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Lumbopelvic stabilization versus Pilates exercises on spatiotemporal gait parameters in chronic nonspecific low back pain

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***Abstract*--- Objectives:** The purpose of the current study is to trace and investigate how lumbopelvic stabilization and Pilates exercises affect the spatiotemporal aspects of gait in persistent nonspecific low back pain cases (NS-CLBP). **Design:** single-blinded randomized controlled trial. Setting: out-patient clinic of faculty of physical therapy. **Participants:** Patients with NS-CLBP (N=90) were

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randomly assigned to three groups: group A (stabilization + traditional therapy), group B (Pilates plus traditional therapy), and group C (traditional therapy) for 12 sessions over six weeks. **Outcome measures:** A Walkway pressure measurement system, The Visual Analog Scale, Modified Oswestry Disability Questionnaire, Biering–Sorensen test, and trunk flexion endurance test were adopted successfully to assess both spatial and temporal parameters, pain, function, and isometric endurance of trunk extensor and flexor sequentially. **Results:** At base line measurement, there was no statistically significant difference between the three groups but after 6 weeks of treatment, there was a statistically significant effect of treatment as p = 0.001 and f-value = 3.12 and Also, there was a statistically significant interaction between treatment and time. Within group analysis, there was statistically significant difference between pre-and post-treatment in stabilizing and Pilates groups but no difference was observed in the control group. **Conclusion:** Both stabilization and Pilates exercises have an effect on pain, disability, endurance, and spatiotemporal gait parameters, but Pilates is superior to others in reducing pain, functional disability, and temporal gait parameters, plus increasing cadence and velocity. Both stabilization and Pilates have an equal effect on increasing flexion and extension endurance.

Keywords: Chronic Nonspecific Low Back Pain, core muscles, Lumbopelvic Stabilization, Pilates Exercise, spatiotemporal gait parameters.

Introduction

One of the most painful musculoskeletal complications is chronic low back pain (CLBP). It has a spectrum of causes and diagnoses. Back pain can be caused due to a variety of components in the lumbar spine, including nerve roots from the spine, facet joints, discs, vertebrae, and spinal muscles. Nonspecific low back pain is a term used to describe CLBP for which no specific cause can be identified or recognized. With an estimated frequency of 80% and substantial healthcare expenses, NS-CLBP is a prevalent and costly disease. Due to the insufficient scale measuring the causes and symptoms of low back pain etiology, most low back pain markers are regarded as nonspecific [1].Furthermore, NS-CLBP refers to a collection of symptoms that are not caused by a specific pathology [2]. NS-CLBP results in problems trapping the patient in a cycle of poor physical performance, exacerbated nociceptive sensations, impaired social functioning, work disability, and depression [3].

Since walking is a clinical and functionally relevant activity, it's often adopted in various rehabilitation programs, especially those for CLBP patients. Speed, stride length, stride frequency, foot contact, and balance time are among the spatiotemporal gait characteristics that differ according to the needed treatment program. All the previously mentioned tools collaborate to ensure that the displacement is appropriate for the task's needs and environment. The treatment process should be carried out efficiently to get the desired end [4].

Mechanical low back pain affects the spatiotemporal parameters of gait. The findings of various studies can be used to allocate ideal rehabilitation procedures. Motor dysfunction in chronic pain patients could be illustrated by the negative changes in brain morphology according to a recent study [5]. On the other hand, some scholars believe that slow walking is a sign of discomfort or fear-avoidance behavior [6]. Taking pain into account as an important factor, it could be an attempt to alleviate pain by reducing spine motions. Acutely induced pain and chronic low back pain patients exhibit higher levels of lumbar erector spinae activation. In patients suffering from low back pain, these changes in muscle activity are frequently assumed to protect or splint the spine [2]. Hicks et al. (2017) have traced the changed spatiotemporal features of gait in older patients with persistent low back pain where a crystal-clear different gait pattern has been found [7].

Low back pain is treated with a variety of interventional procedures, including pharmaceutical therapy and nonmedical approaches. Physical therapy, which involves exercises and pain-relieving strategies, has been used to treat NS-CLBP and may be beneficial [8]. Numerous studies have demonstrated that specific exercises, such as trunk stability exercises [9] and Pilates exercises [7] are more beneficial in minimizing spinal functional impairment and benefiting spinal segments by providing lumbar stability. However, incorrect movements are caused by weak core muscles; lumbar multifidus (LM), transverse abdominal (TrA) [10].

Furthermore, Pilates exercises are considered an important method of performing exercises that enhances Centrology by improving movement, control, and strength of muscles [11]. Pilates plays a vital role in improving gait ability as it aids in spinal stability [12, 13]. Pilates exercise has been adopted in miscellaneous trials to improve gait abilities for old people [14, 15]. No previous study has been done to trace and report the effects of lumbar stabilization or Pilates exercise on spatiotemporal gait parameters in young people with NS -CLBP. Therefore, this study is conducted with a specific goal to investigate these effects.

Material and methods

Study design

The Research Ethics Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/002644) has approved the current study as a single-blind, randomized clinical trial. The trial has been approved according to the Declaration of Helsinki issued in 1964 while taking into account the subsequent amendments and unified trial reporting standard [16]. The current trial has been was registered in the Pan African Clinical Trial Registry (PACTR202001657839875). All patients have provided their voluntary, written informed consent. As for the duration of the trial, it has started from March to the end of December 2020.

Subjects

The participants have been diagnosed as nonspecific low back pain by an orthopedist who has excluded by investigations specific causes of low back pain. After examination and diagnosis, there has been no specific cause for the participants' pain [17]. All the participants have been screened for the appropriateness criteria.

The inclusion criteria encompassed the following aspects: (1) cases with NS-CLBP (>3 months) [18] (2) NS-CLBP patients who are willing to participate in the study [9]. Patients were excluded from the trial if they had the following complications: (1) specific health complications e.g., infection, tumors, osteoporosis, lumbar spine fracture, structural deformity, inflammatory disorder, radicular syndrome, or cauda equina syndrome (2) neurological involvement;

radiculopathy and myelopathy (3) previous spinal surgery (4) spinal infections (5) severe psychiatric illness [9].

Randomization

Ninety participants with nonspecific low back pain were randomly assigned to three experimental groups: lumbopelvic exercise and traditional therapy (experimental group A); Pilates exercise and traditional therapy (experimental group B); or traditional therapy only (control group) using computer generated block (size 4, 1:1 allocation ration) randomized program. The fourth author oversaw randomization but not data collection or treatment. The randomization codes were kept in opaque sealed envelopes to ensure the concealment of allocation.

Interventions

The first author opened the envelopes and began the rehabilitation program after the first interval assessment. The first author had eight years of experience managing nonspecific low back pain patients.

Control group: Patients have received exercises to strengthen the abdomen, back, and buttocks with 3 sessions of 10 repetitions of each exercise **(Table 1)** [19]. No other treatment techniques were added to the therapy process.

Experimental group A: The participants have obtained 3 stages of lumbopelvic stabilization physical activities [20]. No other treatment techniques were added to the therapy process. **(Table 2)**

Experimental group B: The participants were divided into two sub-groups; the first section has received Pilates exercises while the second one has obtained the conventional therapy. Both sub-groups have been evaluated and taught to practice Pilates exercise independently **(Table 3)**. No other treatment techniques were added to the therapy process.

Dosage: 6 weeks; each session lasted for an hour on average [13].

Table (1): Control group strengthening exercise for the abdomen and back [19].

Abdominal strengthening	• Lie on your back and place your feet on a wall so that your knees and hips are bent at 90-degree angles. Tighten your abdominal muscles. • Raise your head and shoulders off the floor. To avoid straining your neck, cross your arms on your chest rather than locking them behind your head. Hold for three deep breaths. • Return to the start position and repeat. • Repeat 10 times and then rest for 1 minute. • Do 3 sets of 15 repetitions • 30 minutes
Back strengthening	• Lie on the ground and bend the knees, placing the feet flat on the floor hip-width apart. • Press the feet into the floor, keeping the arms by the sides. • Raise the buttocks off the ground until the body forms a straight line from the shoulders to the knees. • Squeeze the buttocks with the shoulders remaining on the floor. • Lower the buttocks to the ground and rest for a few seconds. • Repeat 10 times and then rest for 1 minute. • Do 3 sets of 15 repetitions. • 30 minutes

Table 2: lumbopelvic Stabilization exercises program

Distribution of weeks	Application of exercises
First 2 weeks: phase 1	On a segmental basis, control over primary stabilizer's (mainly transversus abdominis (TrA), deep multifidus, pelvic floor, and

	diaphragm). **Activation of the lumbar multifidus (LM):** A submaximal contraction was provoked using the contralateral arm lift maneuver while holding: a small hand weight to attain appropriate activation of the LM (21). **Activation of the TrA:** Participants were given instructions to "cut off your urine intermittently" or "close your rear passage," to augment TrA contraction (21). hold 10 sec: rest 10 sec 10 repetitions 30 minutes for each exercise
Second 2 weeks: phase 2	Closed-chain exercises with low speed and load. Exercises that are closed-chain, low-velocity, and low-load are essential in Phase 2. The weight-bearing load is gradually increased, resulting in actual and harmless load transfer through the body segments. **Phase 2 exercises** 1. Standing position on an unstable surface. 2. Closed-chain lunge exercises. 3. Bridge exercise in a prone position. hold 10 sec : rest 10 sec for 5 repetitions 4. Bridge exercise in a supine position. hold 10 sec: rest 10 sec for 5 repetitions 5. 15 minutes for each exercise
Third 2 weeks: phase 3	Open-chain exercises with high speed and load. Open-chain, high-velocity, and high-load exercises are

	essential in Phase 3. **Phase 3 exercises** • Lower limb abduction • Knee extension in supine position on roller • Upper limb open chain exercise after TrA and multifidus co-contraction (20). hold 10 sec: rest 10 sec for 10 repetitions 20 minutes for each exercise

Table 3: Pilates exercises

	Pilates exercises [22]
Ab prep	The person was lying supine with his knees bent and his feet flat. The patient was asked to take a deep breath in and lengthen the back of his neck and lift his head, neck, shoulders, and arms as his exhale, and look down at his knees, taking a deep breath in and hold the position, then exhale, slowly return to starting position (Hold) count 5, 4,3,2,1 for 8 repetitions. 10 minutes
Breaststroke prep	The person was prone, legs extended along the mat, arms bent, and hands under the shoulder level. Then, during exhalation, reach your arms forward, and during inhalation, circling arms out to the side of the hips and extending cervical and thoracic spine, but bottom rib was on the mat. (Hold) count 5, 4,3,2,1 for 5 repetitions. 10 minutes
Side leg lift series	the individual was in a side-lying position with legs adducted and parallel, bottom arm long supporting head, then one top leg

	abducted, and top leg circles.(Hold) 10 sec for 10 repetitions 10 minutes
One leg circle	The individual was in a supine position with legs long and extended, one leg along the mat and the other reaching the ceiling with hips flexed. Then, during inhalation, asked to bring his leg across his midline and away for the first half of the circle, then as he exhale, bring his leg away from the midline and then toward the torso for the second half of the circle. .(Hold) 10 sec for 10 repetitions 10 minutes
Hundreds	Maintain the patient's legs in a tabletop position with supine and imprinted positions. Then, as inhalation, stay, and as exhalation, rolling up and extending his legs as low as possible while maintaining the imprint. As inhalation, executing vertical pulses with the arms for 5 counts and continue pulsing arms for 5 counts after exhaling. 5 minutes
Shoulder Bridge	The individual was in a supine position with knees flexed, feet on the mat, and arms by your sides. We asked the patients to take a deep breath and hold it for 10 seconds. Then exhale and elevate his pelvis off the mat by extending his hips. As inhalation, keeping his pelvis level and lift one foot and then stretch his knee to reach his toes to the ceiling. Exhale and flex his leg at the hip. As his exhale, asked to bend his knees and lower his foot on the mat 10 repetitions 10 minutes

Spine stretch forward	Patients sit with an extended leg; Inhale, then extend his arms out in front of him, shoulder height. The palms were directed downward and his fingers stretched forward. Keep his arms straight in line with the shoulders and maintain a fixed width between the arms. Then breathe out as he stretching his spine into a large C-shape curve forward. (Hold) count 5, 4,3,2,1 for 8 repetitions. 5 minutes

Outcome measures

Participants were assessed twice: once at the start of the study and again six weeks later. The fifth author, who was not involved in the allocation or treatment stages, made the assessment. The primary outcome was the spatiotemporal gait parameters, which were assessed using a walkway pressure measurement system; secondary outcomes included pain, function, isometric endurance of trunk extensors, and isometric endurance of trunk flexors.

Spatiotemporal gait parameters were investigated by using the "walkway pressure" gait analysis platform system (MA 02127, USA). Furthermore, Software features have enabled the numerical form to record spatiotemporal information Such as dynamic 2D and 3D presentations of real-time and recorded data. To great extent, the walkway pressure measurement system is valid and reliable to analyze the spatiotemporal gait characteristics [(23)]. The gait cycle is the time interval between two successive occurrences of one of the repetitive events of locomotion. The human gait cycle is divided into two separate regions representing the period time when the foot is in contact with the ground according to the recommendations of the International Society of Biomechanics (ISB).

The study's participants were asked to walk barefooted as straight as possible on the walkway platform without assistance on the same day. The spatiotemporal parameters were recorded, and the five repetitions' arithmetic means were determined. The participants were allowed to sit on a chair every time they were asked to have a rest. Moreover, both extremities were assessed for gait time, step time right, step time left, step length right, step length left, cadence, and gait velocity.

- Gait time: The period from one event, usually initial contact, of one foot to the subsequent occurrence of the same event with the same foot.
- Step time right: The elapsed time from the initial contact of the right foot to the initial contact of the left one.
- Step time left: The elapsed time from the initial contact of the left foot to the initial contact of the right one.
- Step length right: The distance from the heel of the right foot-strike to the heel of the left foot-strike.
- Step length left: The distance from the heel of the left foot-strike to the heel of the right foot-strike.
- Gait velocity: the time taken by one to a specific distance.

Pain: VAS was used which was a line, usually 10 cm long, ranging from the no pain indicator (zero) to the worst pain that can be felt (10). VAS is effective and consistent for rating CLBP [(24)].

Function: Modified Oswestry Disability Questionnaire was used which was a ten-question self-reported assessment of functional impairment. The ten questions are centered on the efficacy of performing various activities connected to back pain. Each question contains six alternative answers ranging from 0 to 5 with a maximum score of 50. Higher levels indicate high impairment. The implication is a high level of construct validity and reliability [(25)].

Isometric endurance of trunk extensor: Biering–Sorensen test (low back fatigue test) is one of the few muscle performance tests that have been demonstrated to be both predictive and discriminative in prospective studies [(26)]. The test entails the subject lying prone on the sofa with the buttocks and legs fastened by straps as long as he/she can keep their upper body horizontal.

Isometric endurance of trunk Flexor: Trunk flexion endurance test was used to assess abdominal muscular endurance, the participants were asked to be in a sitting position with their knees contracted so that their legs were on the bed and firmly attached to the bed by a belt to measure abdominal muscle endurance. Then, a board with angles of 55° relative to the bed was installed behind the patient. The patient has maintained the position by having his/her hands on the chest in a cross posture and a flexed trunk near the board. When the subject loses endurance and touches the board, the time is up and reported in the pre-test and post-test registration forms. The subjects' knees and hips were in a 90° flexion position, with arms crossed in front of the chest and hands-on shoulders. To maintain the position, the legs should be fastened [27].

Statistical methods

All the demographic data, spatiotemporal parameters, pain intensity, disability, and flexion and extension endurance test were subjected to test the normality of distribution using the Shapiro–Wilk test. Since the data were normally distributed, parametric tests were available to be used successfully. Statistical software was used to perform the analysis process (SPSS version 25, IBM Corp, New York, USA). A one-way analysis of variance was adopted to detect the difference in demographic data between the three groups (ANOVA). Furthermore, MANOVA with a mixed model was used to detect the effect of treatment on all variables and trace the interaction between time and treatment. The Bonferroni test was also utilized to find out if there were differences between groups. Also, the within-group effects were investigated using a paired t-test. The magnitude of differences between groups was determined by computing partial eta square. (η 2). Finally, the difference between groups in gender was clarified using the chi-square (X2) test. All the previously mentioned steps were done successfully and in a significant way.

Results

The flow chart of patients in the trial was shown in Figure 1. One hundred and ten participants have been assessed for eligibility. Twenty patients were excluded; twelve suffered from long distance transportation and eight patients did not meet the research criteria or have refused to participate in the study. This study included 90 patients of both genders (49 males and 41 females) aged 20–30 years and who had been referred with a diagnosis of NS-CLBP. Demographic data (age, weight, height, body mass index (BMI), and gender), independent variables, and all of the dependent variables that encompassed spatiotemporal parameters, pain intensity, disability, flexion, and extension endurance test were all taken into account in the current study. According to the one-way ANOVA results, there has been no statistically significant disparity in the demographic data and dependent variables at baseline measurements between the three groups. Additionally, the X2 test has revealed the absence of variances in gender variables between groups **(Table 4).**

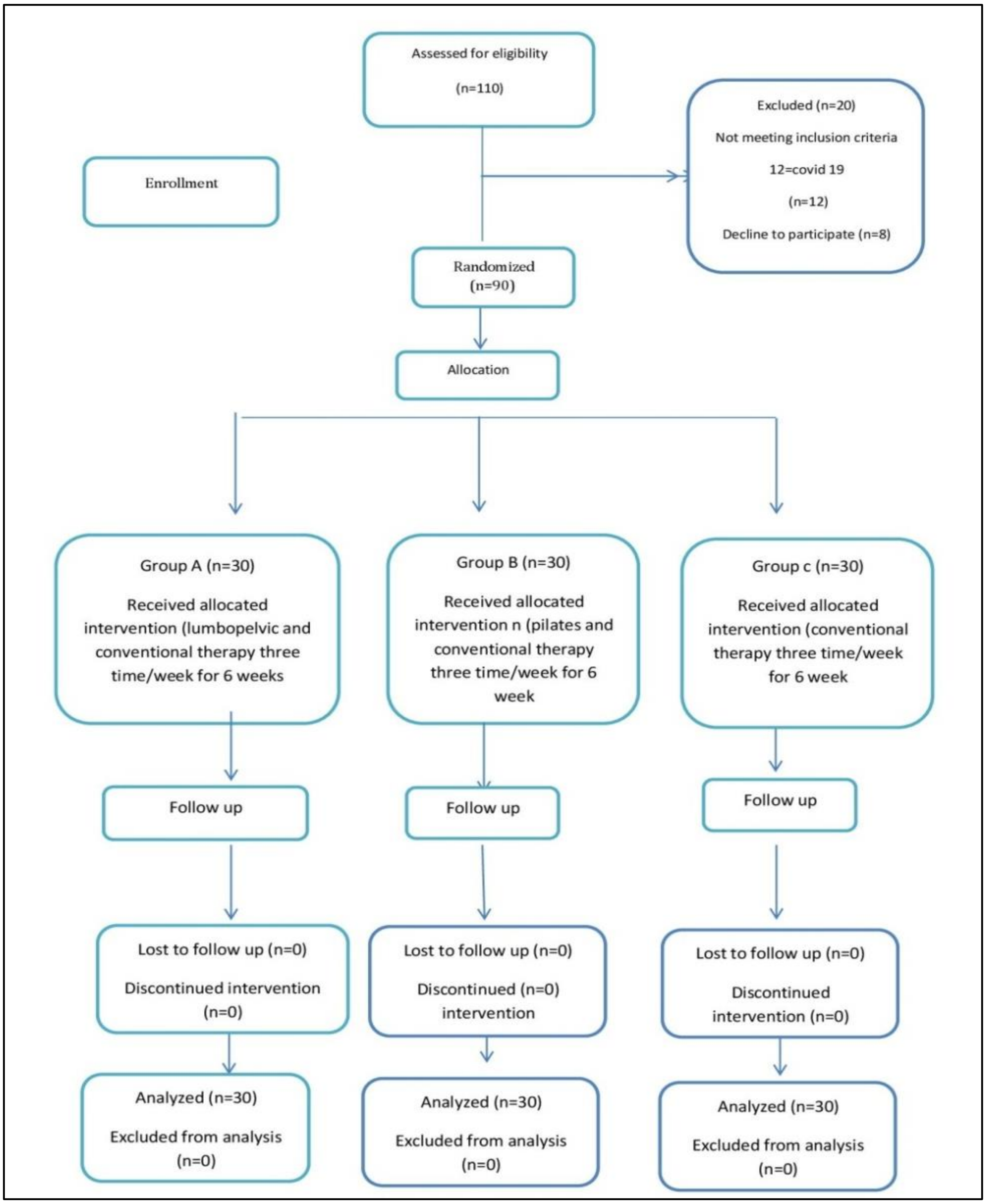

Figure 1. Consort flow diagram

Table 4: Demographic data and baseline measurements of all dependent variables

	Mean ± SD			p-value
	Stabilizing group	Pilates group	Control group	
Age (years)	23.32 ± 1.24	24.46 ± 2.46	23.28 ± 1.32	0.51b
Weight (kg)	63 ± 6.36	69.2 ± 6.26	66.6 ± 7.19	0.36b
Height (cm)	164.2 ± 5.32	168.6 ± 12.41	169 ± 8.21	0.65b
BMI (kg/m2)	21.6 ± 0.89	22.5 ± 3.74	22.8 ± 1.64	0.12b
Male/female	17 males/13 females	14 males/16 females	18 males/12 females	(X2 =1.16) P= 0.55b
Pain intensity	6.5 ± 1.43	6.7 ± 1.15	6.49 ± 1.35	0.92b
Disability	27.6 ± 3.23	26.3 ± 2.86	27.8 ± 2.25	0.44b
Flexion endurance (s)	74.9 ± 4.35	76.2 ± 3.91	76.8 ± 4.36	0.59b
Extension endurance (s)	71.9 ± 3.75	72.8 ± 5.39	73.6 ± 2.75	0.65b
Gait time (minute)	2.41 ± 1.28	2.42 ± 1.17	2.73 ± 1.59	0.83b
Step time R (s)	0.62 ± 0.15	0.61 ± 0.13	0.63 ± 0.10	0.92b
Step time L (s)	0.64 ± 0.10	0.62 ± 0.07	0.61 ± 0.15	0.84b
Step length R (m)	0.39 ± 0.09	0.38 ± 0.08	0.41 ± 0.06	0.87b
Step length L (m)	0.40 ± 0.09	0.39 ± 0.07	0.42 ± 0.07	0.81b
Cadence (step/minute)	108.86 ± 17.79	106.15 ± 15.33	110.71 ± 15.3	0.81b
Velocity (m/s)	0.43 ± 0.04	0.45 ± 0.05	0.43 ± 0.06	0.58b

b=No significance difference; SD: standard deviation; p-value: significance level; BMI: body mass index; X2; chi-square test; S: second; m: meter; R: right; L: left.

Between-group analysis

According to MANOVA, there was a statistically significant effect of treatment as $p < 0.001$ and f-value = 3.12 and Also, there was a statistically significant interaction between treatment and time as $p < 0.0001$ and f-value = 3.44. There was a statistically clear variance between the three groups ($p < 0.05$) (Table 5). In temporal parameters; gait time, step time right, and step time left, there was no noticeable disparity between stabilizing and Pilates groups and stabilizing and control groups (p-value > 0.05). However, there was statistically a crystal-clear variance between the Pilates group and the control group ($p < 0.05$).

In spatial parameters; step length right and step length left, there were no significant differences between stabilizing and Pilates groups (p > 0.05). However, there was a clear variance between stabilizing and control groups and Pilates and control groups (p < 0.05). In cadence, no disparity is found between stabilizing and Pilates groups and stabilizing and control groups. Many differences were found between Pilates and the control group (p < 0.05). In velocity, there was a significant disparity between stabilizing and Pilates groups, Pilates and control groups, and stabilizing and control groups (p < 0.05).

In pain intensity and disability, the Bonferroni test showed significant differences between stabilizing and Pilates groups, stabilizing and control groups, and Pilates and control groups (p < 0.05). Finally, in flexion and extension endurance, no variances between stabilizing and Pilates groups were found (p > 0.05), but there was a significant disparity between stabilizing and control groups and Pilates and control groups (p < 0.05).

Within-group analysis

Paired t-test has revealed a statistically significant disparity between pre-and post-treatment in stabilizing and Pilates groups. However, no clear difference was observed in the control group. The Pilates group had more refinement in all variables than the stabilizing group according to the percent of change in **(Table 6).**

Table 5: Between-group analysis at post treatment

	Mean ± SD			f-value	p-value	η 2
	Stabilizing group	Pilates group	Control group			
Pain intensity	3.2 ± 1.13	1.4 ± 0.35	5.8 ± 0.78	55.98	0.0001a	0.81
Disability	16.1 ± 0.87	13 ± 2.49	27.3 ± 1.7	171.6	0.0001a	0.92
Flexion endurance (s)	93.4 ± 4.88	97.2 ± 7.56	77 ± 3.52	36.95	0.0001a	0.73
Extension endurance (s)	89.9 ± 6.59	91.2 ± 5.73	75.3 ± 2.26	28.72	0.0001a	0.68
Gait time (minute)	1.59 ± 0.57	1.45 ± 0.56	2.22 ± 0.77	4.07	0.02a	0.23
Step time R (s)	0.47 ± 0.1	0.4 ± 0.01	0.56 ± 0.1	5.87	0.008a	0.3
Step time L (s)	0.51 ± 0.08	0.42 ± 0.05	0.54 ± 0.11	5.75	0.007a	0.31

Step length R (m)	0.49 ± 0.03	0.53 ± 0.02	0.42 ± 0.02	18.69	0.0001a	0.58
Step length L (m)	0.52 ± 0.02	0.56 ± 0.1	0.43 ± 0.04	9.51	0.001a	0.41
Cadence (step/minute)	122.36 ± 8.8	127.86 ± 6.8	115.4 ± 9.6	5.36	0.01a	0.28
Velocity (m/s)	0.65 ± 0.07	0.81 ± 0.06	0.49 ± 0.02	68.07	0.0001a	0.83

a = Significance difference; SD: standard deviation; p-value: significance level; BMI: body mass index; S: second; m: meter; R: right; L: left; η 2: partial eta square; η 2 ranges: 0.01 (small effect size), 0.06 (medium effect size), and 0.14 (large effect size).

Table 6: Within-group analysis

Variables	Stabilizing group	Pilates group	Control group
Pain intensity			
Pretreatment	6.5 ± 1.43	6.7 ± 1.15	6.49 ± 1.35
Post treatment	3.2 ± 1.13	1.4 ± 0.35	5.8 ± 0.78
p-value	0.0001a	0.0001a	0.08
Percent of change	50.8%	79%	12%
95% confidence interval	2.4 to 4.19	4.54 to 6.05	−0.12 to 1.5
Disability			
Pretreatment	27.6 ± 3.23	26.3 ± 2.86	27.8 ± 2.25
Post treatment	16.1 ± 0.87	13 ± 2.49	27.3 ± 1.7
p-value	0.0001a	0.0001a	0.51b
Percent of change	41.6%	50.6%	1.8%
95% confidence interval	9.06 to 13.93	10.73 to 15.86	−1.16 to 2.16
Flexion endurance (s)			
Pretreatment	74.9 ± 4.35	76.2 ± 3.91	76.8 ± 4.36
Post treatment	93.4 ± 4.88	97.2 ± 7.56	77 ± 3.52
p-value (within-group)	0.0001a	0.0001a	0.81b
Percent of change	25%	28%	0.26%
95% confidence interval	−14.28 to −10.47	−24.4 to −17.54	−2.04 to 1.64
Extension endurance (s)			
Pretreatment	71.9 ± 3.75	72.8 ± 5.39	73.6 ± 2.75
Post treatment	89.9 ± 6.59	91.2 ± 5.73	75.3 ± 2.26
p-value	0.0001a	0.0001a	0.06b
Percent of change	25%	25%	−2%
95% confidence interval	−21.88 to −4.11	−22.32 to −14.4	−3.48 to 0.086
Gait time (minute)			
Pretreatment	2.41 ± 1.28	2.42 ± 1.17	2.73 ± 1.59
Post treatment	1.59 ± 0.57	1.45 ± 0.56	2.22 ± 0.77
p-value (within-group)	0.03a	0.007a	0.34b
Percent of change	34%	40%	19%
95% confidence interval	0.11 to 1.52	0.33 to 1.61	−0.64 to 1.68
Step time R (s)			
Pretreatment	0.62 ± 0.15	0.61 ± 0.13	0.63 ± 0.10
Post treatment	0.47 ± 0.1	0.4 ± 0.01	0.56 ± 0.1
p-value	0.008a	0.002a	0.09b
Percent of change	24%	34%	11%

95% confidence interval	0.04 to 0.23	0.09 to 0.31	−0.015 to 0.15
Step time L (s)			
Pretreatment	0.64 ± 0.10	0.62 ± 0.07	0.61 ± 0.15
Post treatment	0.51 ± 0.08	0.42 ± 0.05	0.54 ± 0.11
p-value	0.009a	0.0001a	0.08b
Percent of change	20%	32%	11%
95% confidence interval	0.04 to 0.21	0.13 to 0.28	−0.1 to 0.14
Step length R (m)			
Pretreatment	0.39 ± 0.09	0.38 ± 0.08	0.41 ± 0.06
Post treatment	0.49 ± 0.03	0.53 ± 0.02	0.42 ± 0.02
p-value	0.002a	0.0001a	0.4b
Percent of change	26 %	39%	2%
95% confidence interval	−0.14 to −0.05	−0.21 to −0.09	−0.07 to 0.03
Step length L (m)			
Pretreatment	0.40 ± 0.09	0.39 ± 0.07	0.42 ± 0.07
Post treatment	0.52 ± 0.02	0.56 ± 0.1	0.43 ± 0.04
p-value	0.001a	0.0001a	0.54b
Percent of change	30%	44%	2%
95% confidence interval	−0.17 to −0.06	−0.23 to −0.11	−0.08 to 0.04
Cadence (step/minute)			
Pretreatment	108.86 ± 17.79	106.15 ± 15.33	110.71 ± 15.3
Post treatment	122.36 ± 8.8	127.86 ± 6.8	115.4 ± 9.6
p-value	0.02a	0.001a	0.11b
Percent of change	12%	21%	4%
95% confidence interval	−24.89 to −2.1	−31.36 to −12.05	−10.77 to 1.39
Velocity (m/s)			
Pretreatment	0.43 ± 0.04	0.45 ± 0.05	0.43 ± 0.06
Post treatment	0.65 ± 0.07	0.81 ± 0.06	0.49 ± 0.02
p-value	0.0001a	0.0001a	0.055b
Percent of change	51%	80%	14%
95% confidence interval	−0.28 to −0.16	−0.41 to −0.3	−0.09 to −0.001

b No significance difference; a Significance difference; SD: standard deviation; p-value: significance level; BMI: body mass index; S: second; m: meter; R: right; L: left.

Discussion

Injury to the low back can result in considerable pain and dysfunction, as well as altered spatiotemporal gait parameters [28]. Hence, appropriate rehabilitation strategies are required for the management of NS-CLBP [29]. The current study is focusing on concluding whether stabilization or Pilates exercise was superior in terms of spatiotemporal gait parameters, pain, function, and endurance in NS-CLBP cases after six weeks of exercise. The major findings of the current study have revealed that there was a significant disparity between pre-and post-treatment in the stabilizing and Pilates groups. However, no difference was observed in the control group and the Pilates group which had more refinement in all variables than the stabilizing group.

On one hand, many studies have been conducted to demonstrate the role of stabilization or Pilates in NS-CLBP. **Akodu et al. (2018)** have found that stabilization exercises are useful in the treatment process of NS-CLBP [30]. **Natour et al. (2015)** have reported that Pilates exercises were effective in the NS-CLBP management [18].

On the other hand, over a spectrum of studies, it has been found that other studies have compared either stabilization exercise to general exercise [31] or Pilates exercise in opposition to general exercise [32, 18]. It has been declared that both stabilization and Pilates groups have improved significantly in comparison to other groups. The potentiality of improvement could be as the stabilization exercise increases the power of deep abdominal muscles and improves spine balance which is effective in reducing NS-CLBP [33].

Subsequently, strengthening deep muscles has a positive effect on spatiotemporal gait parameters and enables the restoration of normal control of the deep spinal muscles. This could also be due to the exercises' ability to mobilize and stabilize the human body.

Subsequently, certain muscles are activated in a functional sequence at a controlled rate, stressing quality, precision, and control of movement. This allows for the co-contraction of local muscles like TrA (transversus abdominis) and LM (lumbar multifidus) within the neutral zone. The neutral zone refers to the alignment of the lower spine and pelvis in a normal lumbar curve [2].

In previous studies, it has been found that patients' physical activity has improved with core exercise and Pilates exercises [34]. In patients with NS-CLBP, both stabilization and Pilates exercises were found to be effective in improving physical activities [1]. Furthermore, Pilates also promotes trunk and pelvic segment mobility control. Thus, in patients with musculoskeletal injuries, motor relearning of inhibited muscles may be more effective than strength [35]. Thus, both stabilization and Pilates had a prominent effect in the treatment process, but Pilates came out to be on the top.

After taking into consideration the trunk endurance results, it has been discovered that both stabilization and Pilates had an equal effect on increasing trunk endurance. These findings are supported by several studies. **Kalron et al. (2017)** have confirmed that Pilates is a possible treatment option for people with balance instability to improve their walking and balance capabilities. However, this approach does not have any significant advantage over standardized physical therapy [36]. **Adıguzel et al. (2022)** have listed that Modified Pilates exercise has improved trunk control in sitting position, gait, and core muscles in cerebral palsy cases, especially in adults. It has been declared that Modified Pilates exercise (MPE) can be easily applied to the treatment process to increase balance and mobility level [37]. Furthermore, **Chan et al. (2020)** and **Llewellyn et al. (2017)** have reported that the Pilates exercise protocol has reinforced core muscle endurance and lumbar flexibility [38].

On one level, there have been no previous studies that draw a comparison between the effects of stabilization of Pilates exercises on spatiotemporal gait parameters. However, there have been other studies that compared the impact of Pilates exercises on pain and functional disability **(Bhadauria and Gurudut, 2017).** Both Lumbar stabilization exercise and Pilates exercise were found to be important in the treatment of NS-CLBP. Furthermore, lumbar stabilization was found to be highly effective than Pilates and dynamic strengthening for CLBP [9].

On the other level, **Engers et al. (2016)** have conducted a study that figured out the significance of Pilates exercise on healthy adults. It has been found that Pilates boosted gait speed, whereas the control group did not. Hence, increasing the stride length after the exercise period results in increasing the gait speed.

In other words, Pilates exercise charges the stability of the body and this may have helped in boosting the stability of the spine, the muscular strength, and the flexibility of the pelvis and hip joints [34]. This is consistent with the findings of **Cairns et al. (2006)** who have found that the use of spinal stabilization exercises does not recommend the use of stabilization exercises in the treatment process of NS-CLBP [39]. This study contradicts the findings of another one by **Pereira et al. (2012)** who have compared the Pilates method to the stabilization programs and concluded that Pilates did not improve the functional ability or pain in CLBP patients [40]. Subsequently, the previously mentioned findings are not consistent with the finding of the current study.

Limitation: There was no long-term follow-up to trace the treatment's long-term effect. Also, there were no different age groups in this trial which serves as a significant limitation for future research. Finally, since subjects were recruited as volunteers from many private sessions, the study's external validity may be hampered. Subsequently, extending the findings to other settings, such as primary care, should be done with caution.

Conclusion

Both stabilization and Pilates exercises have an effect on pain, disability, endurance, and spatiotemporal gait parameters, but Pilates is superior to others in reducing pain, functional disability, and temporal gait parameters, plus increasing cadence and velocity. Both stabilization and Pilates have an equal effect on increasing flexion and extension endurance.

Recommendations:

Taking into account the trial and its findings, having Pilates exercises as a basic part of the treatment process for NS-CLBP is highly recommended.

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Abbreviations list:

NS-CLBP	Nonspecific chronic low back pain
ANOVA	Analysis of variance
BMI	Body mass index
CLBP	Chronic low back pain
LBP	Low back pain
LM	Lumbar multifidus
MANOVA	Multivariate analysis of variance
PACTR	Pan African Clinical Trial
RMS	Root mean square
TrA	Transversus abdominis
VAS	Visual analog scale
ISB	International Society of Biomechanics

References

1. Smith BE, Littlewood C, May S. An update of stabilization exercises for low back pain: a systematic review with meta-analysis. BMC Musculoskeletal Disord. 2014; 15(1): 416. https://doi.org/10.1186/1471-2474-15-416
2. Tottoli CR, Tulder MV, Da Silva EN, Marques YA, Martins WR, Carregaro R L. Effectiveness and cost-effectiveness of Pilates versus home-based exercises in individuals with chronic nonspecific low back pain: randomized controlled trial protocol, European Journal of Physiotherapy. 2019; 23:2, 95-101 DOI: 10.1080/21679169.2019.1645883
3. Dong Y, Wang H, Zhu Y, Chen B, Zheng Y, Liu X, et al. Effects of whole-body vibration exercise on lumbar-abdominal muscles activation for patients with chronic low back pain. BMC Sports Sci Med Rehabil. 2020 Dec 10;12(1):78. DOI: 10.1186/s13102-020-00226-4.
4. Carvalho AR, Ribeiro Bertor WR, Briani RV, Zanini GM, Silva LI, Andrade A, et al. Effect of nonspecific chronic low back pain on the walking economy: an observational study. J Mot Behav. 2016; 48(3):218-26. DOI: 10.1080/00222895.2015.1079162.
5. De Laat KF, Tuladhar AM, van Norden AGW, Norris DG, Zwiers MP, de Leeuw FE. Loss of white matter integrity is associated with gait disorders in cerebral small vessel disease. Brain. 2011; 134(Pt 1):73-83. DOI: 10.1093/brain/awq343.
6. Nishi Y, Osumi M, Nobusako S, Takeda K, Morioka S. Avoidance Behavioral Difference in Acquisition and Extinction of Pain-Related Fear. *Front Behav Neurosci*. 2019;13:236. Published 2019 Oct 11. doi:10.3389/fnbeh.2019.00236
7. Hicks GE, Sions JM, Coyle PC, Pohlig RT. Altered spatiotemporal characteristics of gait in older adults with chronic low back pain. Gait Posture. 2017; 55:172–176. DOI: 10.1016/j.gaitpost.2017.04.027.
8. Burton AK, Balagué F, Cardon G, Eriksen HR, Henrotin Y, Lahad A, et al. COST B13 Working Group on Guidelines for Prevention in Low Back Pain. Chapter 2. European guidelines for prevention in low back pain. 2004. Eur Spine J 2006; 15 Suppl 2:S136-168. DOI: 10.1007/s00586-006-1070-3.
9. Bhadauria EA, Gurudut P. Comparative effectiveness of lumbar stabilization, dynamic strengthening, and Pilates on chronic low back pain: a randomized clinical trial. Journal of Exercise Rehabilitation. 2017; 13(4):477-485. DOI: 10.12965/jer.1734972.486.
10. Miranda IF, Souza C, Schneider AT, Chagas LC, Loss JF .Comparison of low back mobility and stability exercises from Pilates in non-specific low back pain: A randomized controlled trial. Complement Ther Clin Pract. 2018 May;31:360-368. DOI: 10.1016/j.ctcp.2017.12.005. Epub 2017 Dec 8. PMID: 29248397.
11. Roh S, Gil HJ, Yoon S. Effects of 8 weeks of mat-based Pilates exercise on gait in chronic stroke patients. J Phys Ther Sci. 2016; 28(9):2615-2619. DOI: 10.1589/jpts.28.2615
12. Culligan PJ, Scherer J, Dyer K, Priestley JL, Guingon-White G, Delvecchio D, et al. A randomized clinical trial comparing pelvic floor muscle training to a Pilates exercise program for improving pelvic muscle strength. Int Urogynecol J Pelvic Floor Dysfunct, 2010, 21: 401–408. DOI: 10.1007/s00192-009-1046-z.

13. Critchley DJ, Pierson Z, Battersby G: Effect of pilates mat exercises and conventional exercise programs on transversus abdominis and obliquus internus abdominis activity: a pilot randomized trial. Man Ther, 2011, 16: 183–189. DOI: 10.1016/j.math.2010.10.007.
14. Newell D, Shead V, Sloane L. Changes in gait and balance parameters in elderly subjects attending an 8-week supervised Pilates program. J Bodyw Mov Ther, 2012, 16: 549–554. DOI: 10.1016/j.jbmt.2012.02.002.
15. Mokhtari M, Nezakatalhossaini M, Esfarjani F. The effect of 12-week pilates exercises on depression and balance associated with falling in the elderly. Procedia Soc Behav Sci, 2013, 70: 1714–1723. https://doi.org/10.1016/j.sbspro.2013.01.246
16. Schulz KF, Altman DG, Moher D, CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomized trials. BMJ. 2010; 23; 340:c332. https://doi.org/10.1186/1741-7015-8-18
17. Rydeard R, Leger A, Smith D. Pilates-based therapeutic exercise: effect on subjects with nonspecific chronic low back pain and functional disability: a randomized controlled trial. J Orthop Sports Phys Ther, 2006, 36: 472–484.
18. Natour J, Cazotti Lde A, Ribeiro LH, Baptista AS, Jones A. Pilates improves pain, function, and quality of life in patients with chronic low back pain: a randomized controlled trial. Clin Rehabil. 2015; 29(1):59-68. DOI: 10.1177/0269215514538981.
19. Andrusaitis SF, Brech GC, Vitale GF, Maria DJ, Greve A. Trunk stabilization among women with chronic lower back pain: a randomized, controlled, and blinded pilot study. CLINICS 2011; 66(9):1645-1650. DOI: 10.1590/S1807-59322011000900024
20. Luque-Suárez A, Díaz-Mohedo E, Medina-Porqueres I, Ponce-García T. Stabilization Exercise for the Management of Low Back Pain, Low Back Pain, Dr. Ali Asghar Norasteh (Ed.), ISBN: 978-953-51-0599-2, InTech, Available from: http://www.intechopen.com/books/low-back-pain/exercise-therapy-for-the-management-of-low-back-pain
21. Koppenhaver SL, Fritz JM, Hebert JJ, Kawchuk GN, Childs JD, Parent EC, et al. Association between changes in abdominal and lumbar multifidus muscle thickness and clinical improvement after spinal manipulation. J Orthop Sports Phys Ther 2011; 41(6): 389-99. DOI: 10.2519/jospt.2011.3632.
22. Gagnon LH. Efficacy of Pilates Exercises as Therapeutic Intervention in Treating Patients with Low Back Pain. Ph.D. diss., University of Tennessee, 2005.
23. Coda A, Carline T, Santos D. Repeatability and reproducibility of the Tekscan HR-Walkway system in healthy children. Foot 2014, 24, 49–55. DOI: 10.1016/j.foot.2014.02.004.
24. Olaogun MOB, Adedoyin RA, Ikem IC and Anifaloba OR. Reliability of rating low back pain with a visual analog scale and a semantic differential scale, Physiotherapy Theory, and Practice. 2004; 20(2): 135-142. DOI: 10.1080/09593980490453048
25. Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. Phys Ther 2001; 81(2):776-88.
26. Latimer J, Maher CG, Refshauge K, Colaco L. The Reliability and Validity of the Biering–Sorensen Test in Asymptomatic Subjects and Subjects Reporting

Current or Previous Nonspecific Low Back Pain. spine 1999; 24(20) 2085–209. DOI: 10.1097/00007632-199910150-00004.
27. Nesser TW, Huxel KC, Tincher JL, Okada T. The relationship between core stability and performance in division I football players. J Strength Cond Res. 2008 Nov;22(6):1750-4. DOI: 10.1519/JSC.0b013e3181874564. PMID: 18978631.
28. Hicks GE, Fritz JM, Delitto A, McGill SM. Preliminary development of a clinical prediction rule for determining which patients with low back pain will respond to a stabilization exercise program. Arch Phys Med Rehabil. 2005; 86:1753-1762. DOI: 10.1016/j.apmr.2005.03.033.
29. Ferreira PH, Ferreira ML, Maher CG, Herbert RD, Refshauge K. Specific stabilization exercise for spinal and pelvic pain: a systematic review. Aust J Physiother 2006; 52(2): 79-88. DOI: 10.1016/s0004-9514(06)70043-5.
30. Akodu AK, Akindutire OM. The effect of stabilization exercise on pain-related disability, sleep disturbance, and psychological status of patients with non-specific chronic low back pain. Korean J Pain. 2018; 31(3):199-205. DOI: 10.3344/kjp.2018.31.3.199
31. Gladwell V, Head S, Hagger M, Beneke R. Does a program of Pilate improves chronic nonspecific low back pain. Journal of sports rehabilitation.2006; 15(4): 338-350. DOI:10.1123/jsr.15.4.338
32. Wajswelner H, Metcalf B, Bennell K. Clinical Pilates versus general exercise for chronic low back pain. Journal of medical sports exercise. 2012; 44(7): 1197-205. DOI: 10.1249/MSS.0b013e318248f665.
33. Gordon R and Bloxham. A Systematic Review of the Effects of Exercise and Physical Activity on Non-Specific Chronic Low Back Pain. Healthcare. 2016; 25;4(2):22. DOI: 10.3390/healthcare4020022
34. Engers PB, Rombaldi AJ, Portella EG, da Silva MC. The effects of the Pilates method in the elderly: a systematic review. Rev Bras Reumatol Engl Ed. 2016 Jul-Aug;56(4):352-65. English, Portuguese. DOI: 10.1016/j.rbre.2016.05.005. Epub 2016 Jun 1. PMID: 27476629.
35. Cruz JC, Liberali R, da Cruz TMF, Netto MIA. The Pilates method in the rehabilitation of musculoskeletal disorders: a systematic review. Fisioter Mov. 2016 July/Sept;29(3):609-22.
36. Kalron A, Rosenblum U, Frid L, Achiron A. Pilates exercise training vs. physical therapy for improving walking and balance in people with multiple sclerosis: a randomized controlled trial. Clin Rehabil. 2017 Mar;31(3):319-328. DOI: 10.1177/0269215516637202. Epub 2016 Jul 10. PMID: 26951348
37. Adıguzel H, Elbasan B. Effects of modified pilates on the trunk, postural control, gait and balance in children with cerebral palsy: a single-blinded randomized controlled study. Acta Neurol Belg. 2022 Jan 18. DOI: 10.1007/s13760-021-01845-5. Epub ahead of print. PMID: 35040072.
38. Chan EW, Nadzalan A, Othman Z, Hafiz E, Hamid MS. The Short-Term Effects of Progressive vs Conventional Core Stability Exercise in Rehabilitation of Nonspecific Chronic Low Back Pain. Sains Malays. 2020; 49(10) 2527–2537. ISSN 0126-6039
39. Cairns MC, Foster NE, Wright C. Randomized controlled trial of specific spinal stabilization exercises and conventional physiotherapy for recurrent low back pain. Spine (Phila Pa 1976). 2006 Sep 1;31(19):E670-81. DOI: 10.1097/01.brs.0000232787.71938.5d. PMID: 16946640.

40. Pereira LM, Obara K, Dias JM, Menacho MO, Guariglia DA, Schiavoni D, et al. Comparing the Pilates method with no exercise or lumbar stabilization for pain and functionality in patients with chronic low back pain: systematic review and meta-analysis. Clin Rehabil. 2012 Jan;26(1):10-20. DOI: 10.1177/0269215511411113.