



Pilates Exercise and Functional Balance in Parkinson's Disease

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ABSTRACT

Background: Parkinson's disease as a progressive disorder of the nervous system leads to the disability of postural control system.

Objectives: In the present study the effects of Pilates exercises on functional balance in patients with Parkinson's was investigated.

Materials and Methods: This control trial included 30 patients with idiopathic Parkinson's disease who were selected as subjects randomly and assigned into either exercise groups or control group. Participants in exercise and control groups attended an 8-week Pilates program or walking program respectively. Functional balance, core stability and lower limb strength were evaluated by Fullerton Balance Scale (FAB), valid functional core stability and strength tests respectively, before and after interventions. In order to analyze the data paired samples t-test and independent samples t-test and SPSS version 22 were used.

Results: Attending an eight-week Pilates exercise was associated with a significant improvement in functional balance, core stability indicators and lower limb strength ($p=0.000$), while the difference of the variables in control group was not significant. Also the difference between the results of functional balance, core stability and lower limb strength of two groups in post-test was significant ($p=0.000$).

Conclusion: Given that Pilates exercises involve both musculoskeletal system and nervous system, can be an effective intervention to improving balance in patients with Parkinson's disease.

Keywords: Parkinson Disease; Exercise; Movement

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Introduction

Research suggests that regular exercises are more effective on improving motor function in patients with Parkinson's disease (PD) compared to conventional therapeutic methods [1,2]. The physical exercises prescribed for these patients should be short-term, simple and closely monitored and the barriers to

exercises including high expectations of the outcome, the lack of time and fear of falls should also be overcome. Given the decreased motor learning ability in this group of patients, the exercises should be designed based on amplifying the sensory inputs and doing basic functional trainings and also the familiarity and safety of the training

atmosphere [3-5]. Research results suggest that aerobic exercises are significantly more effective than stretching and strengthening exercises on improving parameters such as walking, balance, motor function and muscle strength and reducing the risk of falls [3-9]. Studies also suggest that regular physical exercises have both long-term and short-term beneficial effects on patients with PD, and that a combination of balance, flexibility and resistance exercises, especially in groups, maximizes the improvement of motor function in the patients [10]. Moreover, from the onset of the disease, patients with PD face problems such as the lack of balance, coordination and flexibility which cause secondary disorders in these patients. So designing a unique and beneficial exercise program in which a combination of muscle strengthening, stretching and aerobic exercises is used to develop muscle function and restore balance seems crucial. Pilates is one of these exercises that plays a key role in skill learning, motor unit recruitment, increasing motor cortex plasticity, improving the use of muscles and restoring balance by creating proper physiological adaptations [11]. Although some studies have been conducted on the effectiveness of Pilates exercises on imbalance, these studies are mostly concentrated on elderly without specific neurologic disorder. Newell *et al.* (2012), who studied the effects of Pilates exercises on balance and walking in older adults, concluded that short-term Pilates exercises can significantly improve variables associated with walking and balance and therefore reduce the risk of falls in this group [12]. Hyun *et al.* (2014) reported significant effects on balance by Pilates exercises and balance exercises on unstable surfaces in old women. Estimates however showed that

Pilates exercises are safer and simpler to improve balance skills, especially dynamic balance, in this group [13]. Considering the higher rate of imbalance and falls in old patients with PD rather than healthy ones, this type of exercises can therefore play a key role in improving motor functions and balance in these patients [14]. Conradsson *et al.* (2015) reported significantly higher effects on neural adaptations in patients with PD for advanced balance exercises compared to conventional therapeutic methods [15]. Canning *et al.* (2014) also reported the effectiveness of balance and strength training programs on reducing the risk of falls in patients with PD [16]. Exercise programs may therefore constitute effective strategies for delaying or reversing motor dysfunction in patients with PD. Exercise can improve physical function, health-related quality of life, strength, balance and walking speed in these patients and so reduce their depression. Exercise can therefore decelerate the progression and emergence of symptoms in the early stages of the disease [10,17]. The key question in the present study is whether physical exercises and controlled programs designed based on Pilates exercises and conventional therapeutic methods can reduce the range of the disease symptoms associated with balance indices in patients with PD?

Materials and Methods

The present randomized controlled clinical trial used a pretest-posttest quasi-experimental approach. The statistical population comprised all patients with PD presenting to neurologists of health centers in Guilan University of Medical Sciences, Guilan province, Iran in 2016. Before beginning the study, this clinical trial was approved by the Ethics Committee of Guilan

University of Medical Sciences (IR.GUMS.REC.1394.460) and registered in the Iranian Registry of Clinical Trials (IRCT2016071228885N1). Based on similar studies conducted, sample size requirements of experimental research and using the sample size estimation formula (Formula 1: $N = \frac{Nt^2s^2}{Nd^2 + t^2s^2}$, where N is the number of presenting patients, $s=1.44$, $d=0.25$, confidence interval=95% and power=80%), the sample size was calculated as 15 for each group.

Formula 1: Sample size calculation $n = \frac{Nt^2s^2}{Nd^2 + t^2s^2}$

Furthermore, the number of subjects in each group was considered 16 to prevent disruption of the study owing to the potential dropout of the subjects for any reasons.

After making the necessary arrangements, all these patients were investigated by neurologists in terms of the inclusion criteria so as to select eligible candidates. The inclusion criteria comprised developing moderate idiopathic PD (stage 2 and 3 of the Hoehn & Yahr Scale [17] (*i.e.* the disease affected one side or both sides of the body and the patient suffered from imbalance while they were still able to perform daily activities), age over 50, the disease being diagnosed at least three years before, lacking other neurological diseases or any chronic physical and psychological disorders, specialists confirming the lack of cognitive disorders, the ability to independently stand and walk, not using balance and walking aids, having a history of balance and walking disorders owing to PD, the lack of involvement in exercise programs or physiotherapy treatments and being able to regularly participate in the training sessions. The exclusion criteria comprised having pain, deformation of limbs and any type of

disorders affecting the safety of the exercise program as well as unwillingness to participate in the study.

The selected patients were briefed on the study objectives and all the relevant issues and introduced to the researcher. Purposive convenience sampling was used to select 32 patients with idiopathic PD based on the inclusion and exclusion criteria and the subject's consent. These patients were randomly and sequentially assigned to the experimental and control groups. It is worth mentioning that one subject in each group withdrew during the study and the number of subjects ultimately reduced to 30 (12 women and 18 men, 11 with stage 2 of the disease and 19 with stage 3).

Before beginning the study, all the subjects were familiarized with the study setting and method during a briefing session and all questions and ambiguities were resolved. Given the physical characteristics of the patients with PD and also their age group, the study setting was completely made safe and selected in the vicinity of a health center so as to provide the subjects with the fastest therapeutic measures in case of the emergence of potential problems. All the participants then completed consent forms and demographic questionnaires. After collecting demographic information such as age, gender, height and weight and familiarizing the subjects with the experiment methods, the study variables including balance and risk of falls indices were measured. It is worth noting that all the study subjects were constantly monitored during the study by a neurologist and consumed their medicines including dopaminergic drugs and/or dopamine agonists. All the tests were administered at least two hours after using these medicines.

The experimental group characteristics

Owing to the problems of patients with PD such as impaired control of posture, gait and balance and inflexibility, which exist from the onset of the disease and cause secondary complications, developing exercise programs based on retraining the proper posture as well as increasing the range of movements and muscle strength and balance becomes increasingly important [18]. The posture of patients with PD mainly consists of forward drop of shoulders and neck and bending of hands and knees. The exercise sessions should therefore begin with teaching how to maintain the proper direction of the posture in different conditions (standing, sitting, supine and prone) as a habit by daily repeating these exercises as often as possible. Balance exercises are a fundamental pillar for rehabilitating patients with PD. Different walking and standing exercises can improve balance in these patients and help them perform daily routines. Stretching and flexibility exercises for joints and muscles are crucial for relieving the rigidity.

Strengthening exercises, particularly those focusing on the muscles responsible for maintaining balance and the standing position such as the plantarflexors, the knee flexor and extensor muscles and the dorsal spinal muscles, also seem crucial. A variety of mobility exercises may also constitute a part of exercise programs in order to enhance the functional capacity and improve gait pattern [19-21]. The Pilates instructor provided the training group with basic information about the method and principles of Pilates exercises in the first session. The training program comprised 24 one-hour sessions, three sessions a week (as a total of 8 weeks). Each session began with 10-minute warm-up exercises, including stretching exercises and mobility exercises for the upper and lower extremity and the trunk, continued for 45 minutes performing 10 selected Pilates exercises aimed at increasing the strength of core muscles, range of motion and strength of lower limb and ended with 5 minutes of recovery exercises including stretching and relaxation exercises (Table 1).

Table 1. The selected Pilates training program

Weeks		The first two weeks (without tools)	The second two weeks (ball)	The third two weeks (TheraBand)	The fourth two weeks (compound)
Warm-up	Stretching	10 minutes	10 minutes	10 minutes	10 minutes
	Main program				
	One Leg Stretch	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Oblique Curl Up	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Knee Fold Scissors	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Shoulder bridge	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Torpedo	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Prone Leg Pull	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Prone Trunk Extension	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Trunk Rotation	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Trunk Lateral bending	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Semi-squat	6 repetitions	8 repetitions	10 repetitions	12 repetitions
	Front/Side Splits				
	One Leg Stance				
Cool-down	Stretching	5 minutes	5 minutes	5 minutes	5 minutes
Break between the sets		30 seconds	30 seconds	15 seconds	15 seconds

The principles of exercise, including the procedure and how to maintain the optimal posture, contraction of truncal muscles and proper breathing during the exercises, were explained to the subjects before each exercise. The patients were adequately supervised and banned from continuing the exercises if they experienced any unpleasant and annoying feelings such as pain, vertigo, malaise and palpitations. The exercises began with 6-8 repetitions depending on the ability of the subjects and without any coercion. The repetitions and duration of exercises gradually increased during eight weeks of the protocol depending on the characteristics of each subject. The Thera-Band® small ball was also used for applying resistance.

The characteristics of control group

The control group subjects were selected to optimally match with those in the experimental group. Along with daily physical activities, the controls proceed to progressive walking from 10 minutes in the first week to 30 minutes at the end of the training period in a timespan similar to that used in the experimental group. Balance and other relevant variables including core stability indices (trunk flexion, trunk extension, lateral trunk flexion and the lumbopelvic complex performance) and the functional lower extremity strength were ultimately evaluated in both groups at the end of the 8th week of the training protocol.

The fullerton advanced balance (FAB) scale

The clinical FAB scale used in the present study to assess balance was developed by Rose and Lucchese in 2006 to evaluate static and dynamic balance under different sensory conditions in community-dwelling higher-

functioning older adult population. In fact, this multidimensional test was designed based on identifying the multiple factors contributing to balance and evaluates the sensory, musculoskeletal and neuromuscular systems that might cause balance disorders. The advantages of this test include high-level balance evaluation and the ability of predicting falls in higher-functioning older adults. This test comprises 10 different balance assignments to measure different dimensions of balance [22]. These assignments include standing with feet together and eyes closed, extending hands forwards with arms stretched to get an object (pencil) held at shoulder height, turning 360 degrees right and left, stepping on and climbing down a 15-cm high stool, tandem walk, standing on one leg, standing on foam with eyes closed, two-footed jump, walking while turning the head and showing the control of postural reaction. This scale is scored between 0 and 40 depending on the subject's performance. Each assignment's score is 0-4, with 0 indicating inability to fulfill the balance assignment and 4 showing the subjects' ability to accomplish the task ideally and totally independently. The total score is calculated by summing up the scores of the ten sections [22,23]. A test-retest reliability coefficient of 0.96 and an inter-rater reliability of 0.94-0.97 were also calculated for this tool [22-24].

Trunk flexion endurance test

The patient sits, with thighs and knees bent by 90 degrees and hands crossed on the chest. In order to create more stability, ankles are fixed using a support band or a supportive person's hand. The patient is then asked to rise from the floor by 60 degrees (besides the angle specified on the wall or using a 60-

degree board) and maintain the trunk flexion at this angle. The duration in which the person is able to maintain their position without losing the favorable posture is recorded in seconds. This test is performed to evaluate the functional capacity of anterior core muscles. Okada *et al.* (2011) reported an internal reliability coefficient of 0.97 for this test [25].

Trunk lateral flexion endurance test

In order to evaluate the strength of lateral core muscles, the person takes a lateral recumbent position with the body along a straight line and no flexion in hip and knee joints. In order to enlarge the supporting surface and create more stability, the upper leg is placed beside and in front of the lower leg. The person is then asked to raise their thighs and buttocks while using only the feet and a forearm to support the body. The opposite arm should also be placed on the chest. The duration in which the person is able to maintain their posture without disrupting the body direction and lateral flexion of the lumbar region is recorded in seconds. This test is performed on both sides of the body. The internal reliability coefficient of this test was calculated as 0.99 by Okada *et al.* [25,26].

Trunk extension endurance test

In this test, the person is asked to take a prone position and hold their chest above the floor using a small pillow in the lower abdomen to avoid excessive curvature in the lumbar region. Efforts are made to maintain the maximum trunk extension as long as possible by maintaining the lumbopelvic stability through gluteal muscles contraction. The duration in which the person can hold this position without disrupting the spine and

pelvis orientation is recorded in seconds. Ito *et al.* (1996) reported a reliability coefficient of 0.94 for this test in women and 0.97 in men [27].

The step-down test

This unilateral test was used in the present study to evaluate the performance of the lumbopelvic complex. The subjects will squat on one leg on an 8-inch (20.32-cm) step and the number of repetitions in 30 seconds is recorded. Each repetition comprises a downward motion with the heel hitting the floor and the thigh returning to the full extension position. This test is also performed on both legs and the total score obtained is calculated. Loudon *et al.* (2002) reported a reliability coefficient of 0.94 for this test [28].

The 30-second chair stand test

This is a proper tool for measuring the functional lower extremity strength in older adults. In order to perform this test, a 17-inch (43-cm) chair is placed against the wall or supported by another person to avoid the risk of slipping. The subject begins the test in a sitting position in the center of the chair without relying on the seatback and with their hands crossed on the chest. On "Go", the subject rises to a standing position and sits down as quickly as possible while maintaining the standard position. The number of correct movements in 30 seconds is then recorded. Duncan *et al.* (2013) used this test for functional evaluations of patients with PD and reported a reliability coefficient of 0.99 [29]. Rikli and Jones (2013) and Telenius *et al.* (2015) also calculated a reliability coefficient of 1 in older adults [30,31].

The Shapiro-Wilk test was finally used to test the normality of the data collected. The

data associated with the subjects' characteristics including age, height and weight and also other descriptive and inferential variables were analyzed in SPSS-22. The paired-samples t-test was used to compare the results obtained before and after the intervention and the independent-samples t-test to compare the results in the two groups. $p \leq 0.001$ was set for statistical significance.

Results

The present study investigated 30 patients with moderate idiopathic PD (stage 2 and 3 of

the Hoehn & Yahr Scale) in the experimental and control groups in terms of functional balance and the relevant factors including core stability indices (trunk flexion, trunk extension, lateral trunk flexion and the lumbopelvic complex performance) and the functional lower extremity strength.

Table 2 presents general characteristics of the subjects and the descriptive data of the quantitative variables in the experimental and control groups.

Table 2. General characteristics of the subjects and descriptive information of quantitative variables

Variable	Experimental	Control group
	Mean±SD	Mean±SD
Age (yr)	57±6.24	58.31±7.37
Duration of PD (yr)	7.27±3.80	8.19±3.14
Height (cm)	164.67±8.49	164.94±8.83
Weight (kg)	71.78±5.78	73.40±8.50
Functional balance (pretest)	7±2.92	7.01±2.54
Functional balance (posttest)	32.67±5.16	7.27±2.84
Trunk flexion (pretest) (sec)	6.27±4.16	4.47±3.11
Trunk flexion (posttest) (sec)	64.93±18.18	6.07±3.41
Trunk extension (pretest) (sec)	1.53±1.88	1.47±1.06
Trunk extension (posttest) (sec)	31.33±7.21	0.93±0.79
Lateral trunk flexion (pretest) (sec)	2±1.46	2.01±1.27
Lateral trunk flexion (posttest) (sec)	49.40±8.34	1.87±1.30
Lumbopelvic function (pretest) (repetition)	11.67±3.57	11.33±4.45
Lumbopelvic function (posttest) (repetition)	49.73±9.76	11.67±4.70
Lower extremity strength (pretest) (repetition)	9.87±3.54	9.93±3.15
Lower extremity strength (posttest) (repetition)	24±2.67	11.53±3.60

Table 3 presents the difference between the two groups in terms of the mean functional balance, the mean core stability indices and the mean lower extremity strength in the pretest and posttest. The results of the paired t-test in the experimental group showed significant improvement in the scores of functional balance, trunk flexion, trunk extension, lateral trunk flexion, lumbopelvic complex performance and the lower extremity

strength after participating in the selected Pilates exercise program ($p < 0.001$). This test, however, showed no significant differences in terms of the scores of functional balance ($p = 0.364$), trunk flexion ($p = 0.268$), trunk extension ($p = 0.135$), lateral trunk flexion ($p = 0.796$), the lumbopelvic complex performance ($p = 0.465$) and the lower extremity strength ($p = 0.158$) in the control group.

Table 3. The difference in the mean results of functional posttests and pretests in the experimental and control group (the paired-samples t-test, $p \leq 0.001$)

Variable	Group	Difference in the mean (posttest-pretest)	T	P	df
Functional balance	Experimental	-25.66±3.67	-27.031	0.000*	14
	Control	-0.26±1.10	-0.939	0.364	14
Trunk flexion	Experimental	-58.67±19.47	-11.67	0.000*	14
	Control	-1.6±5.37	-1.15	0.268	14
Trunk extension	Experimental	-29.80±5.87	-19.66	0.000*	14
	Control	0.53±1.3	1.57	0.135	14
Lateral trunk flexion	Experimental	-47.4±8.53	-21.51	0.000*	14
	Control	0.13±1.96	0.264	0.796	14
Lumbopelvic function	Experimental	-38.07±10.55	-13.28	0.000*	14
	Control	-0.33±1.72	-7.51	0.465	14
Lower extremity strength	Experimental	-14.13±3.54	-15.45	0.001*	14
	Control	-1.6±4.15	-1.49	0.158	14

* The posttest and pretest values are significantly different ($p < 0.001$)

Tables 4 and 5 respectively present the difference in the pretest and post-test mean values of functional balance, core stability indices and the lower extremity strength between the two groups. The independent t-test indicated significant differences between the mean post-test values of functional

balance, trunk flexion, trunk extension, lateral trunk flexion, the lumbopelvic complex performance and the lower extremity strength in the two groups ($p < 0.001$), while the pretest figures showed no significant differences between the two groups.

Table 4. The difference in the mean results of functional pretest between the experimental and control group (the independent-samples t-test, $p \leq 0.001$)

Variable	Difference in the mean	T	P	df
Functional balance	0±1.07	0	1	28
Trunk flexion	1.8±1.34	1.34	0.191	28
Trunk extension	0.07±0.56	0.12	0.906	28
Lateral trunk flexion	0±0.54	0	1	28
Lumbopelvic function	0.33±1.48	0.23	0.823	28
Lower extremity strength	-0.07±1.22	-0.05	0.957	28

Table 5. The difference in the mean results of functional posttest between the experimental and control group (the independent-samples t-test, $p \leq 0.001$)

Variable	Difference in the mean	T	P	df
Functional balance	25.4±1.52	16.69	0.000*	28
Trunk flexion	58.87±4.78	12.32	0.000*	28
Trunk extension	30.40±1.87	16.24	0.000*	28
Lateral trunk flexion	47.54±2.18	21.79	0.000*	28
Lumbopelvic function	38.07±2.8	13.6	0.000*	28
Lower extremity strength	12.47±1.6	10.76	0.000*	28

* There are significant differences between the mean posttest values of the two groups

Discussion

The present study was conducted to investigate the effects of a selected Pilates exercise program on functional balance and the factors associated with balance such as core stability indices and the lower extremity

strength in patients with PD. According to the results obtained, eight weeks of Pilates exercises significantly improved functional balance in the experimental group. Furthermore, significant differences were

observed in the core stability indices such as trunk flexion, trunk extension, lateral trunk flexion, the lumopelvic complex performance and the lower extremity strength improved by this exercise. Postural instability is one of the most debilitating aspects of PD, which can increase falls and reduce mobility and functional capacity in these patients. Patients with PD suffer a smaller range of stability and consequently higher postural fluctuations compared to other peers. Postural control disorders are also significantly associated with the risk of falls in these patients [32]. Many studies confirm the effectiveness of regular exercises on improving motor and non-motor symptoms in patients with PD. Postural control indices are significant and effective factors on maintaining independence and quality of life in these patients and significantly improve by training interventions [2,16,33]. Different training interventions including aerobic exercises, hydrotherapy as well as balance and gait training cause significant therapeutic benefits by enhancing the functional capacity in these patients [34,35]. There are different theories as to how exercise programs improve balance. Generally, physical activities improve balance through modifying the central and peripheral balance systems in the body [5]. The results of most researchers suggest that resistance training and balance exercises are more effective on improving balance disorders, especially in patients with mild and moderate levels of PD, compared to other exercise methods [10,36]. Based on physiological principles, skeletal muscles are heavily affected by Pilates exercises as a type of resistance training, in which the body weight is applied as the resistance and the increasing repetitions as the overload weight [37]. The balance improvement caused by Pilates

exercises can be investigated based on the systems theory. According to this theory the ability to control the body's position resulted from simultaneous and complex interaction between the nervous system and the musculoskeletal system (the postural control system). A combination of sensory data (to detect the body position in space) and the musculoskeletal system ability is essential to apply proper force for the postural and balance control and consequently movement using the systems cited. In this model, the central nervous system uses the visual, vestibular and proprioceptive data, including joint position sensation and peripheral sensation, to obtain data about the body's center of gravity concerning gravity and base of support and provide appropriate motor responses as pre-programmed movement patterns. Based on the systems theory and also the effect of physical activities on improving these systems, Pilates exercises can be associated with balance improvement in patients with PD who experience balance disturbance caused by the central nervous system dysfunction [38,39]. In addition, Pilates exercises can improve balance through improving psychological factors such as stress and anxiety in participants. Also it increases the muscle strength. Since reduction in the lower extremity strength move the center of gravity to in front of the ankle, which in turn causes imbalance and falls, the Pilates therefore seems to correct balance disorders by focusing on the functional improvement of core muscles and axial stability through creating neuromuscular adaptations [18,37,40,41]. Kibar *et al.* (2015) found eight weeks of Pilates exercise to have beneficial effects on the static and dynamic balance and core muscle endurance in older adults, while they found no significant

relationship between core muscle endurance and balance [42]. Kloubec *et al.* (2010) also found these exercises to significantly improve core muscle strength, while failing to significantly affect balance and posture in the middle-aged [43]. Comparing the effects of Pilates and balance exercises designed on unstable surfaces, Hyun reported that both of these methods significantly improve static and dynamic balance in old women and increase their balance abilities, and that Pilates seems a safer method for improving balance capacity in older adults if more safety measures are taken [13]. Given the significant differences observed in the functional balance of the study subjects participating in the Pilates exercise program compared to that of the controls, the selected Pilates training program used in the present study can have desirable effects on the improvement of balance in patients with PD, which is consistent with the studies conducted by Bird *et al.* (2013), Newell *et al.*, Oliviera *et al.* (2015), Mesquita *et al.* (2015) and Jonson *et al.* (2013) [12,36,41,44,45]. Furthermore, Pilates exercises seem to be associated with the functional improvement in core stability muscles and also strength improvement and recruitment of trunk and lower extremity muscles. This activation of core muscles in mobility patterns of extremities improves postural control and generates rotational torque to move the limbs. These results are consistent with the studies conducted by Kibler *et al.* (2006) and Jankovic *et al.* (2007) [46,47]. Pilates was designed based on the principle of retraining postural control and motor learning and is therefore a proper method for exercising mind-body awareness and controlling postural movements, particularly to maintain balance in older adults. This is why these exercises are more

effective on balance functions than is light walking. The studies conducted by Gopal Nambi *et al.* (2014) and Appell *et al.* (2012) indicate more significant effects of Pilates exercises on balance than those of walking, which is consistent with the present study [48,49]. Some studies however indicate significantly positive effects of more complicated types of exercises such as walking on treadmill and in different directions, walking on unstable surfaces with open and closed eyes, walking in different directions as well as moving and walking in water on balance indices. These exercises mainly improve the musculoskeletal factors contributing to mobility, neuromuscular coordination and the application of balance-motor strategies, which are followed by facilitating motor learning, while light walking does not cause such significant changes [15,50-54].

Conclusion

Given that Pilates exercise affects both the muscular and the nervous system, they can well treat balance disorders emerging especially in patients with postural control disorders. This type of training program can therefore be recommended as a modality of treatments for these patients.

Study Limitations

Owing to the limitations in selecting subjects, the present study recruited male and female patients with PD aged over 50. Moreover, only patients with stage 2 and 3 of PD could be included owing to the patients' limited cooperation. It was also impossible to accurately control medication consumption during the study, therefore, a neurologist

asked to help include subjects that followed the most similar medication regimens.

Study Recommendations

Similar studies are recommended on larger sample sizes, separately for men and women, in longer periods and with different interventions to investigate the effects of other training methods on patient performance and identify the most effective protocols on improving other disorders.

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Conflict of Interest

The authors have no conflict of interest.

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