JETR

JOURNAL OF
EXERCISE THERAPY
AND REHABILITATION

Journal of Exercise Therapy and Rehabilitation. 2024;11(2):71-80. DOI: 10.15437/jetr.1376656

ORIGINAL ARTICLE

# Parkinson hastalarında Pilates egzersizlerinin core kas kalınlığı, fiziksel performans ve yorgunluk üzerine etkisi: Randomize kontrollü bir çalışma

*Effect of Pilates exercises on core muscle thickness, physical performance, and fatigue in patients with Parkinson's disease: A randomized controlled trial*

Derya ÇAĞLAR[1], Arzu GÜÇLÜ-GÜNDÜZ[2], Ahmet TÜFEKÇİ[3], Mehmet BEYAZAL[4], Mustafa-Umut ÇAĞLAR[5], Sefa ELDEMİR[6]

Öz

**Amaç:** Parkinson hastalığı (PH) olan hastalarda Pilates egzersizlerinin core kas kalınlığı, fiziksel performans, yorgunluk, günlük yaşam aktivitesi (GYA) ve yaşam kalitesi (YK) üzerindeki etkilerinin incelenmesi amaçlandı.
**Yöntem:** Bu çalışma, Pilates veya kontrol grubuna rastgele atanan 34 hasta (her biri n=17) ile gerçekleştirildi. Pilates grubuna 8 hafta boyunca haftada 3 gün Pilates eğitimi verilirken, kontrol grubuna ev programı olarak solunum egzersizleri, aktif eklem hareket açıklığı egzersizleri ve gevşeme egzersizleri verildi. Core kas kalınlığı ultrasonografi ile, core stabilitesi, core kuvvet ve dayanıklılık testleri ile değerlendirildi. Alt ekstremite fonksiyonel kuvveti 5 Kez Otur-Kalk Testi ile, denge Berg Denge Skalası ile, fonksiyonel mobilite Zamanlı Kalk ve Yürü Testi ile, fonksiyonel egzersiz kapasitesi ise 6 Dakika Yürüme Testi ile değerlendirildi. Yorgunluk, Parkinson Yorgunluk Ölçeği-16 ile değerlendirildi.
**Bulgular:** Pilates grubunda transversus abdominus ve multifidus kas kalınlıkları (sağ taraf multifidus kası hariç), fiziksel performans parametreleri, yorgunluk, GYA ve YK'de gelişme görüldü ($p<0,05$). Kontrol grubunda ise sadece GYA'da iyileşme görüldü ($p<0,05$).
**Sonuç:** Sonuçlar, PH'li bireylerde Pilates sonrası core kas kalınlığının yanı sıra fiziksel performans, yorgunluk, GYA ve YK'de iyileşme olduğunu göstermektedir. Sonuç olarak, core bölge antrenmanı olan Pilates, core bölge kaslarını eğitmek ve fonksiyonel sonuçları, yorgunluğu ve günlük aktiviteleri iyileştirmek için kullanılabilir.
**Anahtar kelimeler:** Parkinson hastalığı, Pilates egzersizleri, Abdominal kaslar, Fiziksel performans, Core stabilite.

Abstract

***Purpose**: It was aimed to examine the effects of Pilates exercises on core muscle thickness, physical performance, fatigue, activities of daily living (ADL), and quality of life (QoL) in patients with Parkinson's disease (PwPD).*
***Methods:** This study was conducted with 34 patients randomly assigned to the Pilates or Control group (n=17 each). The Pilates group received Pilates training 3 days a week for 8 weeks, while the control group received breathing exercises, active range of motion exercises, and relaxation exercises as a home program. Core muscle thickness was evaluated by ultrasonography and core stability was evaluated by core strength and endurance tests. Lower extremity functional strength was evaluated with the 5 Times Sit-Up Test, balance with the Berg Balance Scale, functional mobility with the Timed Up and Go Test, and functional exercise capacity with the 6-Minute Walk Test. Fatigue was evaluated with the Parkinson's Fatigue Scale-16,.*
***Results:** Transversus abdominus and multifidus muscle thicknesses (except for right side multifidus muscle), physical performance parameters, fatigue, ADL, and QoL improved in the Pilates group ($p<0.05$). In the control group, improvement was observed only in ADL ($p<0.05$).*
***Conclusion:** Results show core muscle thickness as well as improved physical performance, fatigue, ADL, and QoL after Pilates in PwPD. As a result, core-based training, Pilates, may be used to train core muscles and improve functional results, fatigue, and daily activities.*
***Keywords:** Parkinson's disease, Pilates exercises, Abdominal muscles, Physical performance, Core stability.*

1: Recep Tayyip Erdogan University, Guneysu Vocational School of Physical Therapy and Rehabilitation, Rize, Türkiye.
2: Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Türkiye.
3: Recep Tayyip Erdogan University, Department of Neurology, Faculty of Medicine, Rize, Türkiye.
4: Recep Tayyip Erdogan University, Department of Radiology, Faculty of Medicine, Rize, Türkiye.
5: Can Selale Special Education and Rehabilitation Center, Rize, Türkiye.
6: Sivas Cumhuriyet University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Sivas, Türkiye.
Corresponding Author: Sefa Eldemir: sefa.eldemir@gmail.com
ORCID IDs (order of authors): 0000-0003-4167-3212; 0000-0001-8464-1929; 0000-0003-1240-6609; 0000-0002-4748-4941; 0000-0003-1107-5764; 0000-0002-2122-5706
Received: October 16, 2023. Accepted: January 26, 2024.

## INTRODUCTION

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by both motor and non-motor symptoms.[1] Patients experience increased difficulties in mobility as a result of decreased movement skills, balance, muscle strength, postural alignment, and aerobic capacity. All of these lead to a decrease in independent activities of daily living, resulting in a decrease in quality of life.[2] In the management of the disease, together with medical treatments, exercise has an important place.[3]

Exercise provides effective use of dopamine by regulating dopamine circulation in PD.[4] It has been shown to contribute to neuroprotection, neurorestorative, and neuroplasticity and, as a result, slows the progression of PD.[5] Exercise has been shown to effectively improve motor impairments such as muscle strength, balance, mobility, aerobic capacity, walking, and freezing and, non-motor impairments such as cognitive function and sleep quality in PD.[6] Traditional exercises consist of interventions to improve the symptoms of patients with PD (PwPD), such as breathing, relaxation exercises, active range of motion, stretching, strengthening, and balance training.[7-9] Nowadays, while traditional exercise methods are still used, it is seen that the exercise habits of the patients have changed, They prefer sports that they can enjoy individually or in groups such as music and dance therapy, Pilates, yoga, and Tai Chi, and there are participating more in these training compared to classical neurorehabilitation training.[7,10,11] Pilates, one of the most remarkable exercise methods, was developed at the beginning of the 20th century by Joseph Pilates as a core-based mind-body exercise method that improves body smoothness and awareness.[12] The effects of Pilates on lower extremity muscle strength,[13] balance,[13-15] mobility,[14-16] motor impairments,[13,15] and quality of life[17] have been examined in PD. Although it is stated in these studies that Pilates can be used as an exercise method in PD, it is said that further studies are needed. Additionally, although Pilates is a core stability-based training method, its effects on core stability and the core muscle thickness have not been investigated yet in PD. Demonstrating these effects may be instructive in order to better understand the effects of Pilates on functional improvements in PD.

Therefore, the purpose of this study is to investigate the effects of Pilates on the core muscle thickness, core stability, lower extremity muscle strength, balance, functional mobility, functional exercise capacity, fatigue activities of daily living (ADL), and quality of life (QoL).

## METHODS

### Subjects

Thirty-four patients (26 men and 8 women; mean age 61.41±11.82 years) with idiopathic PD participated in this study. Inclusion criteria were: (a) 40-80 years of age and (b) Hoehn and Yahr stages 1 through 2.5. Exclusion criteria were: (a) the presence of cardiovascular, pulmonary, orthopedic, or history of different neurological diseases other than PD that limited participation in Pilates and (b) a Standardized Mini-Mental Test score <24. There was no change in medication type or dose in any patient throughout the study. This study was in accordance with the Declaration of Helsinki and written informed consent was obtained from all participants.

The study was approved by the Republic of Gazi University Faculty of Medicine Clinical Research Ethics Committee (issue: 2019/10 date: 10.09.2019).

### Procedure

Participants were assigned to the Pilates group and control group with computer-generated random numbers using the simple randomization method. Simple randomization is a method that ensures that the assignment of subjects to a particular group is random and is reliable in creating similar numbers of subjects in groups.[18] While the Pilates group performed only Pilates exercises, the control group followed with a home program. Pilates training was given by a physiotherapist (DC) who is certified by the Australian Institute of Pilates and Physiotherapy (APPI) and working on Pilates and neurological physiotherapy. Evaluations were made before and after treatment by a blinded physiotherapist (MUC).

### Interventions

Pilates was carried out as group exercises for 8 weeks, 3 days a week. Before starting the

exercise training, all subjects were taught the key elements of Pilates for 1 session. These key elements were breathing, centering, rib cage placement, shoulder girdle placement, and head and neck position. Each movement was shown firstly by the physiotherapist so that the patients could perform the movements correctly. During Pilates, movements were controlled by the physiotherapist and necessary corrections were made with verbal or tactile stimuli.

Pilates started with standing warm-up exercises and centering in the supine position. For centering, the abdominal hollowing - abdominal draw-in maneuver was used to activate the M. transversus abdominis (TrA) muscle.[19] The intensity of the exercises was increased using different positions and elastic bands (Theraband Elastic Band Hygienic Corporation, Akron, Ohio). The details of Pilates are presented in Figure 1.

Figure 1. Pilates training program.

| | |
|---|---|
| Centring | Warm-up (5 min) |
| Segmental extremity movements | |
| Overhead reach | Pilates (50 min) |
| Abdominal preparation | Clam |
| Oblique preparation | Hip twist |
| One leg stretch | Swimming |
| Scissors | Arm opening |
| One leg circle | Side bend |
| Double leg stretch | Breast stroke |
| Heels together toe apart | Cobra |
| Hundreds | Spine twist |
| Leg pulls in prone | Mermaid |
| Shoulder bridge | Chest lift |
| | Crisscross |
| Single knee to chest | Cool-down (5 min) |
| Double knee to chest | |
| Camel stretch | |
| Cat stretch | |
| Standing quadriceps stretch | |
| Seated forward bend stretch | |
| Lying trunk rotation | |

The control group was followed up with a home program including breathing, active range of motion, and relaxation exercises. The control group performed the exercises 3 days a week for 8 weeks, as in the Pilates group. Additionally, the control group was followed with an exercise chart, and they were called by phone every week to check whether the exercises were performed regularly.

**Outcome measures**

TrA and Multifidus (MF) muscles were visualized by ultrasonography, and evaluations were performed by an experienced specialist radiologist who was blinded to the case groups. Toshiba Aplio 500 US (Toshiba Medical Systems Corporation, Otawara, Japan) device was used for all ultrasonography examinations. Ultrasound recordings were made by using B-mode ultrasound. The TrA muscle thickness was examined by the 12-Mhz linear transducer placed transversely over the iliac crista in the mid-axillary line while the patient was lying in the supine position. The MF muscle thickness was examined by the 5-Mhz convex transducer while the patient was lying in a prone position with a pillow under the abdomen. Ultrasonographic imaging of the MF muscle was performed in the transverse plane and thickness measurement was taken from the cross-sectional area using the curved probe. All measurements were performed both in the resting position and during the abdominal drawn-in maneuver to minimize the activity of the superficial global muscles and emphasize the deep local muscle activity.[20,21]

Core strength was evaluated with sit-up test and modified push-up test. The sit-up test was started with the knees flexed at 90° on a mat, the feet stabilized and the hands placed behind the head. The patient was asked to the trunk flexion up to the lower angle of the scapula.[22,23] The modified push-up test was performed in the prone position with the arms, elbows, and knees flexed. The subjects were asked to raise the head, shoulders, and trunk off the ground by bringing their elbows to full extension.[24]

Core endurance was evaluated with lateral bridge test, trunk flexor endurance test, and prone bridge test. In the lateral bridge test, the subjects were asked to lie on their right/left side, to raise their body on their forearms and toes, and to maintain their position.[23] In the trunk flexor endurance test, subjects were asked to remain in the 60° trunk flexion position while the hip and knee were in 90° flexion.[23] In the

prone bridge test, the subjects were positioned in the prone position, on their forearms with both arms shoulder-width apart, both feet open to hip-width, elbows flexed to 90°. They were asked to raise their torso by placing their weight on their forearms and toes.[25]

The functional strength of the lower extremity was evaluated with the 5 Times Sit-Up Test (5XSST).[26] Balance was assessed with the Berg Balance Scale (BDS) which is widely used to assess the ability to maintain balance during different positions and postural changes.[27] Functional mobility was evaluated with the Timed Up and Go Test (TUG)[28] and functional exercise capacity was evaluated with the 6-Minute Walk Test (6-MWT).[29]

The Parkinson's Fatigue Scale-16 (PAS-16) was used to examine the effect of fatigue, one of the non-motor findings associated with Parkinson's, on daily life and to evaluate its physical effects.[30] The scale consists of 16 questions rated between 1 (strongly disagree) and 5 (strongly agree). When the total score was 8 points or more, it is considered as fatigue. In this study, the Turkish version of the PAS-16 scale, whose reliability and validity were investigated, was used.[31]

ADL was evaluated with activities of daily living (II) subscale of the Unified Parkinson's Disease Rating Scale (UPDRS).[32] In this study, the Turkish version of the UPDRS scale, whose reliability was investigated, was used.[33] QoL was assessed with the Parkinson's Disease Quality of Life Questionnaire-39 (PDQ-39) in patients with PD.[34] The PDQ-39 has eight dimensions ranging from 0 to 100; being the higher the score, the worse the QoL. In this study, the Turkish version of the PDQ-39 scale, whose reliability and validity were investigated, was used.[35]

### Statistical analysis

The sample size was determined by performing a power analysis (G*power version 3.1.9.2, Heinrich Heine Universitaet, Düsseldorf, Germany). For this, a pilot study was conducted and it was carried out considering the clinically significant differences in the core endurance test scores. According to the power analysis results, the average number of individuals for each group was determined as 17 participants (power=95% and alpha=0.05). Statistical analysis of the study was

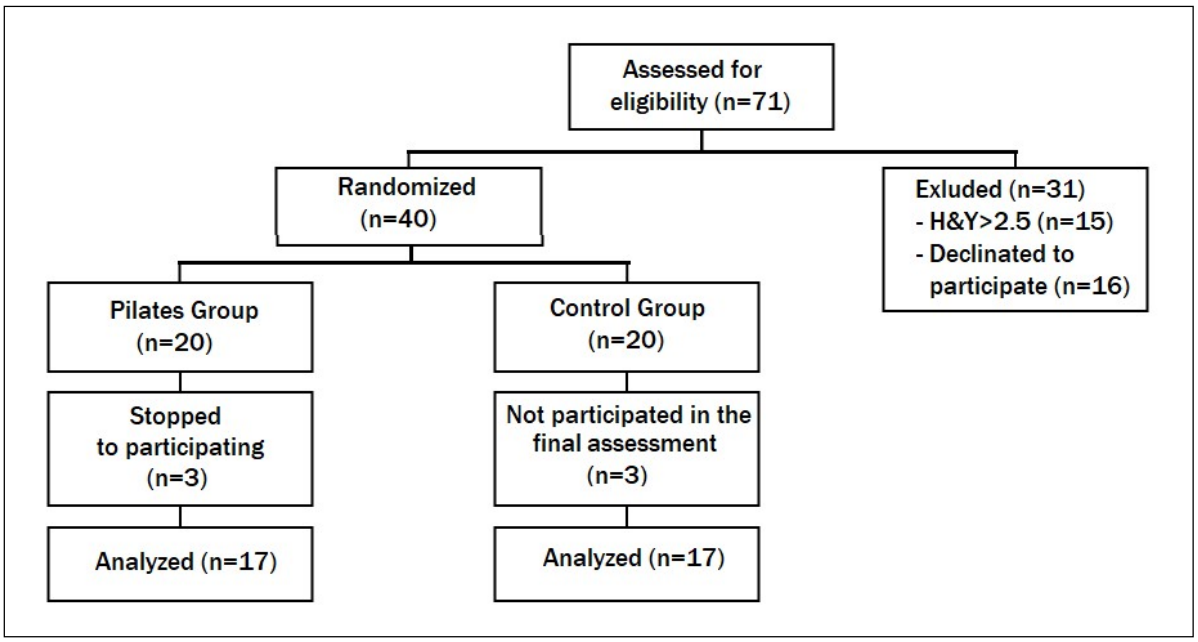


Figure 2. Participants flow through the study. Consolidated Standards of Reporting Trials (CONSORT) flow chart.

performed using the SPSS version 23 (SPSS inc. Chicago, IL, USA) program. The normality and homogeneity of variances were assessed via a Shapiro-Wilk test. Statistics of numerical variables were expressed by giving the mean ± standard deviation for normally distributed variables, and the median and interquartile range (25-75 interquartile range: IQR) for non-normally distributed variables. Descriptive statistics of categorical variables were expressed as frequency and percentage (%). Demographic characteristics and outcome measures of participants were compared between the groups using the independent samples t-test, Mann–Whitney U test, or the Chi-square test. Comparison of data within groups was made by using the dependent group's t-test or Wilcoxon test. The statistical error level was taken as $p<0.05$.

## RESULTS

A total of 71 participants were assessed for eligibility, with 34 randomized to the Pilates group or the control group (see Figure 2).
Age, gender, body mass index, disease duration, Hoehn and Yahr stage, and outcome measures (except left side TrA muscle thickness during abdominal drawn-in) were similar between the groups ($p>0.05$) (Table 1).

Table 2 and 3 show the comparison of outcome measures for groups. The core muscle thickness, core stability, lower extremity functional strength, balance, functional mobility, and functional exercise capacity improved in the Pilates group ($p<0.05$). In addition, fatigue decreased and ADL improved in the Pilates group ($p<0.01$). There was no significant increase in right side multifidus muscle thickness only in the Pilates group ($p>0.05$). The quality of life developed in both groups, improved more in the Pilates group than in the control group ($p<0.05$). The PDQ-39 (0-156) change scores were -38.05±15.68 and -3.35±4.35 for Pilates Group and Control Group, respectively. There was a difference between the two groups ($p<0,001$).

## DISCUSSION

This study has shown that an 8-week Pilates exercise program resulted in significant improvements in both sides TrA and left multifidus thickness, core stability, lower extremity functional strength, balance, functional mobility functional exercise capacity, fatigue, ADL and QoL in PwPD.

Core muscle strength and endurance improved in the Pilates group after 8 weeks, while it did not change in the control group in this study. The effect of pilates on core muscle strength and endurance in patients with chronic low back pain[36,37] or neurological diseases[10,38,39] has previously been investigated. Only one of these studies reported that Pilates produced significant improvements in core strength and endurance in PwPD.[39] The study stated that improvements in core endurance after 6-week Pilates training in PD were associated with increases in TrA activity which demonstrated this with ultrasound imaging, the main muscle of core stability. In our study, core muscle strength and endurance were evaluated, and the findings were also supported by ultrasonographic examination. An increase in TrA muscle thickness was detected both in the resting position and during the abdominal retraction maneuver. At the end of the study, a similar increase in thickness was observed in the left multifidus muscle. Our results showed the effectiveness of Pilates training on core muscles, consistent with previous studies. The lack of improvement in the control group may be due to the fact that the exercise content is not directly aimed at improving core muscle strength and endurance.
Another important result of this study is that there was an improvement in functional strength of the lower extremity in the Pilates group, only. Pilates is basically a training that aims to improve core stability. Core stability does not mean static stability, it means the ability to dynamically adapt to the movement of the trunk and extremities and maintain balance. In Pilates, core muscles are activated with extremity and trunk movements.[12,40] Additionally, by using resistance bands and moving ground (Pilates ball), this activation is tried to be increased even more. Thus, both core and extremity muscles are strengthened, and balance is improved. In our study, we think that functional strength in the lower extremity increased with this basic mechanism. Another reason for strengthening the lower extremity muscles is that the core area is the key point for

extremity movements. If the core muscles are strong and stable, extremity movements become free, and strength and coordination increase in the extremities.[14] Based on this reason, it can be said that the increase in core stability is an important factor in the development of the functional strength of the lower extremity. Consistent with the present study, Cardalda et al.[13] found that the functional strength of the lower extremity improved in PwPD after Pilates. In addition, we think that improving the sit-to-stand activity, which is one of the most difficult activities for Parkinson's patients in daily life, is one of the important achievements of education as mentioned above.

Another important result of this study in the Pilates group is the improvement in balance. As a result of the nature of the Pilates exercise method, we can easily expect an improvement in balance. In the literature, there are studies examining the effects of Pilates on balance with mild to moderate PH patients, and the result of the present study is consistent with the literature.[13-15] Although these studies attribute

Table 1. Comparison of demographic and baseline characteristics of the groups.

| | | Pilates Group (N=17) | Control Group (N=17) | p |
|---|---|---|---|---|
| Age (years) (e) | | 61.0 (50.0-70.5) | 69.0 (63.5- 73.5) | 0.068 (b) |
| Gender (Female/Male) (n (%)) | | 4/13 (24/76) | 4/13 (24/76) | 1.000 (c) |
| Body mass index (kg/m$^2$) (e) | | 26.22 (24.65-31.24) | 30.42 (28.09-33.46) | 0.052 (b) |
| Disease duration (years) (e) | | 6.00 (1.50-7.00) | 3.00 (2.00-4.50) | 0.251 (b) |
| Hoehn and Yahr stage (0-5) (n (%)) | 1 | 5 (29) | 6 (35) | |
| | 2 | 11 (65) | 10 (59) | 0.747 (c) |
| | 2.5 | 1 (6) | 1 (6) | |
| Core muscle thickness (d) | | | | |
| M. Transversus abdominus (mm) | | | | |
| Resting position | Right | 3.79±0.81 | 4.31±0.80 | 0.143 (a) |
| | Left | 3.74±0.72 | 4.45±0.83 | 0.051 (a) |
| Abdominal drawn-in | Right | 4.69±0.83 | 5.40±1.03 | 0.092 (a) |
| | Left | 4.71±0.86 | 5.79±1.22 | 0.028* (a) |
| M. Multifidus (mm) | | | | |
| Resting position | Right | 21.97±3.96 | 21.10±2.04 | 0.524 (a) |
| | Left | 21.66±3.26 | 21.59±1.99 | 0.950 (a) |
| Abdominal drawn-in | Right | 20.90±3.57 | 20.70±2.13 | 0.881 (a) |
| | Left | 21.21±3.15 | 20.85±1.37 | 0.730 (a) |
| Core Power (e) | | | | |
| Sit-up (repetition/30 sec) | | 3.94 (0.00-7.00) | 4.00 (0.00-7.00) | 0.902 (b) |
| MPT (repetition/30 sec) | | 7.17 (4.00-11.00) | 5.76 (0.50-9.00) | 0.342 (b) |
| Core Endurance (e) | | | | |
| Side bridge Test (sec) | Right | 10.41 (0.00-15.50) | 6.52 (0.00-12.50) | 0.315 (b) |
| | Left | 10.76 (3.50-14.00) | 5.23 (0.00-8.50) | 0.056 (b) |
| Trunk Flexor Test (sec) | | 5.94 (0.00-5.50) | 1.64 (0.00-2.50) | 0.338 (b) |
| Prone Bridge (sec) | | 20.82 (8.50-28.00) | 14.17 (3.00-26.00) | 0.202 (b) |
| Five Times Sit to Stand Test (5XSST) (sec) (d) | | 20.88±7.04 | 18.47±3.89 | 0.228 (a) |
| Berg Balance Scale (BBS) (0-56) (d) | | 50.41±4.43 | 51.64±3.49 | 0.374 (a) |
| Time Up and Go Test (TUG) (sec) (e) | | 14.35 (11.00-18.00) | 13.29 (11.00-15.00) | 0.664 (b) |
| 6-Minute Walk Test (6-MWT) (d) | | | | |
| Distance (m) | | 360.00±91.63 | 378.18±60.65 | 0.500 (a) |
| Maximal heart rate reached (%) | | 58.14±6.10 | 58.84±3.00 | 0.221 (a) |
| PFS-16 (16-80) (d) | | 51.94±7.13 | 47.64±8.99 | 0.193 (a) |
| UPDRS-II (0-52) (d) (e) | | 13.35±5.54 | 11.05 (6.00-14.50) | 0.156 (b) |
| PDQ-39 (0-156) (d) | | 49.47±17.75 | 39.41±18.14 | 0.112 (a) |

*p<0.05. (a): Independent Samples t-Test. (b): Mann–Whitney U Test. (c): Chi-Square Test. (d): Mean±SD. (e): Median (IQR). MPT: Modified push-up test. PFS-16: Parkinson's Disease Fatigue Scale. UPDRS-II: Unified Parkinson's Disease Rating Scale-Motor assessment subscale. PDQ-39: Parkinson's Disease Quality of Life Questionnaire-39.

Table 2. A comparison of the previous and subsequent measurements of parameters for the Pilates Group (N=17).

| | | Before | After | p |
|---|---|---|---|---|
| Core muscle thickness (d) | | | | |
| M. Transversus abdominus (mm) | | | | |
| Resting position | Right | 3.79±0.81 | 4.74 ±0.98 | <0.001 (a) |
| | Left | 3.74±0.72 | 4.80±0.75 | <0.001 (a) |
| Abdominal drawn-in | Right | 4.69±0.83 | 6.45±1.19 | <0.001 (a) |
| | Left | 4.71±0.86 | 6.67±1.23 | <0.001 (a) |
| M. Multifidus (mm) | | | | |
| Resting position | Right | 21.97±3.96 | 20.74±2.81 | 0.136 (a) |
| | Left | 21.66±3.26 | 22.04±3.13 | 0.015* (a) |
| Abdominal drawn-in | Right | 20.90±3.57 | 20.49±2.86 | 0.547 (a) |
| | Left | 21.21±3.15 | 21.70±2.58 | 0.044* (a) |
| Core Power (e) | | | | |
| Sit-up (repetition/30 sec) | | 3.94 (0.00-7.00) | 11.17 (6.50-16.00) | <0.001 (b) |
| MPT (repetition/30 sec) | | 7.17 (4.00-11.00) | 17.52 (11.00-21.00) | <0.001 (b) |
| Core Endurance (e) | | | | |
| Side bridge Test (sec) | Right | 10.41 (0.00-15.50) | 37.41 (17.00-50.50) | <0.001 (b) |
| | Left | 10.76 (3.50-14.00) | 41.76 (22.50-56.00) | <0.001 (b) |
| Trunk Flexor Test (sec) | | 5.94 (0.00-5.50) | 16.05 (4.50-24.00) | <0.001 (b) |
| Prone Bridge (sec) | | 20.82 (8.50-28.00) | 61.00 (44.00-82.50) | <0.001 (b) |
| Five Times Sit to Stand Test (5XSST) (sec) (d) | | 20.88±7.04 | 10.64±2.91 | <0.001 (a) |
| Berg Balance Scale (BBS) (0-56) (d) | | 50.41±4.43 | 55.35±0.70 | <0.001 (a) |
| Time Up and Go Test (TUG) (sec) (e) | | 14.35 (11.00-18.00) | 8.47 (7.00-10.00) | <0.001 (b) |
| 6-Minute Walk Test (6-MWT) (d) | | | | |
| Distance (m) | | 360.00±91.63 | 482.82±98.79 | <0.001 (a) |
| Maximal heart rate reached (%) | | 58.14±6.10 | 60.52±4.52 | 0.035* (a) |
| PFS-16 (16-80) (d) | | 51.94±7.13 | 32.11±3.56 | <0.001 (a) |
| UPDRS-II (0-52) (d) | | 13.35±5.54 | 3.70±2.91 | <0.001 (a) |
| PDQ-39 (0-156) (d) | | 49.47±17.75 | 11.41±6.45 | <0.001 (a) |

*p<0.05. (a): Independent Samples t-Test. b: Mann–Whitney U Test. (d): Mean±SD. (e): Median (IQR). MPT: Modified push-up test. PFS-16: Parkinson's Disease Fatigue Scale. UPDRS-II: Unified Parkinson's Disease Rating Scale-Motor assessment subscale. PDQ-39: Parkinson's Disease Quality of Life Questionnaire-39.

the development of balance to the improvement in core stability, it is seen that they do not prove this with the improvement in the strength, endurance, and core muscle thickness. This study provides evidence for the hypothesis underlying Pilates' improvement of balance in PD.

Although Pilates is not a gait training, we found that our patients walked faster and their walking distance increased, according to TUG and 6-MWT. Johnson et al.[15] have shown that Pilates is beneficial to PD patients who are prone to falls and reported significant improvements in their step cadence and mobility. Similarly, Pandya et al.[14] and Daneshmandi et al.[16] who investigated the effects of Pilates on PD, found that functional mobility increased in their studies. Both these studies and current study show that walking performance can improve in patients with a core-based training. It can be said that the basis of this development is similar to the underlying reasons for the development achieved in sit to stand.

The 6-MWT evaluates both exercise capacity and walking performance. In this study, although the primary purpose of Pilates is not to increase exercise capacity, our results have shown that it may also increase exercise capacity. When the literature is analyzed, there is no study investigating the effect of Pilates training on exercise capacity in PwPD. These results are another unique aspect of our study.

Prevalence of fatigue has been reported between 33% and 58% in PD, and it is one of the most common non-motor symptoms.[41] Although

Table 3. A comparison of the previous and subsequent measurements of parameters for the Control Group (N=17).

| | | Before | After | p |
|---|---|---|---|---|
| Core Muscle Thickness (d) | | | | |
| M. Transversus Abdominus, (mm) | | | | |
| Resting position | Right | 4.31±0.80 | 4.23±0.76 | 0.203 (a) |
| | Left | 4.45±0.83 | 4.48±0.86 | 0.539 (a) |
| Abdominal Drawn-in | Right | 5.40±1.03 | 5.39±0.94 | 0.894 (a) |
| | Left | 5.79±1.22 | 5.75±1.25 | 0.712 (a) |
| M. Multifidus, (mm) | | | | |
| Resting position | Right | 21.10±2.04 | 21.40±2.14 | 0.729 (a) |
| | Left | 21.59±1.99 | 21.97±3.05 | 0.586 (a) |
| Abdominal Drawn-in | Right | 20.70±2.13 | 21.52±2.05 | 0.303 (a) |
| | Left | 20.85±1.37 | 21.82±1.90 | 0.114 (a) |
| Core Power (e) | | | | |
| Sit-up (repetition/30 s) | | 4.00 (0.00-7.00) | 4.64 (0.00-6.00) | 0.250 (b) |
| MPT (repetition/30 s) | | 5.76 (0.50-9.00) | 6.23 (0.50-10.50) | 0.119 (b) |
| Core Endurance (e) | | | | |
| Side Bridge Test (s) | Right | 6.52 (0.00-12.50) | 6.00 (0.00-12.50) | 0.496 (b) |
| | Left | 5.23 (0.00-8.50) | 5.31 (0.00-8.00) | 0.777 (b) |
| Trunk Flexor Test (s) | | 1.64 (0.00-2.50) | 1.29 (0.00-2.00) | 0.084 (b) |
| Prone Bridge (s) | | 14.17 (3.00-26.00) | 15.11 (4.50-25.00) | 0.152 (b) |
| Five Times Sit to Stand Test (5XSST) (sec) (d) | | 18.47±3.89 | 18.05±4.26 | 0.300 (a) |
| Berg Balance Scale (BBS) (0-56) (d) | | 51.64±3.49 | 52.17±3.45 | 0.095 (a) |
| Time Up and Go Test (TUG) (sec) (e) | | 13.29 (11.00-15.00) | 12.64 (11.00-14.00) | 0.091 (b) |
| 6-Minute Walk Test (6-MWT) (d) | | | | |
| Distance (m) | | 378.18±60.65 | 371.76±65.98 | 0.233 (a) |
| Maximal heart rate reached (%) | | 58.84±3.00 | 58.76±3.02 | 0.079 (a) |
| PFS-16 (16-80) (d) | | 47.64±8.99 | 46.88±8.67 | 0.301 (a) |
| UPDRS-II (0-52) (e) | | 11.05 (6.00-14.50) | 11.11 (6.00-15.50) | 0.917 (b) |
| PDQ-39 (0-156) (d) | | 42.76±16.50 | 39.41±18.14 | 0.006 (a) |

*p<0.05. (a): Independent Samples t-Test. (b): Mann–Whitney U Test. (d): Mean±SD. (e): Median (IQR). MPT: Modified push-up test. PFS-16: Parkinson's Disease Fatigue Scale. UPDRS-II: Unified Parkinson's Disease Rating Scale-Motor assessment subscale. PDQ-39: Parkinson's Disease Quality of Life Questionnaire-39.

few studies have shown that exercise approaches reduce fatigue in PD,[42,43] there is no study yet examining the effect of Pilates on fatigue. This study is the first to show that Pilates reduces the fatigue level and the effect of fatigue on daily functions. We think that the improvement in muscle strength and endurance in the core and extremities, balance, mobility, and exercise capacity is related to the reduction of fatigue and the development of ADL skills.

In current study, it was observed that the QoL in the Pilates group more improved than the control group after the training. Cancela et al.[17] examined the feasibility and effectiveness of 12-week Pilates in 16 patients with mild and moderate PH. They stated that Pilates could be applied as a useful rehabilitation strategy to improve the QoL in PD. It can be said that the improvements in the QoL in PwPD are related to the improvements in physical performance and fatigue in our study. In addition, we think that the physiological benefits of exercise and its contribution to the mood of the individual may have been effective in the developments in the groups, too.

There was no significant improvement in the functional strength of the lower extremity, balance, walking performance, and exercise capacity in the control group. While the Pilates group performed the exercises under the guidance of a therapist, the control group applied it as a home program. In addition, although the control group with a home program was followed, the exercises may not have been done properly. The observation that the patients in the Pilates group increased their compliance with exercise and performed the exercises properly supports the improvements achieved.

### Limitations

This study had some limitations. Firstly, all participants were people with a mild-to-moderate stage of PD. Therefore, the results cannot be generalized in terms of an advanced stage of the disease. Second, there was no long-term follow-up. Future studies may be planned more comprehensively considering the limitations of this study.

### Conclusion

This study revealed that Pilates improves the core muscle thickness, core stability, lower extremity functional muscle strength, balance, functional mobility, functional exercise capacity, fatigue, ADL, and QoL. Therefore, Pilates may be suggested as an exercise method for PwPD.

**Acknowledgement:** *None*

**Authors' Contributions: DÇ:** study design, data collection/processing, literature search, writing, data analysis/interpretation, critical review; **AGG:** study design, literature search, writing, critical review; **AT:** providing subjects, literature search, writing, critical review; **MB:** providing subjects, literature search, writing, critical review; **MUÇ:** providing subjects, data collection/processing, literature search, writing, critical review; **SE:** literature search, writing, data analysis/interpretation, critical review

**Funding:** *None*

**Conflicts of Interest:** *None*

**Ethical Approval:** The protocol of the present study was approved by the Republic of Gazi University Faculty of Medicine Clinical Research Ethics Committee (issue: 2019/10 date: 10.09.2019).

## REFERENCES

1. Atroshi Alexander GE. Biology of Parkinson's disease: pathogenesis and pathophysiology of a multisystem neurodegenerative disorder. Dialogues Clin Neurosci. 2022;6:259-280.
2. Tomlinson CL, Herd CP, Clarke CE, et al. Physiotherapy for Parkinson's disease: a comparison of techniques. Cochrane Database Syst Rev. 2014;6:CD002815-CD002815.
3. Monticone M, Ambrosini E, Laurini A, et al. In-patient multidisciplinary rehabilitation for Parkinson's disease: a randomized controlled trial. Mov Disord. 2015;30:1050-1058.
4. Francardo V, Schmitz Y, Sulzer D, et al. Neuroprotection and neurorestoration as experimental therapeutics for Parkinson's disease. J Exp Neurol. 2017;298:137-147.
5. Fisher BE, Li Q, Nacca A, et al. Treadmill exercise elevates striatal dopamine D2 receptor binding potential in patients with early Parkinson's disease. Neuroreport. 2013;24:509-514.
6. Feng Y-S, Yang S-D, Tan Z-X, et al. The benefits and mechanisms of exercise training for Parkinson's disease. Life Sci. 2020;245:117345.
7. Combs SA, Diehl MD, Chrzastowski C, et al. Community-based group exercise for persons with Parkinson disease: a randomized controlled trial. NeuroRehabilitation. 2013;32:117-124.
8. Pohl M, Mrass GJ, Oertel WH. Rehabilitation in Parkinson's disease. Parkinson's disease: the treatment options LeWitt P, Oertel W, eds. 1st ed. Martin Dunitz Ltd, London; 1999:215-228.
9. Strojek K, Karpińska A, Piekorz Z, et al. Different forms movement therapy used in rehabilitation of Parkinson's disease. Health and Sport. 2018;8:290-298.
10. Bulguroglu I, Guclu-Gunduz A, Yazici G, et al. The effects of Mat Pilates and Reformer Pilates in patients with Multiple Sclerosis: A randomized controlled study. NeuroRehabilitation. 2017;41:413-422.
11. Deuel LM, Seeberger LC. Complementary therapies in Parkinson disease: a review of acupuncture, Tai Chi, Qi Gong, yoga, and cannabis. Neurotherapeutics. 2020;17:1434-1455.
12. Josephs S, Pratt ML, Meadows EC, et al. The effectiveness of Pilates on balance and falls in community dwelling older adults. J Bodyw Mov Ther. 2016;20:815-823.
13. Mollinedo-Cardalda I, Cancela-Carral JM, Vila-Suárez MH. Effect of a Mat Pilates Program with theraband on dynamic balance in patients with Parkinson's disease: feasibility study and randomized controlled trial. Rejuvenation Res. 2018;21:423-430.
14. Pandya S, Nagendran T, Shah A, et al. Effect of Pilates training program on balance in participants with idiopathic Parkinson's disease-An interventional study. Int J Heal Sci Res. 2017;7:186-196.
15. Johnson L, Putrino D, James I, et al. The effects of a supervised Pilates training program on balance in Parkinson's disease. Advances in Parkinson's disease. 2013;2:58-61.
16. Daneshmandi H, Sayyar S, Bakhshayesh B. The effect of a selective Pilates program on functional balance and falling risk in patients with Parkinson's disease. Zahedan J. Res. Med. Sci. 2017;19:7886.
17. Cancela JM, Mollinedo Cardalda I, Ayán C, et al. Feasibility and efficacy of mat pilates on people with mild-to-moderate Parkinson's

disease: A preliminary study. Rejuvenation Res. 2018;21:109-116.
18. Suresh K. An overview of randomization techniques: an unbiased assessment of outcome in clinical research. J Hum Reprod Sci. 2011;4:8-11.
19. Joyce AA, Kotler DH. Core training in low back disorders: role of the pilates method. Curr Sports Med Rep. 2017;16:156-161.
20. Whittaker JL, Stokes M. Ultrasound imaging and muscle function. J Orthop Sports Phys Ther. 2011;41:572-580.
21. Kim M-H, Oh J-S. Effects of performing an abdominal hollowing exercise on trunk muscle activity during curl-up exercise on an unstable surface. J Phys Ther Sci. 2015;27:501-503.
22. Rayes ABR, de Lira CAB, Viana RB, et al. The effects of Pilates vs. aerobic training on cardiorespiratory fitness, isokinetic muscular strength, body composition, and functional tasks outcomes for individuals who are overweight/obese: a clinical trial. PeerJ. 2019;7:6022.
23. Özyürek S, Bayraktar D, Genç A. Are the alterations in body posture related to decreased trunk muscle endurance in healthy young adults? J Back Musculoskelet Rehabil. 2018;31:431-436.
24. Zalleg D, Dhahbi AB, Dhahbi W, et al. Explosive push-ups: from popular simple exercises to valid tests for upper-body power. J Strength Cond Res. 2020;34:2877-2885.
25. De Blaiser C, De Ridder R, Willems T, et al. Evaluating abdominal core muscle fatigue: Assessment of the validity and reliability of the prone bridging test. Scand J Med Sci Sports. 2018;28:391-399.
26. Duncan RP, Leddy AL, Earhart GM. Five times sit-to-stand test performance in Parkinson's disease. Arch Phys Med Rehabil. 2011;92:1431-1436.
27. Goodwin VA, Richards SH, Taylor RS, et al. The effectiveness of exercise interventions for people with Parkinson's disease: a systematic review and meta-analysis. Mov Disord. 2008;23:631-640.
28. Podsiadlo D, Richardson S. The timed "Up and Go" test. Arch Phys Med Rehabil. 1989;67:387-389.
29. Gibbons WJ, Fruchter N, Sloan S, et al. Reference values for a multiple repetition 6-minute walk test in healthy adults older than 20 years. J Cardiopulm Rehabil Prev. 2001;21:87-93.
30. Fu R, Cui SS, Du JJ, et al. Validation of the Parkinson Fatigue Scale in Chinese Parkinson's disease patients. Brain Behav. 2017;7:00712.
31. Çilga G, Genç A, Çolakoğlu BD, et al. Turkish adaptation of Parkinson fatigue scale and investigating its psychometric properties. Int J Rehabil Res. 2019;42:20-25.
32. Opara J, Małecki A, Małecka E, et al. Motor assessment in Parkinsons disease. Ann Agric Environ Med. 2017;24:411-415.
33. Akbostancı M, Balaban H, Atbaşoğlu C. Birleşik Parkinson Hastalığı Değerleme Ölçeği Motor Muayene Bölümü ve Anormal İstemsiz Hareketler Ölçeği'nin değerlendiriciler arası güvenilirlik çalışması. Parkinson Hastalığı ve Hareket Bozuklukları Dergisi. 2000;3:7-13.
34. Jesus-Ribeiro J, Vieira E, Ferreira P, et al. Reliability and Validity of 39-Item Parkinson's Disease Questionnaire and Parkinson's Disease Quality of Life Questionnaire. Acta Med Port. 2017;30:395-401.
35. Kayapınar T. Parkinson Hastalığı Yaşam Kalitesi Anketi (PDQ-39) Güvenirlik ve Geçerlilik Çalışması [Yüksek Lisans Tezi]. İstanbul: Haliç Üniversitesi; 2018.
36. Batıbay S, Külcü DG, Kaleoğlu Ö, et al. Effect of Pilates mat exercise and home exercise programs on pain, functional level, and core muscle thickness in women with chronic low back pain. J Orthop Sci. 2021;26:979-985.
37. Cruz-Díaz D, Bergamin M, Gobbo S, et al. Comparative effects of 12 weeks of equipment based and mat Pilates in patients with Chronic Low Back Pain on pain, function and transversus abdominis activation. A randomized controlled trial. Complement Ther Med. 2017;33:72-77.
38. Rodríguez-Fuentes G, Silveira-Pereira L, Ferradáns-Rodríguez P, et al. Therapeutic Effects of the Pilates Method in Patients with Multiple Sclerosis: A Systematic Review. J Clin Med Res. 2022;11:683.
39. Göz E, Özyürek S, Aktar B, et al. The effects of Pilates training on abdominal muscle thickness and core endurance in patients with Parkinson's disease: a single-blind controlled clinical study. Turk J Med Sci. 2023;53:990-1000.
40. Bliss LS, Teeple P. Core stability: the centerpiece of any training program. Curr Sports Med Rep. 2005;4:179-183.
41. Herlofson K, Kluger BM. Fatigue in Parkinson's disease. J Neurol Sci. 2017;374:38-41.
42. Ortiz-Rubio A, Cabrera-Martos I, Torres-Sánchez I, et al. Effects of a resistance training program on balance and fatigue perception in patients with Parkinson's disease: A randomized controlled trial. Med Clin. 2018;150:460-464.
43. Lamotte G, Rafferty MR, Prodoehl J, et al. Effects of endurance exercise training on the motor and non-motor features of Parkinson's disease: a review. J Parkinsons Dis. 2015;5:21-41.