Research Article

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Effect of clinical Pilates training on balance and postural control in patients with Parkinson's disease: a randomized controlled trial

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Background: Clinical pilates exercises have been shown to improve balance. Our study aims to compare effects of clinical Pilates and conventional physiotherapy exercises on balance and postural control in Parkinson's disease patients. **Materials & methods:** Forty patients were randomly assigned into either clinical Pilates (CLP) or conventional physiotherapy (COP) group. Exercises were performed twice a week for 8 weeks. Balance, lower-extremity strength, fall risk and functional mobility were assessed at the beginning and end of the exercise period. **Results:** All measurements indicated significant increase in two groups ($p < 0.05$). Compared with the COP group, the CLP group showed significant improvement in dynamic balance values ($p < 0.05$). **Conclusion:** CLP was as effective as COP, with better dynamic balance results, and could be used in rehabilitation for patients with Parkinson's disease.

Clinical trial registration number: NCT04063605.

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Keywords: Parkinson's disease • physiotherapy • pilates training • postural balance

Parkinson's disease (PD) is an extrapyramidal system disorder characterized by a loss of dopaminergic function, leading to diminished motor function. One of the cardinal symptoms of PD is postural instability caused by neuronal lesions, which may occur at all stages of the disease [1,2] and result in difficulties in the performance of daily life activities [3] and trigger falls and injuries. Individuals with PD have been reported to have greater balance problems and higher fall risk than older adults of the same age [3].

Extensive research has been conducted on both nonmodifiable (e.g., age, genetic mutations, race) and modifiable (e.g., environmental factors, lifestyle changes, chemical exposures, stress) risk factors for postural instability in PD [4]. The main causes of balance disorders in PD include muscle weakness [5], axial rigidity, bradykinesia, 'freezing,' and impairments in sensorimotor integration and cognitive function [6–8]. Different studies have reported that a reduction in truncal flexibility due to axial rigidity contributes to a decrease in balance and functional mobility and an increase in fall risk [9,10].

The importance of various exercise training programs has been highlighted owing to their effectiveness in improving physical function, strength, balance, walking and health-related quality of life and in promoting continuous independence among individuals with PD [5,11]. Conventional physiotherapy and rehabilitation interventions have been shown to produce beneficial effects on motor symptoms, such as gait disorders, decreased balance, increased fall risk and reduced physical function among individuals with PD [5,12]. Because of diminished motor learning ability [13], exercises that provide more sensory input, include basic functional activities and can be performed in a safe environment have been suggested [11,13].

Pilates exercises are structured mind–body exercises that aim to improve core stability, strength, flexibility, posture and breathing. These exercises are executed using a mat or equipment, such as springs [12,14]. First

introduced in the 1920s, Pilates exercises were subsequently modified and adapted for therapeutic use by healthcare professionals under the name of 'clinical Pilates exercises' in the 2000s [12,15]. Clinical pilates exercises focus on trunk flexion and extension, abdominal and back strengthening, motor control and trunk stabilization [16]. With this exercise method, physiotherapists can progress activities by reducing assistance and can modify exercises to challenge the body differently. Furthermore, patients are educated about the importance of moving with purpose and learn about the consequences of their faulty movement patterns and how to correct them.

The most evident features distinguishing Pilates and clinical Pilates exercises from conventional physiotherapy programs are the general principles that need to be followed during exercises – namely, concentration, breathing, focusing on the center, control, stability and isolation [12]. These principles are provided by the simultaneous activation of muscles responsible for trunk stabilization, thus increasing awareness of the neutral spine position and strengthening the deep postural spinal muscles with less ground impact and joint stress [17]. These exercises can be performed at various intensity levels, and the difficulty level can be adjusted.

Both types of Pilates exercises have been shown to stimulate the spine, increase balance and stability and even reduce the risk of falls and physical injuries [15]. A recent systematic review that included eight studies investigating the effects of Pilates on PD indicated that Pilates is a viable treatment and has positive effects on physical fitness, balance and lower limb function among individuals with PD [18]. Nonetheless, all of the included studies evaluated the effects of Pilates exercises, not clinical Pilates exercises. Additionally, the investigators concluded that more studies with larger sample sizes and better methodological quality are required to be conducted with the PD population to consolidate the scientific evidence. Thus, a well-designed randomized controlled trial is necessary to ascertain the benefits of clinical Pilates exercises in patients with PD. We chose to determine the effectiveness of this exercise method in the PD population because patients with PD have trunk flexibility problems related to balance disorders and clinical Pilates exercises have been shown to focus on trunk flexibility and stabilization.

The present study aimed to compare the effects of clinical Pilates exercises and conventional physiotherapy exercises on balance, functional mobility and fall risk in patients with PD. We hypothesized that clinical Pilates exercises are as effective as conventional physiotherapy exercises in improving balance, functional mobility and fall risk among patients with PD. The results of our study would be beneficial to rehabilitation professionals and facilitate the incorporation of clinical Pilates exercises into the rehabilitation program for patients with PD.

Materials & methods

Design

The present study was a randomized controlled trial (clinical trial registration number: NCT04063605). This trial was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the Ethical Research Committee of the *European University of Lefke* (approval no.: UEK/32/02/03/1819/01). All participants provided signed informed consent forms before participation, and their rights were protected throughout the study.

Sample size

Patients diagnosed with PD and followed up at *Dr. Burhan Nalbantoğlu State Hospital* between September and October 2019 were referred by their neurologist to this study. Sample size was calculated using G*Power software version 3.1.9.2. Under parametric test (t-test) conditions, equation was computed by given effect size (d) and power ($1 - \beta = 0.95$). Studies in the literature have indicated that the effect size was high when the 'Timed Up and Go' (TUG) test was used as a reference; therefore, power was calculated by taking $d = 0.8$. For a power of 95% with an effect size of 0.8, a sample comprising 40 patients, 20 experiments and 20 control cases were recommended.

The participants who volunteered for this study were randomized into two groups based on the last digit of their identity card number. Patients with double-digit numbers were assigned to the clinical Pilates exercise (CLP) group ($n = 20$), and those with single-digit numbers were assigned to the conventional physiotherapy exercise (COP) group ($n = 20$). The randomization procedure is presented in Figure 1. This study was conducted on 40 participants, all of whom completed the assigned therapies, which is unusual for this type of trial.

Inclusion & exclusion criteria

With respect to the inclusion criteria, patients with Hoehn and Yahr stage 2–3 PD aged 45–70 years who had a Mini-Mental Test (MMT) score of at least 26 and had PD for a minimum of 2 years were included in the trial. However, patients with severe mental and psychological disorders, marked musculoskeletal disorders, lower-

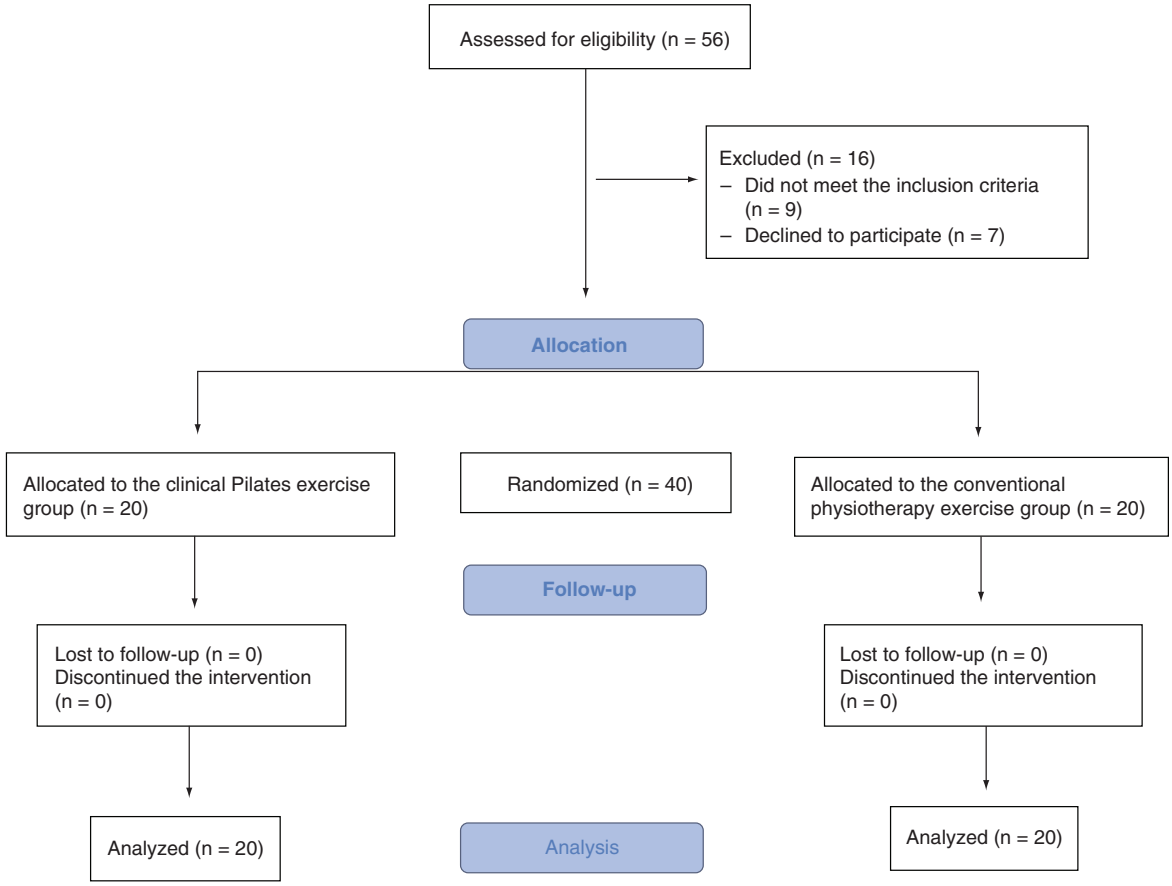

Figure 1. Flow of participants in the trial.

extremity deformation, other neurological diseases and drug or dose changes during treatment were excluded. Nine of the referred patients were excluded because of advanced age and low MMT score, and seven patients did not agree to participate in the study.

Data collection tools

The participants were assessed at baseline and after the intervention (within 48 h after the last session) while on antiparkinsonian medications. Before the study, one of the researchers informed all participants about the study evaluation procedures in detail.

Sociodemographic data of participants, including age, sex, height, weight, BMI, disease stage and duration, working status, smoking status and fall status (number of falls during the past 3 months), were recorded in a patient information form at baseline. Additionally, MMT and modified Hoehn and Yahr staging scores were used as independent variables when testing patients for study eligibility.

Different methods for measuring balance, functional mobility and fall risk in the PD population were employed to determine the effectiveness of interventions. All measurements were performed at 1 day before program commencement and were repeated at the end of 8 weeks of treatment.

Static balance measurements

Static balance was measured in the participants using the one-leg stance (OLS) test [19] and tandem stance test (TST) [20], which are valid methods for static balance measurement. The OLS test assesses the ability to stand on one leg in seconds for both sides, whereas the TST evaluates the ability to stand in tandem position in seconds for both sides. Both tests were repeated three times, and the mean was calculated [21,22].

Dynamic balance measurement

Dynamic balance was measured using the functional reach test (FRT), which is a reliable and valid method. The participants were instructed to form a fist and stretch their arms forward; the tip of the third metacarpal was recorded. The participants were subsequently asked to reach as far forward as possible without losing their balance or taking a step; the tip of the third metacarpal was marked. The difference between the two points was recorded in centimeters, and the mean of three trials was recorded [21,23].

Functional mobility measurement

Functional mobility was evaluated using the TUG test, which is also reliable and valid. Upon issuing the command 'Go,' the participants stood up from a normal chair, walked 3 meters, turned, walked back to the chair and sat. The time began with the command 'Go' and ended when the participants sat back to the chair. This test was repeated three times, and the shortest performance time was recorded [24,25].

Muscle strength measurement

The 30-second chair-stand test (CST), which is a reliable and valid method, was used to assess lower-extremity strength and endurance. During the test, the participants sat upright on an armless chair, crossed their arms in front of their chest and pressed their feet on the ground to stand. The number of sitting and getting up from the chair within 30 s indicated the score for this test [26,27].

Measure of fall risk

Fall risk, together with static and dynamic balance performance, was measured by Berg Balance Scale (BBS), which is a commonly used, reliable and valid measure. The BBS is a 14-item test that uses sequential scoring from 0 to 4 for each item and is frequently applied to geriatric individuals for postural control assessment and fall risk prediction [26,28]. The total score ranges from 0 to 56, with a higher score indicating better balance and lower fall risk.

Intervention

For both the intervention group (i.e., CLP group) and control group (i.e., COP group), exercises were performed twice a week for a period of 8 weeks between September 2019 and January 2020. The duration of each exercise session was 45 min, which included 5 min of warm-up, 30 min of actual exercise performance, and 10 min of cool-down. The exercise sessions were designed to increase in difficulty every week based on each patient's accomplishments.

Exercises for the intervention and control groups included clinical Pilates exercises and conventional physiotherapy exercises, respectively. Clinical Pilates exercises were supervised by a certified physiotherapist, who provided continuous feedback to the patients, promoted proper posture throughout the session and corrected breathing while performing specific exercises. The number of repetitions was increased when the exercise methods were correctly performed by the patients. Warm-up exercises included upper-extremity proprioceptive neuromuscular facilitation exercises, mini-squat, chest stretch and spine stretch. Main exercises comprised 'the lower lift,' 'the hundred,' one-leg stretch, hip twist, shoulder bridge, arm opening, side kick, leg lift, abdominal preparation, oblique preparation, one-leg kick, swimming, 'the cobra' and the half roll back. Finally, cool-down exercises consisted of swinging, 'the toy soldier,' spine stretch, 'the saw,' 'the corkscrew' and 'the mermaid.'

A physiotherapist also conducted the conventional physiotherapy exercises. Warm-up exercises included breathing and posture exercises, and range-of-motion exercises and strength training were subsequently applied to the upper and lower extremities. Furthermore, trunk muscle training, balance and coordination training, walking training and stair-climbing training were used. Cool-down exercises consisted of breathing exercises and stretching exercises for the trunk, upper extremities and lower extremities.

All participants started training with eight repetitions during the first week to enable them to understand the types and principles of exercises. On the basis of the participants' capabilities, two repetitions were added weekly starting from the second week. After 8 weeks, the participants executed a maximum of 20 repetitions for all exercises. The exercise protocol for both groups is summarized in Table 1.

Statistical analysis

Statistical analysis of study data was conducted using IBM SPSS Statistics version 20.0 (IBM Corp., NY, USA). Percentage, mean and standard deviation values were calculated for the sociodemographic data. The sociodemographic

Table . Exercise protocols.

	Conventional physiotherapy (n = 20)	Clinical pilates (n = 20)
Warm-up exercises	• Posture exercises • Breathing exercises	• Upper-extremity proprioceptive neuromuscular facilitation exercises • Mini-squat • Chest stretch • Spine stretch
Main exercises	• Range-of-motion exercises for the upper and lower extremities • Strengthening exercises for the trunk, upper extremities and lower extremities • Balance and coordination training • Walking training • Stair-climbing training	• 'Lower lift' • 'The hundreds' • One-leg stretch • Hip twist • Shoulder bridge • Arm opening • Side kick • Leg lift • Abdominal preparation • Oblique preparation • One-leg kick • Swimming • 'The cobra' • Half roll back
Cool-down exercises	• Stretching exercises for the trunk, upper extremities, and lower extremities • Breathing exercises	• Swinging • 'The toy soldier' • Spine stretch • 'The saw' • 'The corkscrew' • 'The mermaid'

Table 2. Comparison of sociodemographic and clinical characteristics between the experimental and control groups.

Characteristics	Clinical Pilates exercise group, n (%)	Conventional physiotherapy exercise group, n (%)	p-value
Age (years) (mean ± SD)	58.85 ± 8.09	60.75 ± 7.62	0.449
BMI (kg/cm^2) (mean ± SD)	28.07 ± 6.53	27.7 ± 4.05	0.836
Sex:			
Male	9 (45)	10 (50)	0.486
Female	11 (55)	10 (50)	
Fall status:			
Falls	3 (15)	5 (25)	0.129
No falls	17 (85)	15 (75)	
Disease duration (years) (mean ± SD)	5.32 ± 6.23	5.35 ± 3.33	0.987
Hoehn and Yahr score (mean ± SD)	2.05	2.30	0.135

Values are presented as sample mean.
SD: Standard deviation.

characteristics of patients included in this study were compared between the two groups using the chi-square test. Independent samples t-tests were used to check whether no difference between the two groups existed at baseline. The paired-samples t-test was employed to compare outcome measurements between the patient groups, and independent t-test was used to compare difference in means of outcome measurements. In all statistical analyses, a p-value <0.05 was considered significant.

Results

Examination of participants' sociodemographic & clinical characteristics

Forty patients participated in this study (21 females, 19 males; mean age: 59.8 ± 7.86 years) and were randomly divided into two groups. No statistically significant difference in sociodemographic and clinical characteristics was observed between the two groups ($p > 0.05$, Table 2).

Analysis of intervention effects

Comparison of static and dynamic balance, lower-extremity strength, fall risk and functional mobility scores before and after the intervention indicated that all outcome measurements significantly improved after the intervention in both groups ($p < 0.05$, Table 3).

Table 4 presents the independent-samples t-test results for the comparison of difference in means of outcome measurements according to groups. The CLP group was not significantly different from the COP group with respect to the BBS ($p = 0.35$), OLS test – left ($p = 0.34$), OLS test – right ($p = 0.97$), TST – left ($p = 1.00$), TST – right ($p = 0.83$), TUG test ($p = 0.51$) and 30-s CST ($p = 0.99$). Among the measurements, only the FRT results were identified to be significantly different between the CLP and COP groups ($p = 0.00$). Nonetheless, the posttest FRT results for the CLP group were higher than those for the COP group.

Discussion

In this study, we investigated the effects of clinical Pilates exercises on postural control, balance and associated factors such as functional mobility, lower-extremity strength and endurance and fall risk in patients with PD. Thus, we compared an 8-week clinical Pilates exercise program with a conventional physiotherapy exercise program and observed significant improvements in all outcome measures related to balance, postural control and fall risk in both the CLP and COP groups, confirming our hypothesis. Furthermore, the CLP group showed better improvement in dynamic balance than the COP group.

The effectiveness of conventional physiotherapy methods in improving balance and functional capacity among patients with PD has been well investigated. Nonetheless, it is important to emphasize the effectiveness of different exercise methods in improving impairments commonly observed in this patient population and symptoms occurring in other neurologic patient population. Both the CLP and COP groups exhibited good improvements in all measured variables at the end of the 8-week program, which is an exceptional result. We believe that these improvements happened because all participants had not received any exercise intervention for 6 months. Additionally, 28 of 40 participants had joined an exercise program for the first time, which probably rendered these improvements possible, considering that they had considerable room for improvement. Despite a disease duration of approximately 5 years in our sample and the well-known exercise needs of patients with PD, the number of referrals to physiotherapy was low among patients with PD. This may be related to the disease stage because all participants were at stage 1 or 2 of PD, in which they were just beginning to become aware of their illness and were functionally independent. Furthermore, some might not have accepted their illness and thought that they did not require exercise. We think that our study results will aid in increasing awareness among both healthcare professionals and the PD population in our country about the effectiveness of different exercise methods at all stages of PD.

Because we had not identified any study that used clinical Pilates exercises as a treatment method for PD, we discussed our results by comparing them with the findings of randomized controlled trials conducted with the Pilates method. In a randomized controlled trial, Mollinedo-Cardalda *et al.* investigated the effects of a mat Pilates (MP) exercise program with TheraBand resistance training on dynamic balance. Twenty-six patients were randomly allocated to the MP and control groups, and both groups received interventions that involved two 60-min weekly sessions for 12 weeks. In the control group, aerobic exercises were performed together with calisthenic exercises. Significant improvements in BMI, TUG test, five-times sit-to-stand test and 30-s CST were observed in the MP group, whereas only the TUG test parameter improved in the control group. According to Mollinedo-Cardalda *et al.*, the significant change on the TUG test of the MP program could be explained by the improvements in coordination and trunk muscle control consequent to the provision of optimal lumbopelvic stabilization, as well as by the inclusion of strength training [29]. In our study, the 30-s CST parameter increased together with the balance parameters. We attribute the parameter improvement in both directions to the fact that lower-extremity strength is related to balance and falls. We did not apply any resistance training to our clinical Pilates exercise program; nevertheless, our results are parallel to the findings of this previous study, as both parameters showed significant improvement.

Daneshmandi *et al.* investigated the effects of a Pilates program on functional balance and fall risk in 30 patients with PD. The exercise group joined a Pilates program, whereas the control group joined a walking program in addition to daily physical activities. Balance and fall risk were evaluated in patients at the end of the 8-week Pilates program using the Fullerton Advanced Balance Scale and TUG test, respectively. Compared with the control group, the exercise group exhibited significant improvements in both balance and fall risk measures [30]. The results

Table 3. Pretest and posttest group comparison.

	Clinical Pilates (n = 20)				Paired-samples test		Conventional physiotherapy (n = 20)				Paired-samples test	
	Pre-test		Post-test				Pre-test		Post-test			
	$\bar{x}$	S	$\bar{x}$	S	t	p-value	$\bar{x}$	S	$\bar{x}$	S	t	p-value
TUG	11.825	3.6341	8.412	2.6987	7945	0.000†	12.995	4.4161	9.955	4.1423	8.229	0.000†
30s-CST	11.55	3.734	14.15	3.498	4619	0.000†	10.01	2.909	12.60	3.299	4.650	0.000†
FRT	21.925	6.8658	27.975	9.8401	2813	0.011†	20.025	6.4082	21.735	6.7062	5.293	0.000†
OLS – left	8.623	8.8227	13.130	14.2969	1840	0.028†	9.820	7.6370	12.100	6.3611	2.297	0.033†
OLS – right	8.440	7.6808	12.520	11.6811	5584	0.000†	9.660	6.7106	13.790	7.5263	3.417	0.003†
TST – left	17.045	11.7530	51.255	43.1746	3263	0.004†	17.535	14.3489	51.775	56.0397	4.036	0.001†
TST – right	20.680	14.9163	61.525	46.3129	4408	0.000†	20.335	14.9498	58.515	46.3283	4.888	0.000†
BBS	47.45	4.807	51.70	2.975	5030	0.000†	45.10	11.234	48.45	9.451	6.285	0.000†

†$p < 0.05$.

$\bar{x}$: Sample mean; 30s-CST: 30-s chair stand test; BBS: Berg Balance Scale; FRT: Functional reach test; OLS: One-leg stance; S: Sample standard deviation; TST: Tandem stance test; TUG: Timed Up and Go test.

Table 4. Comparison of posttest postural control and balance measurements according to the groups of cases.

	Clinical Pilates (n = 20)		Conventional physiotherapy (n = 20)		Independent-samples test	
	Different mean	S	Different mean	S	t	p-value
TUG	3.41	1.86	3.04	1.71	0.66	0.51
30s-CST	2.60	2.50	2.59	2.51	0.01	0.99
FRT	6.05	5.11	1.71	2.72	3.35	0.00†
OLS-left	4.51	8.77	2.28	5.54	0.96	0.34
OLS-right	4.08	5.34	4.13	3.31	0.04	0.97
TST-left	34.21	37.90	34.24	46.93	0.00	1.00
TST-right	40.85	37.37	38.18	38.73	0.22	0.83
BBS	4.25	3.02	3.35	2.98	0.95	0.35

†$p < 0.05$.

$\bar{x}$: Sample mean; 30s-CST: 30-s chair stand test; BBS: Berg Balance Scale; FRT: Functional reach test; OLS: One-leg stance; S: Sample standard deviation; TST: Tandem stance test; TUG: Timed Up and Go test.

pertaining to the benefits of Pilates program are parallel to our study results. However, as conventional physiotherapy is the gold standard rehabilitation intervention for patients with PD, a comparison between the Pilates method and conventional physiotherapy instead of the walking program would be a better choice.

Bakhshayesh *et al.* examined the effects of Pilates exercises on functional balance, core stability and lower-extremity strength in 30 patients with PD. Patients were randomly allocated to either the Pilates exercise group or the control group. Both groups received treatment thrice a week for 8 weeks. The control group joined a 10- to 30-min walking program in addition to daily physical activities. All measured variables showed significant improvements compared with those in the control group, including 30-s CST, which is the same as our lower-extremity strength and endurance measure. Similar to our study, the number of repetitions was increased every 2 weeks in this previous study. However, TheraBand and ball were also added to the program to provide resistance, which is similar to Mollinedo-Cardalda *et al.* study [11,29]. Unlike these studies, we did not use a resistance tool to increase strength; nonetheless, we used body weight for resistance in our CLP group. Despite this, the 30-s CST score increased, indicating an increase in lower-extremity strength. Although resistance training provides positive results, the use of body weight as resistance in clinical Pilates training for the PD population can be suggested as a safe method.

In a randomized controlled trial, Pandya *et al.* divided 30 patients with PD into two groups, with one group being treated with conventional physiotherapy and the other with both Pilates exercises and conventional physiotherapy for 7 weeks. Their results indicated significantly greater improvements in the experimental group than in the control group with respect to functional balance (BBS), confidence level (Activities-Specific Balance Confidence Scale), and functional mobility (TUG test). Despite the effectiveness of conventional physiotherapy reported in the literature, the authors preferred to combine two methods, which achieved good improvement [31]. Important differences from our study include the provision of treatment to individuals aged 65 years and younger, the use of ball and TheraBand during clinical Pilates exercises and treatment sessions for 1 h, three times a week. Nevertheless, the findings of this previous study were parallel to our study results.

All measurements in both groups showed positive improvements; however, our analysis revealed that the CLP group exhibited better improvement in FRT, which is a dynamic balance measure. There may be two reasons for this. First, movement strategy and reduced spine flexibility affect functional reach distance [25]. Clinical Pilates exercises improve trunk stabilization and provide flexibility; hence, the CLP method can improve trunk flexibility. Second, Johansson *et al.* reported that balance is a combination of both physical balance and the balance resulting from mind–body interactions [32]. A recent study has shown that clinical Pilates can produce an additional positive effect on dynamic balance development by fostering body awareness and maintaining mind–body integrity [33]. Mokhtari *et al.* evaluated the effects of Pilates training on depression and balance in the elderly and measured functional mobility and dynamic balance using with FRT and TUG test, respectively. Their result indicated significant improvements in FRT and TUG test results by 16.7 and 7.3%, respectively, after 12 weeks of Pilates training [34]. Thus, the improvement in dynamic balance may have been achieved through improvements in flexibility and body awareness among the patients. Furthermore, FRT has been shown to detect fall risk at a score of 25 cm and below [35]. If we examined the test results of the two groups, the reach length increased from 21.93to 27.98 cm

in the CLP group and from 18.43 to 21.11 cm in the COP group. Therefore, we could put forward that clinical Pilates exercises also had a positive effect on fall risk compared with conventional physiotherapy exercises in our study. Because PD patients experience an increased number of falls compared with a same-age population without PD, this remarkable result of using CLP exercise as a rehabilitation method may decrease fall risk and prevent other complications.

The present study has some limitations. Because clinical Pilates exercises have been shown to have a positive effect on trunk stabilization and increased body awareness, assessment of trunk mobility and trunk postural changes should have been included in our evaluations. Further studies are required to clarify the effectiveness of interventions at 1-month follow-up or longer. Additionally, we suggest studies investigating the effects of clinical Pilates exercise on stage 3 and 4 PD.

Conclusion

In conclusion, our study showed that clinical Pilates exercises had positive effects on balance, functional mobility, lower-extremity strength and fall risk in individuals with PD. Although conventional physiotherapy is known to be successful way of rehabilitation of PD patients, clinical Pilates exercises, which can be modified according to patients needs, have also been found to be a beneficial way of improving functional capacity of PD patients. These exercises can be suggested as an effective and safe rehabilitation method for patients with PD.

Summary points

- Parkinson's disease (PD) patients experience postural instability problems caused by muscle weakness, axial rigidity, bradykinesia and impairments in sensorimotor integration and cognitive function. These problems lead to decreased functional capacity of patients.
- Conventional physiotherapy interventions that include various exercise methods are recommended as an effective form of rehabilitation in patients with PD and have been shown to produce beneficial effects on motor symptoms and functional capacity.
- Clinical Pilates exercises have recently been proven to be a successful form of rehabilitation for many patient groups focus, with improvement on trunk flexion and extension, abdominal and back strengthening, motor control and trunk stabilization.
- The principles of clinical Pilates exercises facilitate activation of muscles responsible for trunk stabilization, increase awareness of the neutral spine position and strengthen the deep postural spinal muscles with less ground impact and joint stress. These, in turn, improve spinal flexibility, which is shown to contribute to functional capacity, balance capacity and fall risk of patients.
- This study compared conventional physiotherapy program and clinical Pilates exercise method for two groups of patients with PD over an 8-weeks period. Balance, functional mobility and fall risk between groups have been assessed.
- Clinical Pilates exercises are found to be as effective as conventional physiotherapy in improving static balance, dynamic balance, functional mobility and fall risk.
- Dynamic balance of patients with PD who received clinical Pilates exercise therapy improved more than patients who received conventional physiotherapy.
- This study provides important evidence regarding the effectiveness of clinical Pilates exercises in rehabilitation of patients with PD.

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No writing assistance was utilized in the production of this manuscript.

Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

Data sharing statement

The authors certify that this manuscript reports original clinical trial data. Deidentified, individual participant data collected during the trial will be available beginning 3 months and ending 36 months after publication. Data will be shared with researchers who provide a methodologically sound proposal to the corresponding author. To access data, requestors will need to sign a data access statement. Clinical trial registration number: NCT04063605.

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