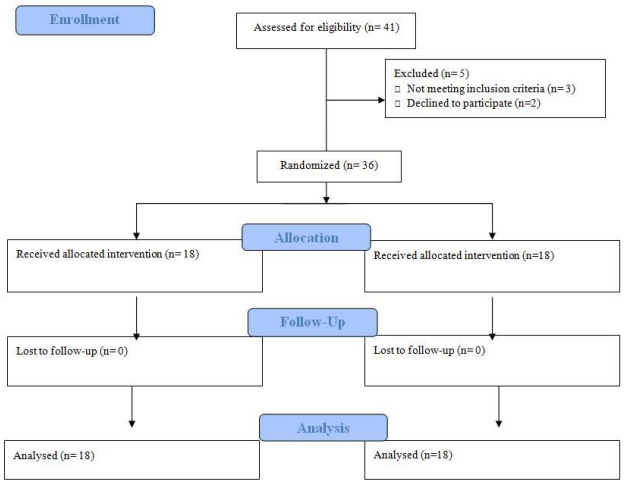


Figure 1. *Flow diagram.*

Pain intensity was measured by the Visual Analogue Scale (VAS)[22]. Isometric trunk flexion as well as extension force were assessed using handheld dynamometry (HHD) (Model 01165, Lafayette Instrument Company, Lafayette, IN, USA). Isometric trunk flexor force was tested in two positions: a) supine with both knees extended, and b) supine with hips flexed at 30° and trunk supported at this angle with both knees extended. The dynamometer was positioned on the sternum, secured by a strap, beneath the supra-sternal notch. Patients were told to put their hands on the opposing shoulders[23].

Isometric trunk extensor force was measured from two positions: A) prone position with both knees extended, B) prone position with hips flexed at 30° and the trunk supported in this 30° angle with both knees extended. The dynamometer was positioned at the level of T4, secured by a strap, and the patients rested their foreheads on the back of their hands. Patients were secured with straps above the lateral malleolus, at the anterior superior iliac spine to prevent pelvic movement during flexion strength tests, and at the posterior superior iliac spine for trunk extension strength tests. Force was placed perpendicular to the trunk using a non-elastic belt to stabilize movement without examiner interference. Patients gradually increased their isometric trunk flexion or extension strength, holding a maximal effort for 5 seconds[24]. The data analysis used three trials, each separated by a 15-second rest, with a 5-minute rest between position changes to prevent fatigue. The isometric trunk muscle force was presented in pounds and kilograms, subsequently converted to Newtons based on Jaric's research[25], and tests ended if participants failed to maintain the correct position, experienced discomfort or pain, or chose to stop voluntarily[26].

The Trunk Impairment Scale (TIS) assessed seated balance and trunk coordination in a sitting position[27]. The assessment measured seated balance and trunk coordination in MS patients. The static subscale evaluated the ability to keep a seated position with feet supported both passively and actively. Patients crossed their stronger leg over the weaker one, determined by resistance testing or preference if strength was equal. The dynamic subscale included tests of lateral trunk flexion, unilateral hip lifting, and trunk rotation. To assess trunk coordination, the patient was given instructions to rotate the upper or lower portion of the trunk six times, beginning from the shoulder girdle or the pelvic girdle, respectively, according to Geert et al.[27].

Each task was rated on a 2, 3, or 4-point ordinal scale. The maximum scores were 7 for static balance, 10 for dynamic balance, and 6 for trunk coordination, with a total possible TIS score of 23, where higher scores indicated better performance. Tests began from a standard sitting position, and patients were allowed three attempts per item, with the best performance scored[27].

Treatment procedures

Eighteen patients received Pilates-based core training exercises as previously described[28], which has strong evidence for decreasing pain and disability in CLBP[29–32] and for enhancing balance, gait, and functional capacity in PWMS[33–35] or ECC trunk training exercises as described[36], which has a potential to cause significant strength adaptations at relatively low metabolic cost, which may be beneficial for PWMS who experience heat sensitivity and fatigability[18,36,37]. Both interventions share common targets of improving trunk stability, postural control, and functional strength, making them comparable and potentially complementary approaches[30,38].

Both groups received transcutaneous electrical nerve stimulation (TENS) in exercise sessions to decrease pain and improve tolerance to physical exercise. This approach was intended to ensure adherence and allow the effects of the different exercise interventions to be more accurately observed. High-frequency TENS was used from 80-100 Hz, pulse duration from 50-100 µs, and intensity according to patient tolerance for 20 min. The electrodes were positioned at a distance of 3 cm on each side of the lumbar spinous processes (6 cm apart from each other) and centered over the painful segment of the lumbar spine.

Pilates-based training exercises

Every motion was performed 10 times over 2-3 sets; the entire program lasted six weeks, with 12 sessions[28]. The degree of difficulty began at an initial level (beginner-intermediate) covering pelvic clock, femur arcs, prone supine extension, and femur circles, and gradually increased over time (intermediate-advanced) covering quadruped series, rollup, and mermaid to reduce the potential of unintentional damage to the patients.

Pelvic clock

The patient is in a crook lying position and performing pelvic clock movements and controlled tilts of the pelvis in multiple directions to enhance spinal mobility (flexion, extension, rotation, and lateral flexion). The abdominal muscles are engaged throughout to support core stability[39].

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Femur arcs

The patient is lying in a crook position. The sequence is as follows:

1) Inhale – Flex one hip to 90°, lifting the leg with the knee also flexed to 90° (as in a tabletop position);
2) Exhale – Lower the leg back to its initial position in a controlled way;
3) Repeat the same movement on the opposite leg[39].

Prone spine extension

The patient is in a prone position with Hands at eye level, Elbows supported on the plinth, and Legs parallel and hip-width apart. Movement sequence:

1) Inhale to prepare;
2) Exhale – Press the elbows into the mat and gently extend the upper back and rib cage, lifting the upper body while keeping the lower ribs in contact with the mat (a gentle back extension);
3) Inhale at the top of the movement;
4) Exhale – Lower the upper body back down in a controlled manner[39].

Femur circles

The patient is in the supine position with arms beside the pelvis, palms facing down, right leg extended toward the ceiling, and left leg extended on the mat. Movement sequence: inhale – gently shift the right leg across the midline of the body (toward the opposite side), exhale – use the leg to draw a controlled circular motion on the ceiling, moving from inside to outside, then returning inside while lowering slightly, maintain pelvic stability and core engagement throughout the motion, and repeat the sequence on the left leg after completing reps on the right[39].

Quadruped series

The patient is in a quadruped position, hands under the shoulders and knees under the hips. Movement sequence: inhale to prepare, then exhale – Lift the right hand off the mat and extend the arm forward, keeping it parallel to the ground, Inhale – return the arm to the mat, repeat with the left arm, exhale – extend the left leg backward, lifting it until it is parallel to the floor, exhale again as you return the leg to the starting position. Repeat with the other leg[39].

Roll up

The patient lies on their back, arms behind the head, legs together, and feet in plantar flexion (toes pointed). Movement Sequence: inhale – move the arms toward the ceiling, then roll the head and upper trunk off the mat, while simultaneously dorsiflexing the feet, exhale – reach the hands toward the feet, engaging the core, and continue to roll up smoothly into a seated position, inhale – take a deep breath at the top, exhale – Roll down slowly, returning to the mat, and plantar flexing the feet again[39].

Mermaid

Patient is in a cross-legged seated position with arms extended to the sides, parallel to the ground, and shoulders relaxed and wide. Movement Sequence: inhale – lengthen the spine upward, maintaining an upright posture and reaching the arms out to the sides, exhale – reach the right arm toward the ceiling while side-bending the spine to the left, allowing the left fingertips to glide along the floor, inhale – return to the starting position, spine tall and centered, and repeat the movement to the opposite side, reaching the left arm up and bending to the right[39].

ECC trunk training exercises

The course program was 12 sessions total, with exercises performed for 2 to 3 sets with 10 to 15 repetitions each and 2 min rest between each set[36].

Trunk extension

The patient was in the prone position at the edge of the bed with feet supported by the therapist, and the patient was asked to lower the back and neck downwards from the neutral position slowly to allow eccentric contraction of back extensors.

Crunches

The patient is seated with both knees bent and flexed trunk at the hips, arms crossed in front of the chest, and the trunk will be lowered downwards toward the floor to allow eccentric contraction of abdominal flexors. Upward movement assisted by arms to return to the starting position.

Bridging

The patient is in a crook lying position, pushing the hip up with both legs on the ground, extending one lower limb, and then the lower back while supported on one lower limb. Lower the extended lower limb to get back to the crook lying position, repeat with the other leg.

Lateral flexion

The patient is seated on the edge of the bed with both arms crossed in front of the chest and feet supported on the floor. The patient starts bending the trunk laterally to both sides slowly to allow eccentric contraction of the lateral flexors.

Trunk rotation

The patient is seated on a high chair to support the lower limbs, holding pulleys with both hands to rotate the trunk away from the pulleys and get back slowly while keeping the pelvis and lower limbs stable.

Statistical analysis

Statistical analysis was performed using the SPSS software package version 25 for Windows (SPSS, Inc., Chicago, IL). An independent t-test was applied to compare age, weight, height, and EDSS variables between groups, a Mann-

Whitney U test for ordinal data (EDSS, TIS), and a chi-square test was used for gender comparisons. To analyze the dependent variables across different groups and time points, a Multivariate Analysis of Variance (MANOVA) was conducted. For pairwise comparisons within and between groups where the MANOVA indicated significant F-values, the Bonferroni correction test was applied. Statistical significance was determined at a probability level of P ≤0.05.

RESULTS

Thirty-six patients of both genders (14 male and 22 female) diagnosed with MS with LBP were included. The results indicated no statistically significant variations (p >0.05) in demographic data for height, weight, age, and gender between the Pilates group and the ECC group, and the Mann-Whitney U test showed no significant difference between both groups for EDSS (0.971) *(Table 1)*.

A Shapiro-Wilk test was employed to evaluate the

Items	Groups		p value
	Pilate group (n = 18)	Eccentric group (n = 18)	
Age (year)	30.33 ± 6.748	32.56 ± 6.022	0.305
Weight (kg)	74.06 ± 11.053	79.17 ± 18.611	0.324
Height (cm)	171.78 ± 8.974	167.67 ± 9.068	0.181
Gender (males/females)	8 (44.44%)/10 (55.56%)	6 (33.33%)/12 (66.67%)	0.494

Table 1. *Comparison of general characteristics between groups Pilate and eccentric.*
Abbreviations: p value, probability value; NS, non-significant.

Variables	Items	Groups (median , interquartile range)		U	p value
		Pilate group (n = 18)	Eccentric group (n = 18)		
TIS (static subscale)	Pre-treatment	7(1)	7(1)	145	0.645
	Post-treatment	7(0)	7(0)]	153	0.317
	Z	-2.33	-2.53		
	p value	0.02*	0.011*		
TIS (dynamic)	Pre-treatment	9(3)	9(3)	161.5	0.986
	Post-treatment	10(2)	10(0)	135	0.213
	Z	-2.71	-2.75		
	p value	0.001*	0.006*		
TIS (coordination)	Pre-treatment	4(0)	4(2)	161	0.971
	Post-treatment	6(1)	6(1)]	159	0.909
	Z	-3.36	-2.84		
	p value	0.001*	0.004*		
TIS (total)	Pre-treatment	19.5(4)	19.5(7)	161.5	0.987
	Post-treatment	23(3)	23(2)	153	0.733
	Z	-3.46	-3.195		
	p value	0.001*	0.001*		

Table 2. *Comparison within and between groups for TIS.*
*Abbreviations: U, Mann-Whitney U; Z, Wilcoxon Signed Ranks Test; p value, probability value; *Significant p <0.05*

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Variables	Items	Groups (mean ± SD)		Change	p value
		Pilate group (n = 18)	Eccentric group (n = 18)		
Pain intensity	Pre-treatment	7.22 ± 1.40	7.42 ± 1.73	-0.194	0.713
	Post-treatment	2.44 ± 2.28	2.17 ± 0.99	0.278	0.638
	Change	-4.778	-5.250		
	Improvement (%)	66.2	70.75		
	p value	0.0001*	0.0001*		
Isometric trunk flexor with hips flexed 0°	Pre-treatment	28.24 ± 5.99	25.75 ± 3.84	2.489	0.147
	Post-treatment	32.27 ± 5.07	28.83 ± 3.97	3.433	0.03*
	Change	4.028	3.083		
	Improvement (%)	14.27	11.96		
	p value	0.0001*	0.0001*		
Isometric trunk flexor with hips flexed 30°	Pre-treatment	28.7 ± 5.89	26.65 ± 3.78	2.048	0.223
	Post-treatment	32.2 ± 5.47	29.43 ± 3.78	2.767	0.086
	Change	3.504	2.786		
	Improvement (%)	12.2	10.4		
	p value	0.0001*	0.0001*		
Isometric trunk extension with hips flexed 0°	Pre-treatment	34.2 ± 5.2	32.1 ± 5.15	2.103	0.232
	Post-treatment	38.6 ± 7.01	34.8 ± 5.3	3.733	0.08
	Change	4.363	2.733		
	Improvement (%)	11.7	8.4		
	p value	0.0001*	0.0001*		
Isometric trunk extension with hips flexed 30°	Pre-treatment	33.8 ± 5.2	31.8 ± 7	1.956	0.350
	Post-treatment	38.1 ± 4.9	33.1 ± 7.3	5	0.021*
	Change	4.386	1.341		
	Improvement (%)	12.7	4.1		
	p value	0.001*	0.003*		

Table 3. *Comparison within and between groups for trunk flexors and extensors isometric strength.*

normality of the dataset, confirming that the data were normally distributed, as evidenced by a p-value greater than 0.05. Furthermore, Levene's test, used to assess the homogeneity of variance, indicated no significant differences (p >0.05), thereby supporting the assumption of normal distribution and justifying the use of parametric analyses.

Table 2 shows a significant (p <0.05) rising TIS (static, dynamic, coordination, and total) in the Pilates and ECC groups after treatment compared to pre-treatment. The results indicate no significant differences (p >0.05) in TIS elements between the Pilates and ECC groups before and after treatment.

Time effect for pain intensity, trunk flexors, and extensors isometric strength variables within the Pilates and ECC groups *(Table 3)* revealed significant (p <0.05) increases in all variables after treatment compared to pre-treatment within the Pilates group and ECC group. Moreover, the

Pilates group improved trunk flexors and extensor strength more than the ECC group.

The results indicate no significant differences ($p > 0.05$) in pain intensity between the Pilates and ECC groups before and after treatment. Group effect for trunk flexors and extensors isometric strength between Pilates and ECC groups before and after treatment *(Table 3)* revealed no significant differences ($p > 0.05$) in all isometric trunk (flexors and extensors) strength at pre-treatment and in trunk flexor strength with hip flexion 30 degrees ($p = 0.086$) and trunk extensor with hip extension ($p = 0.08$) between Pilates group and ECC at post-treatment. However, there were statistically significant differences ($p < 0.05$) in Isometric trunk flexor with hips extended ($p = 0.03$) and Isometric trunk extension with hips flexed 30° ($p = 0.021$) between Pilates and ECC groups at post-treatment.

DISCUSSION

The current randomized clinical research compared the effects of Pilates-based stability training to eccentric (ECC) trunk training in MS patients suffering from CNSLBP. Both therapies were augmented with TENS. Following six weeks of training, both groups experienced significant improvements in pain intensity, trunk isometric strength, and trunk performance (TIS scores). Pilates training, on the other hand, resulted in significant increases in trunk flexor and extensor strength in specific test positions than ECC training did.

The findings showed a significant reduction in pain intensity after treatment in both groups, with 66.2% improvement in the Pilates group and 70.75% improvement in the ECC training group. However, there was no statistically significant difference in pain intensity reduction between the two groups, suggesting that both interventions are equally effective in managing CNSLBP in PWMS.

The reduction of pain in both groups may be due to a mechanism called exercise-induced hypoalgesia that leads to decreased pain sensitivity[40]. Further exercise has neuroprotective and neurodegenerative effects[41,42] and may modify disease progression[43]. Regular exercise reduces the inflammatory reaction, promotes an anti-inflammatory environment in the body, and lowers the risk of chronic disease[44,45]. Improved physical fitness, including improved muscular support of the spine, better posture and alignment, exercise tolerance, and mobility, has been demonstrated by exercise interventions in PWMS[7,46], which can reduce pain caused by muscle stiffness, spasticity, and deconditioning.

Considering that pain in PWMS is complex and associated with muscle weakness, stiffness, and postural deficits, exercise methods that target core stability and muscle function are essential. The equivalent pain alleviation between Pilates and ECC groups implies that both therapies might effectively relieve discomfort, possibly through mechanisms such as better muscle support of the trunk and enhanced neuromuscular control. Although both training methods were successful, the lack of significant differences between groups indicates that Pilates and ECC can be suggested as non-pharmacological treatments for lowering LBP in PWMS.

These findings are consistent with earlier research indicating the effectiveness of exercise in pain management among PWMS[32–34]. Our results are consistent with Byrnes and Whillier[14] and Van Der Linden et al.[47], who found that the Pilates group had a statistically significant decrease in pain and is feasible for PWMS who also use a wheelchair. These findings showed that Pilates exercises may be adapted to different intensity levels according to the patient`s specific physical ability and conditioning. Also, Knapova et al.[48] found that significantly reduced back pain intensity in PWMS with mild–moderate disability after Pilates training.

In contrast to this study's findings, Previous studies[49,50] found no significant differences in pain reduction between Pilates and other exercise programs, implying that its efficacy might differ based on the program's structure, individual characteristics, treatment duration, and the population studied.

Eccentric training may offer distinct benefits[51], as it allows for the application of high mechanical loads at a relatively low metabolic cost, which is important given that PWMS frequently have low energy reserves and early fatigue[52].

The use of TENS in both groups likely enhanced the results through immediate and lasting analgesic effects by spinal gating of nociceptive input[53], activation of endogenous opioid systems[54], reduction of central sensitization[55], and enhanced local circulation, so reducing ischemic pain[56].

Pilates training resulted in significantly larger gains in isometric trunk flexor strength (hips extended) and extensor strength (hips flexed 30°) than ECC training. This finding might be attributable to Pilates' emphasis on core stabilization, breathing control, and precise motor movements, which all improve recruitment and endurance of deep trunk stabilizers[13,28]. In contrast, ECC training, while helpful for muscle strength and adaptations[17], may have prioritized vast superficial muscle groups over neuromuscular coordination. This could explain the difference in outcomes between the two groups.

Researchers suggest that Pilates' emphasis on neuromuscular concentration and segmental control may provide extra benefits for targeted extensor strength development, particularly in MS and CNSLBP patients. Eccentric exercise has also been connected to altered motor unit recruitment and cross-education effects, both of which may contribute to improved functional performance[17]. Despite these potential benefits, research on eccentric exercise in MS is scarce.

Pilates studies in PWMS have had conflicting results. Panhan et al.[57] showed that Pilates practitioners demonstrated greater trunk flexion torque and neuromuscular efficiency of the internal oblique with lower EMG activity, indicating improved motor control. Similarly,

Güngör et al.[58] reported that supervised Pilates-based core stability training increased muscle strength, postural control, and stability more than home-based training. In contrast, Duff et al.[59] found that Pilates enhanced walking endurance and mobility but had no significant effect on trunk muscular endurance, balance, or quality of life.

Regarding the effect of ECC training in PWMS with LBP, this is considered to be the first study to be performed, so it is difficult to compare it with previous literature. However, the ECC training conducted in LPB patients who do not suffer from MS, Althobaiti et al.[60] reported that patients with chronic LBP who performed progressive resistive exercise to trunk muscles had significantly improved isometric lumbar extension strength when compared to lumbar flexion. Hermann and Barnes[61] demonstrated that eccentric contractions of the lumbar extensor muscles cause higher multifidus EMG activity to create a specific quantity of torque than the iliocostalis lumborum muscle.

Both groups showed significant enhancements in TIS subscales (static, dynamic, and coordination) following the intervention. This finding suggests that both training methods can improve trunk coordination and seated balance in PWMS, which is consistent with prior research indicating that exercise improves functional results in neurological disorders[14,50]. The lack of significant between-group variations in TIS indicates that Pilates and ECC are equally effective at improving trunk coordination and postural control, as both modalities target trunk–limb integration during functional movement[58]. The fact that trunk control is directly related to functional independence in MS means that these findings have significant clinical implications.

Across three studies, targeted core stability interventions consistently improved trunk function in MS as measured by the TIS. Arntzen et al.[62] reported significant gains that persisted up to 30 weeks, though with diminishing effect. AbadiMarand et al.[63] found dynamic neuromuscular stabilization superior to conventional core training with sustained improvements, while Küçük et al.[64] showed Pilates enhanced trunk control alongside broader physical and cognitive benefits but with no improvement in TIS.

Clinical implication

This is the first study to directly compare Pilates with ECC training in PWMS and CNSLBP. While Pilates has been more frequently studied, there is very limited evidence on ECC loading in this population, making the present findings quite valuable in demonstrating its benefits. Both interventions were safe and effective for ambulatory MS patients with mild-to-moderate disability (EDSS <4.5), reducing pain and improving trunk function. These results are less generalizable to patients with advanced disability, cognitive impairment, or severe spasticity who may require modified exercise approaches. Overall, the study enhances existing evidence on targeted exercise therapies in MS and supports the integration of both Pilates and ECC loading into multidisciplinary management strategies to improve function, independence, and quality of life in this subgroup.

Limitations

This study has several limitations that should be noted. First, no long-term follow-up was implemented. Second, the study was conducted during the summer, which may have influenced those with MS's responsiveness, as high ambient temperatures can increase MS symptoms and impede physical performance. Finally, the study only included people aged 18 to 40, which may limit the findings' application to older adults with MS.

CONCLUSION

The Pilates exercise improved the strength of trunk flexors and extensors more than the ECC exercise. However, there were no significant differences between them in pain intensity and TIS. The results indicate that although both therapies effectively manage CNSLBP in PWMS, Pilates may provide additional advantages in improving trunk muscle strength.

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