

The influence of Pilates reformer exercises on non-specific lumbar pain

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Abstract

This study aims to determine the impact of basic Pilates exercises performed on Reformer machines to alleviate lumbar pain. The term lumbar pain implies different forms of pain in the lower back region, i.e., Low Back Pain (LBP), which can be caused by various mostly undetected factors and across all generations and gender groups. The research was conducted on a sample of 53 women aged 42.5 ± 8.1 , divided into an experimental and a control group. The experimental group consisted of 32 women aged 41.5 ± 8.1 , while the control group included 21 women aged 44.2 ± 7.9 . The selection of exercises focused on strengthening the core muscles, concerning breathing techniques and body mechanics, is classified as beginner level, both in terms of intensity and complexity. The Oswestry Low Back Pain Questionnaire (OLBPQ) was utilized to assess functional status and individual disability related to LBP before and after the experiment. Within the experimental group, Wilcoxon signed-rank tests demonstrated statistically significant reductions in mean rank scores from pre- to post-intervention for every item (for example, Q3: $MR_{pre} = 24.70$ vs. $MR_{post} = 21.26$; $Z = -3.77$; $p < 0.001$) and for the overall Oswestry Disability Index ($MR_{pre} = 26.78$ vs. $MR_{post} = 22.82$; $Z = -4.47$; $p < 0.001$), indicating a marked improvement in functional status following the eight-week Pilates reformer program. A series of controlled exercises, in conjunction with a meticulously guided procedure for performing Pilates exercises on the reformer machines through core muscle strengthening, breathing techniques, and body mechanics, have been demonstrated to alleviate non-specific lumbar pain.

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Introduction

According to the World Health Organization (WHO), lower back pain (LBP) is defined as pain occurring between the lower part of the floating ribs and the pelvic region. Depending on its duration, the pain may be classified as acute (short-term), subacute (medium-term), or chronic if it lasts longer than three months (WHO, 2023). LBP limits individuals in various activities and daily responsibilities. In 90% of cases, the pain is non-specific, meaning its origin and cause cannot be determined (WHO, 2023). At the end of the 20th century, it was predominantly associated with age and degenerative changes (Adams & Roughley, 2006). Due to inactivity and obesity nowadays, it affects all age groups and is increasingly seen among the younger population. It is closely related to a sedentary lifestyle, postural abnormalities, and eventually causes psychological issues affecting all age groups, influencing their quality of daily life (Machikanti et al., 2014). While the exact reasons some individuals develop LBP remain

unclear, common causes include a sedentary lifestyle, heavy lifting, ageing, sudden or improper movements, and other physical factors (Machikanti et al., 2014). Therefore, LBP is associated with physical inactivity, which often targets body posture and mechanics.

There are two primary approaches to treating lower back pain. The first is medical-surgical, a predominant treatment when degenerative changes occur (disc herniation, spinal stenosis, spondylolisthesis), since such alterations frequently result in structural impairment and neurological manifestations, necessitating invasive medical or surgical interventions. The second is conservative and non-surgical, involving exercise sciences as kinesiotherapy, physiotherapy, and pharmacotherapy (Savigny et al., 2009) as well as strength and conditioning in line with health and wellness coaching (Chiarotto & Koes, 2022). Conservative treatment is predominant when inactivity and obesity, a sedentary lifestyle, are probable etiologies of LBP, as it targets the underlying behavioral and physical causes in a non-invasive manner. Among

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conservative methods, structured physical activity focused on core muscle activation and body mechanics has emerged as a particularly promising approach. Due to extensive research (Kim & Shin, 2023; Maher et al., 2017; Akhtar et al., 2017), it is being implied that strengthening the core region is of prime importance in a conservative approach.

Patients with LBP frequently exhibit weakness in core stabilizing muscles, particularly the transversus abdominis (TA), multifidus, intercostal muscles (external and internal), erector spinae, and pelvic floor muscles, which play a crucial role in spinal stabilization. Strengthening these muscles acts as a "corset" for the spine, reinforcing the connections between vertebrae, reducing disc pressure, and alleviating lower back tension (Akhtar et al., 2017). They also exhibit a problem with a herniated disc (Dydyk et al., 2023), commonly linked to mechanical injuries, sudden movements, or inactivity, and result in pain, numbness, and weakness in the lower back and legs (Machikanti et al., 2014). This region also houses most digestive and reproductive organs and core muscles, further intensifying pressure on intervertebral spaces and vertebrae, potentially leading to discomfort in this spinal region. Therefore, poor posture, which needs to be supported and stabilized, whether genetically predisposed or acquired, is another factor contributing to lumbar pain (Karpuz et al., 2021).

Within the realm of conservative therapeutic modalities, Pilates, which is a focal point of the present study, stands as an exercise system that places particular emphasis on strengthening the core region of the body in conjunction with proper breathing techniques and body mechanics (Lopes et al., 2017; Saritaş, 2024; Saçlı, 2025). It has gained recognition as a potentially effective modality for addressing lumbar pain (Akhtar et al., 2017; Saritas & Pisirici, 2024), and has been shown to alleviate discomfort, improve posture, increase joint mobility, enhance flexibility, and promote neuromuscular control and body awareness.

Clinical trials have shown that Pilates exercises can significantly alleviate pain and improve functionality in patients with chronic LBP (Bascan, 2021). Research also suggests that Pilates provides greater short-term improvement in functional abilities and pain relief compared to traditional physiotherapy (Lim et al., 2011). However, some findings due to insufficient emphasis on specific exercise treatment plans for its prevention (Kwok et al., 2021), mitigation or alleviation (Hayden et al., 2005), are contradictory and

inconclusive (Wells et al., 2013), or even indicate no significant difference between Pilates exercises and standard rehabilitation routines (Gladwell, 2006; Posadzki, et al., 2011; Lin, et al., 2016). Most studies have focused on Pilates exercises using mats and props (Lim, et al., 2011; Shi, et al., 2022), with significantly fewer studies investigating the effects of Pilates exercises performed on Reformer machines with strictly controlled and supervised procedure (Kwok et al., 2021) but focused on other health problems (Kılınç, 2024).

This presents a critical gap in the literature. While mat-based Pilates has been relatively well-explored, the unique mechanical and resistance features of the Reformer apparatus remain under-researched, particularly regarding their long-term impact on non-specific LBP. There is also a lack of structured, instructor-led protocols using Reformer Pilates tailored specifically to individuals suffering from chronic LBP.

Pilates, created by German-born Joseph Pilates in the early 20th century, focuses on strengthening the deep core muscles (Wells et al., 2012). These core muscles include the transversus abdominis (TA), rectus abdominis (RA), diaphragm, internal and external intercostal muscles, multifidus, erector spinae, and pelvic floor muscles. Together, these muscles enhance core strength and stability, maintain and improve somatic motor nerve control, and increase spinal control and somatic stability (Eliks, 2019; Saritis & Pisirici, 2024). The exercises require excellent control of breathing and body mechanics (Wells et al., 2012). Pilates on reformer machines includes work on the reformer machines with the application of springs that create additional load and make the exercise harder or easier. The resistance and support provided by the springs provide a greater range of motion and self-adjustment to the exercises. Working on reformers gives the possibility of precisely engaging certain muscle groups, including the deepest ones that are harder to hit in mat work. Therefore, the role of the instructor is essential, particularly as to ensure proper breathing techniques and body alignment in Pilates, the effectiveness of the performed exercise meaning to engage muscles properly and to coordinate movements, as well as to assure safety in rightfully performing body mechanics.

Therefore, this study aims to address this gap by exploring the effects of a standardized Reformer-based Pilates program—implemented with professional supervision—on individuals with non-specific LBP. The main objective of this study is to determine the

impact of basic Pilates exercises performed on Reformer machines in alleviating and mitigating LBP. It is hypothesized that a carefully designed and professionally implemented Reformer Pilates exercise program, conducted over an extended period, will lead to significant pain reduction and improved functional outcomes.

This study will contribute to the existing body of knowledge by providing new insights into whether machine-assisted Pilates can offer measurable advantages over traditional mat-based or generic physiotherapeutic interventions.

Methods

The Pilates on Reformer exercises were selected from the basic repertoire of Level 1 and 2 Pilates Reformer exercises to ensure accessibility for all participants. Each

training session included: 1) Warm-Up: Preparation focused on footwork; 2) Neutral Spine Alignment: Finding the neutral position of the spine (a middle between posterior and anterior pelvic tilts); 3) Breathing Technique: Emphasizing deep stabilizer muscle activation (inhale through the nose, exhale through slightly open lips, engaging thoracic muscles); 4) Reformer Exercises: Performed lying on the back, kneeling, sitting and lying on Reformer box. During the first four weeks, the exercises were at a beginner level. Starting with the fifth week, exercises were combined with advanced-level movements. The intensity of the exercises increased gradually through the progression of movements and adjustments to the resistance of the Reformer springs. The names and sequence of exercises performed over the eight weeks are provided in additional material (Table 1).

Table 1
Exercise Intensity and Spring Resistance

Exercise Name	Exercise Intensity 1	Springs 1	Exercise Intensity 2	Springs 2
Preparation: "V" foot position	Basic	2 red, 1 yellow	Basic	1 green, 1 yellow
Parallel feet	Basic	2 red, 1 yellow	Basic & walking	1 green, 1 yellow
Open feet	Basic	Basic	Basic	1 green, 1 yellow
Turned-in feet "V"	Basic	2 red, 1 yellow	Basic	1 green, 1 yellow
Raised knee	Basic	2 red, 1 yellow	Modified	1 green, 1 yellow
Prep for the Hundred	Basic	1 blue	Basic	1 red
The Hundred	Basic	1 blue	Intermediate	1 red
Coordination	Basic	1 blue	Intermediate	1 red
Bridge on the padded part of the foot (parallel)	Basic	2 red, 1 yellow	Intermediate (1 leg raised)	1 red, 1 yellow
Rope pulling backwards in a kneeling position	Basic	1 red	Intermediate	1 red, 1 yellow
Kneeling push-ups on the platform	Basic	1 blue	Intermediate	1 red
Position on the box with a flat back	Basic	All springs	Intermediate	All springs
"T" pulling on the box	Basic	1 blue	Basic	1 red
Swimming/pulling without/with ropes	Basic	-	Intermediate (pulling with ropes)	1 red
Stretching	Basic	1 yellow	Intermediate	-

Notes: The intensity levels are marked as "Basic," "Intermediate" and "Modified" depending on the exercise and progression requirements. Spring resistance is denoted by specific color-coded spring combinations (e.g., red, yellow, blue, green) to adjust the resistance accordingly. Variations in intensity and spring use are customized for progressive adaptation and client needs.

Participants

The study was conducted on a sample of 53 women, an average age of 42.5 years (± 8.1). The experimental group consisted of 32 women, an average age of 41.5 years (± 8.1), while the control group included 21 women, an average age of 44.2 years (± 7.9). The basic selection criteria for inclusion were that all participants were regular members of the Star Pilates Studio who were familiar with using Reformer machines for a period of at least 2 months. The criteria for the inclusion of the participants was pain in the lower back that has not been medically treated and lasted longer than 6 months. All participants had a recommendation from their doctors and physiatrists to try conservative methods for the alleviation of pain. The Oswestry Disability Index (ODI) is one of the most commonly used and validated tools for low back pain-related disability that was used as a Standardized self-report questionnaires capturing the patient's perception of pain, disability, and quality of life in a validated way that's comparable across studies. The basic selection criteria for the inclusion were that participants reported experiencing LBP (level 3 to 5 on the scale 1 to 5) on the Oswestry Disability Index (ODI) and did not have any other health issues. Participants were informed about the study's objectives and procedures and provided written consent for their voluntary participation. The study was conducted in compliance with the General Data Protection Regulation (GDPR) of the European Commission and ethical principles outlined by the American Psychological Association's Code of Conduct. The study was approved by the Ethics Committee of Singidunum University (approval no. 160; dated 22 Feb. 2024).

Participants were assigned to control and experimental group according to the fact that at the time of the research they were actively exercising, i.e. they were former exercisers or currently taking a break from exercising. The first, experimental group consisted of 32 participants exercising regularly in Star Pilates studio. They were divided into five subgroups across two locations. Subgroups were formed with the idea that one trainer can dedicate themselves to working with a maximum of 7 trainees to conduct exercises and breathing technique accurately. Each participant had the flexibility to schedule training sessions from the offered time slots. Training sessions were available in two morning and two afternoon slots over six days a week, allowing participants to complete three sessions per week over the eight weeks. The studio's conditions and flexible scheduling facilitated the research process.

Participants' adherence rates and attendance consistency were observed individually. Participants were considered to have consistently performed the exercises if they have attended more than 75% of the scheduled exercises, not skipping more than two workouts in a row. More than 80 % of participants had more than 90% adherence and attendance consistency, and the rest 20 % no less than 75% adherence and attendance rate without any health complications. The second control group consisted of 21 participants, former clients who took a break and did not practice Pilates at the time. They had the activity of light walking (Borg's Scale ranks between 1 and 2 known as "light walking") for 45-50 minutes over the period of eight weeks in the presence of a trainer who advised them on proper walking techniques and paid attention to walking speed and consistency in their presence. Each participant had the flexibility to schedule sessions in the morning or in the evening three times per week.

Procedure

The research was twofold. The first refers to data collection according to a clearly defined procedure, the Oswestry Low Back Pain Disability Questionnaire (OLBPQ) before and after 8 week exercise protocols for experimental and control group. The second refers to data processing using the Mann-Whitney U test, i.e. Wilcoxon signed-rank test. All statistical analyses were carried out using SPSS 20 (IBM Corp., 2011, IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY). Additionally, power analysis was performed to ensure the reliability of the statistical conclusions.

Data Collection

Data collection took place twice. Firstly, a week before the training or walking program begun, participants completed a socio-demographic status questionnaire and the Oswestry Low Back Pain Disability Questionnaire (Fairbank & Pynsent, 2000). The Oswestry Low Back Pain Questionnaire (OLBPQ) is designed to evaluate the impact of LBP on an individual's functional status and disability. The test was developed in the 1980s by Dr. J. Oswestry, a specialist in orthopedic rehabilitation, from whom it derives its name. It is widely used in clinical and research practice. The questionnaire was originally published in English with detailed questions, scoring and interpretation procedure (Fairbank & Pynsent, 2000) and translated into Serbian for this research. The OLBPQ is regarded as the "gold standard" for assessing functional outcomes related to lower back pain (Fairbank, 2000) and is essential for research as it allows measuring and

assessing functional disability in individuals with lower back pain (LBP). The first OLBPQ was done individually without time constraints in the business premises of the fitness-center, a week before the beginning of the program. The second data collection session took place a week after the eight-week training or walking program, for both groups, aimed to assess changes in condition.

Data Analyses

For the Wilcoxon signed-rank test, at a type I error probability (α) of 0.05, a statistical power ($\beta-1$) of 0.80, and a medium effect size ($d_z = 0.5$), the minimum required sample size was 35 participants. Statistical significance was defined at a confidence level of 95%, with $p < 0.05$. Descriptive statistical analysis was conducted, including mean rank (MR) and sum of ranks (SR). The Kolmogorov-Smirnov test was used to evaluate the normality of the data distribution. Non-parametric statistical methods were applied to assess the effects of the intervention: Mann-Whitney U test, i.e. Wilcoxon signed-rank test, which were used in similar circumstances and are widely accepted for similar research aims (Karlsson, et al., 2014; Suni, et al., 2017). P-values were corrected for multiple comparisons where necessary. All statistical analyses were carried out using SPSS 20 (IBM Corp., 2011, IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY: IBM Corp.). Additionally, power analysis was performed to ensure the reliability of the statistical conclusions.

Results

Results of the descriptive and comparative analysis are presented in additional material Table 2. The Kolmogorov-Smirnov test indicated that all variables significantly deviated from a normal distribution (Q1). The tests revealed significant departures from normality across all questionnaire items ($Z = 2.48-3.58$; $p < 0.001$), justifying the use of nonparametric methods. Within the experimental group, Wilcoxon signed-rank tests demonstrated statistically significant reductions in mean rank scores from pre-to post-intervention for every item (for example, Q3: MR = 24.70 vs. MR = 21.26; $Z = -3.77$; $p < 0.001$) and for the overall Oswestry Disability Index (M = 26.78 vs. MR = 22.82; $Z = -4.47$; $p < 0.001$), indicating a marked improvement in functional status following the eight-week Pilates reformer program. In contrast, the control group showed no significant within-group changes (all $|Z| < 1.41$; $p > 0.05$). Between-group comparisons using

Mann-Whitney U tests further confirmed that posttest scores in the experimental cohort were significantly lower (i.e., less disability) than in the control cohort for each item (e.g., Q2: $U = 192$; $p < 0.001$; Q10: $U = 221$; $p < 0.01$) and for the total ODI ($U = 202.5$; $p < 0.001$).

Moreover, the consistency of significant post-intervention improvements across key functional domains—such as lifting (Q3: $Z = -3.77$; $p < 0.001$) and walking (Q4: $Z = -2.65$; $p < 0.01$)—indicates that the Pilates Reformer protocol yielded broad-based gains in both pain reduction and mobility beyond simple analgesic effects. The overall Oswestry Disability Index exhibited a particularly pronounced change ($Z = -4.47$; $p < 0.001$), reflecting a large and clinically meaningful decrease in self-reported disability following eight weeks of structured Pilates training. In contrast, the control group's non-significant changes (all $|Z| < 1.41$; $p > 0.05$) affirm that these improvements cannot be attributed to natural recovery or measurement artifacts. These findings indicate that the structured Pilates intervention effectively alleviates pain-related disability, whereas the light-walking regimen yields no comparable benefit. Clinically, this supports the incorporation of reformer-based Pilates into rehabilitation protocols aimed at reducing lower back pain and enhancing patient quality of life.

Discussion

The results showed that in the domain of lifting, sitting and standing, the pain is significantly mitigated, which indicates that through the Pilates system of exercise on the reformer machines working on strengthening the deep muscles of the core, centering the posture and improving mobility, that is, working on the improved mechanics of the movement itself improves major causes of sedentary life-style and wrong posture.

At the final measurement, variance analysis identified significant differences with large effect sizes between the experimental and control groups across all questionnaire items and the total score. When comparing the basic scores before and after the intervention, variance analysis showed no significant differences in the control group. However, significant differences were evident in all questionnaire items and the total score in the experimental group. More specifically, given that the questionnaire indicates the biggest difference between the experimental and control groups in the domain of sitting, it is the conclusion that the Pilates system of exercise on Reformer machines directly affects the prevention of a sedentary lifestyle

and affects the improvement of the quality of life. The exception is question 10, where a significant drop in the main score was observed in the control group as well, both before and after the measurement which is in relation with the fact that walking was practiced within control group. It is interesting that even though experimental group did not walk as a part of exercise practice improvements in question 10 were also evident. These findings are in line with the results of earlier studies (Baskan, 2021; Manman, 2022; Lim, et al., 2011) and they add to the overall conclusion that Pilates enhance quality of life. Taken together with the power analysis confirming adequate sample size for medium effect detection, findings underscore the efficacy of Reformer-based Pilates as a targeted intervention for chronic LBP, offering clinicians a validated approach to enhance patient quality of life.

In order to gain a deeper understanding of the connection between Pilates on the Reformer machines

and the results obtained, i.e. to elucidate the rationale behind the substantial modifications implemented in the experimental group concerning sitting, standing, and lifting, the discussion goes deeper into a consideration of the targeting effects of specific exercises concerning the time devoted to them and effects they provide. Exercises were meticulously categorized into distinct groups according to their targeted corrective domains. These groups were then systematically compared based on their predominant effect, which was hypothesized to fall into three primary categories: 1) strengthening the core, 2) enhancing balance and coordination, and 3) promoting flexibility and mobility. These benefits are considered fundamental to the efficacy of Pilates in the prevention of LBP. A particular emphasis was placed on the temporal aspect of each exercise sequence, with the discourse centering on the distinct advantages offered by Pilates on reformer machines.

Table 2

Descriptive statistics and variance analyses: Experimental and Control group.

Questions	Groups	Pre-test	Post-test	WSRZ	Tests	MWU	KSZ
		MR (SR)	MR (SR)				
Q1	EG	27.03 (865)	23.06 (738)	-3.17**	Pre-test	335	2.48***
	CG	26.95 (566)	33 (693)	-1	Post-test	210**	3.45***
Q2	EG	24.62 (643)	22.5 (720)	-2.83**	Pre-test	260	3.02***
	CG	30.61 (643)	33.85 (711)	-0.58	Post-test	192***	3.58***
Q3	EG	24.7 (790.5)	21.26 (680.5)	-3.77***	Pre-test	262.5	2.09***
	CG	30.5 (640.5)	35.73 (750.5)	-1.41	Post-test	152.5***	3.30***
Q4	EG	24.37 (780)	22.28 (713)	-2.65**	Pre-test	252	2.81***
	CG	31 (651)	34.19 (718)	-0.58	Post-test	185***	3.45***
Q5	EG	26.71 (855)	23.32 (746.5)	-3.57***	Pre-test	327	1.90**
	CG	27.42 (576)	32.59 (684.5)	-2.24	Post-test	218.5**	3.08***
Q6	EG	27.51 (880.5)	23.62 (756)	-3.62***	Pre-test	319.5	2.25***
	CG	26.21 (550.5)	32.14 (675)	-1	Post-test	228**	3.31***
Q7	EG	24.89 (796.5)	22.76 (728.5)	-2.53**	Pre-test	268.5	3.01***
	CG	30.21 (634.5)	33.45 (702.5)	-1	Post-test	200.5***	3.51***
Q8	EG	25.32 (810.5)	23.25 (744)	-2.89**	Pre-test	282.5	2.47***
	CG	29.54 (620.5)	32.71 (687)	-1.41	Post-test	216**	3.25***
Q9	EG	24.75 (792)	22.5 (720)	-2.65**	Pre-test	264	3.07***
	CG	30.42 (639)	33.85 (711)	0	Post-test	192***	3.52***
Q10	EG	24.95 (798.5)	23.40 (749)	-2.12*	Pre-test	270.5	3.02***
	CG	30.11 (632.5)	32.47 (682)	0	Post-test	221**	3.30***
ODI	EG	26.78 (857)	22.82 (730.5)	-4.47***	Pre-test	329	2.31***
	CG	27.33 (574)	33.35 (700.5)	-0.79	Post-test	202.5***	2.48***

MR: Mean rank; SR: Sum of ranks; Q: Question; ODI: Oswestry Disability Index Scores; EG: Experimental group, CG: Control group; WSRZ: Wilcoxon Signed Ranks Z; MWU: Mann-Whitney U; KSZ: Kolmogorov-Smirnov Z.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3

Target aspect for each exercise group exercise.

Exercise Name	G	SC	CB	MF	Effects
Preparation: "V" foot position	GI - 10 min				Focuses on footwork directed towards the activation of the spinal column through the activation of feet and strengthening of the core. It is intended towards balance and warming of the core. Emphasis is on positioning and centering of the whole body. The moving surface introduces an additional level of complexity, necessitating a higher degree of acknowledging control over body relations and movement.
Parallel feet		+	+	+	
Open feet					
Turned-in feet "V"					
Raised knee					
Preparation for the Hundred	GII - 8 min	++			Focuses solely on strengthening the core enhancing the strength and coordination of the core, arms, and legs. It emphasizes precise execution of movements while maintaining neutral spinal alignment. The utilization of springs results in the application of additional strain to the shoulder girdle and core, accentuating the multilateral work of all extremities. The core is stabilized and centered, and body becomes aware of benefits of dynamic balance and coordination between legs, arms and central spinal column.
Coordination	GIII - 5 min	+	++		Enhance both the coordination of movements and the strength of core muscles. Ropes and springs introduce an additional level of complexity, rendering the task more arduous than on a mat. Coordination exercise is further intensifying results of the previous group.
Bridge on the padded part of the foot (parallel)	GIV - 5 min	+		++	Focused on strength but primarily utilizes mobility, incorporating various springs to enhance the level of challenge in comparison to Mat. By adjusting the load at the initiation of the exercise training, the task can be facilitated for the client, and as proficiency is achieved by reducing the springs, the exercise transitions from mobility exercise to one that activates the backchain muscle group as well.
Rope pulling backwards in a kneeling position	GV - 9 min	+	++		Enhance the strength of the core musculature focusing on muscles of the shoulder girdle, while also developing equilibrium in the upper part of the body. This approach is designed to strengthen the upper muscles of the spinal column and at the same time to engage the muscles of the pelvic floor. The Reformer offers an augmented load and challenge through balance. There the actual presence of trainers is essential as engagement of the precision of their breathing coordination is necessary because of the simultaneous nature of the activity.
Kneeling push-ups on the platform					
Position on box with a flat back	GVI - 8 min				Strengthen the muscles of the back and differ from their counterparts performed on a mat. The springs introduce an additional level of complexity and awareness of the whole-body stabilization, increasing its difficulty over time.
"T" pulling on box		+	+	+	
Swimming - pulling without and with ropes					
Stretching	GVII-5			+	Focuses on flexibility, breathing and relaxation also returning into regular position of the body and mind.

Note: + moderate focus; ++ strong focus; SC – Strengthening the Core; CB – Coordination and Balance; MF – Mobility and Flexibility

Concerning time devoted to a specific set of exercises, the majority of exercises (Table 3) focuses on strengthening the core, then on the balance and coordination and at the end on mobility and flexibility. Though it seems logical it has to be noted that due to the fact that exercises are performed on the moving platform with the help of springs and through lying and sitting on the box positioned on the platform balance and coordination, as mobility and flexibility are important for each exercise execution.

With respect to the Pilates method practiced on a Mat, the disparities can be categorized into three distinct domains. The Reformer has a moving platform (carriage) that glides with the help of springs and wheels. This requires greater body stabilization, which contributes to the development of coordination and balance among muscle groups, especially during exercises that engage the core and extremities simultaneously. The utilization of springs fosters learning process by facilitating their adjustment. It renders certain exercises more manageable, thereby enhancing the learning process for novice and pain-afflicted individuals. For advanced practitioners, the adaptability of the load weight engenders a more arduous challenge, thus promoting continuous development and refinement of skills. The Reformer box allows the execution of various exercises in seated, lying, or side-lying positions, often increasing the range of motion and targeting specific muscles, improving proprioception and activation of the back muscles.

As demonstrated above, it is evident that exercises are designed and dedicated to enhance the function and optimize the condition of the spinal core (group II, IV, V, VI), These exercises are performed either as a comprehensive whole (II group) or focusing on specific regions such as the lower part of the spine (IV group), the shoulder girdle (V group), the back and the middle part of the spinal column (VI group). It is evident that sitting and standing are most effectively corrected through this method. The 15-minute training focus is centered on the principles of balance and coordination. The focus is on dynamic balance, which is defined as the capacity for proper posture while walking, lifting, and standing (group III and V). Proper posture is defined as the positioning of the body while standing or sitting, which is determined by the position of the pelvis, hips, and lower back. In this way, several groups of muscles are simultaneously activated which is not the case in everyday life, causing LBP. Therefore, the precision of their execution and directed training by the trainer are essential. Furthermore, the aforementioned

factors, exercises performed lying on the back, kneeling, sitting, and lying on the Reformer box (group VI) serve to enhance equilibrium and fortify the core musculature. This, in turn, contributes to an increased degree of safety during routine quotidian activities. Concerning breathing technique, they emphasize deep stabilizer muscle activation. It is imperative to maintain a deliberate and measured pace of breathing, with a recommendation of four to five counts of inhalation and exhalation. This rhythmic breathing technique not only influences the cadence of the exercise itself but also plays a crucial role in enhancing precision and movement control.

Conclusion

The research has shown that, unlike studies that failed to demonstrate significant efficiency of Pilates, as they predominantly focus on Mat Pilates, this study utilized a Reformer machine protocol that proved effective results. We conclude that Pilates exercises performed on Reformer machines can be beneficial for individuals suffering from LBP. The controlled execution of movements and focus on strengthening the core muscles can help improve posture, increase flexibility, and strengthen the muscles supporting spinal stability. This approach may alleviate LBP by reducing the stress on intervertebral discs and improving overall spinal alignment. Before starting any new exercise program, including Pilates, clients with LBP syndrome should consult their healthcare provider. Exercises must be tailored to the individual's specific condition to ensure safety and efficacy.

The findings demonstrate 8-week timeframe is sufficient to observe the initial indications of enhancement in the functionality of the training. Given the extensive range of exercises available on the Reformer, it is recommended that modifications be introduced after eight weeks to ensure variety and prevent stagnation. It is imperative to transition from fundamental exercises to those of an intermediate and advanced level. This creates space for further research, which would include longitudinal analyses of 8-week intervals multiple times. Furthermore, it is essential to ensure that every sixth training session is dedicated to a specific focus area, thereby facilitating a comprehensive approach to developing the relevant competencies.

This study uniquely contributes to the existing literature by focusing on the effects of Reformer-based Pilates, emphasizing the integration of core strengthening, breathing techniques, and body mechanics within a professionally supervised and

individually adjusted framework—an approach not yet fully explored in previous clinical trials. The results indicate that precisely planned exercises, particularly when conducted under continuous expert supervision and with individualized modifications, contribute to the alleviation of lower back pain. Reformer Pilates, thanks to its use of springs and a moving platform, allows for greater precision in both exercise selection and execution, which appears crucial for pain relief. Further research could focus on the differences between specific exercise procedures, frequency, rhythm, and duration of exercise, as well as the importance of personalization, particularly when lower back pain coexists with other conditions such as back deformation, degenerative changes, osteoporosis and postural dysfunctions.

It is important to note significant limitations of this study. Firstly, the authors did not conduct a formal a priori power analysis based on a specific published study, they performed a systematization of similar research articles and found that comparable interventions typically included up to 50 participants. Given the structure of the study — a six-week intervention with group exercise sessions held three times per week for up to six women per group — it was logistically unfeasible to include a significantly larger sample. Therefore, the chosen sample size reflects practical constraints related to the intervention's design and delivery. Then, relying solely on one instrument to measure disability may limit the findings. While the OLBPO is widely used and validated, it would be beneficial to include additional tools for evaluating disability and quality of life to provide a broader understanding of the effects of Pilates exercises on Reformer machines in preventing LBP. Lastly, although the focus of our study was exclusively on female participants in middle age, this exercise system could be recommended to other parts of the population. It is necessary to carry out this type of research on the male population, because they even have more frequent back pain problems than women. In this particular case, the problem lies in the popularization of this way of exercise among the male population. Also, one important limitation of the study is the lack of random allocation to experimental and control groups. Participants chose whether to engage in the intervention or simply continue walking, introducing a potential self-selection bias. This means that pre-existing differences in motivation, health status, or expectations may have influenced the results, rather than the intervention itself. Without randomization, it is difficult to determine whether observed effects were

due to the intervention or to characteristics of the individuals who opted into it. This significantly limits the internal validity and the strength of any causal claims. Although significant improvements were observed in the Pilates group, the potential influence of placebo-effect, psychological factors unrelated to the intervention, or differences in participants' sociodemographic or lifestyle habits was not addressed, which may limit the interpretation of the results and their attribution solely to the exercise program. All the above make room for further research and practical application. This form of Reformer machine-based exercise could be proposed as an additional therapeutic option in the prevention and treatment of non-specific LBP.

Authors' Contribution

Study Design: TR, Data Collection: TR, Statistical Analysis: TR, Manuscript Preparation: TR, Funds Collection: TR

Ethical Approval

The study was conducted in compliance with the General Data Protection Regulation (GDPR) of the European Commission and ethical principles outlined by the American Psychological Association's Code of Conduct. The study design was approved by the Ethics Committee of Singidunum University (Approval no. 160; Dated 22 Feb. 2024).

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Conflict of Interest

The author hereby declares that there was no conflict of interest in conducting this research.

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