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Original Article

# The effects of Pilates exercise training on static and dynamic balance in chronic stroke patients: a randomized controlled trial

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**Abstract.** [Purpose] The purpose of this study was to analyze the effects of Pilates exercise on static and dynamic balance in chronic stroke patients. [Subjects and Methods] Nineteen individuals with unilateral chronic hemiparetic stroke (age, 64.7 ± 6.9 years; height, 161.7 ± 7.9 cm; weight, 67.0 ± 11.1 kg) were randomly allocated to either a Pilates exercise group (PG, n=10) or a control group (CG, n=9). The PG attended 24 exercise sessions conducted over an 8-week period (3 sessions/week). Center of pressure (COP) sway and COP velocity were measured one week before and after the exercise program and compared to assess training effects. [Results] Pilates exercise positively affected both static and dynamic balance in patients with chronic stroke. For static balance, COP sway and velocity in the medial-lateral (M-L) and anterior-posterior (A-P) directions were significantly decreased in the PG after training while no significant differences were found in the CG. For dynamic balance, measured during treadmill walking, the PG showed significantly reduced COP sway and velocity in the M-L and A-P directions for both the paretic and non-paretic leg. [Conclusions] The findings provide initial evidence that Pilates exercise can enhance static and dynamic balance in patients with chronic stroke.

**Key words:** Stroke, Balance, Exercise training

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## INTRODUCTION

A stroke is a cerebrovascular event in which the supply of blood delivered to the brain is significantly altered[1–3)]. The resulting deficits or impairments following stroke vary according to the location and extent of the lesion, but often include hemiparesis, communication disorders, and cognitive deficits[4)]. In isolation or combined, these deficits often lead to significant difficulty completing activities of daily living. Even after extensive rehabilitation, up to 50% of stroke survivors experience lingering motor deficits[4, 5)]. Although the majority of stroke patients are able to walk independently, most do not reach a walking level that enables them to perform all of their daily activities. Impaired walking function, including reduced gait stability and asymmetric walking, is a common neurological deficit following stroke[4)]. For example, Laufer et al. reported that the nonparetic lower limb assumes 61–80% of the full body weight during normal walking in patients with hemiparesis[5)]. Asymmetric walking caused by hemiparalysis can become a cause of instability during daily activities, and these patients have a higher rate of falls than elderly individuals in the general population[4)]. Thus, gait recovery is a major objective of rehabilitation programs for patients with stroke.

Recent studies about hemiplegia include multifaceted explorations of gait and balance problems. Studies have focused especially on the musculoskeletal effects of stroke, such as strength and muscle density, which are implicated in gait and balance problems[6–8)].

Diminished muscle activity has been identified as a factor contributing to balance impairment in patients with hemiplegia,

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and as such, treatment to increase muscle activity has been attempted as a method to improve balance capacity[9].

Trunk muscles are activated during the rhythmic movement that is part of the execution of gait. Core strengthening exercises are used to specifically strengthen the trunk muscles and have become a specialty area in the field of rehabilitation[10].

Recently, in the United States and Europe, Pilates has become a target of interest as a useful exercise. Pilates exercises were developed by Joseph H. Pilates (1880–1967) as an exercise method to relax and strengthen the body. The exercises have a scientific, rational system for adjusting the center of the body[11].

Pilates training is based on 8 principles: control, breathing, flowing movement, precision, centering, stability, range of motion, and opposition. Mat-based Pilates exercises have been developed that use equipment for those who cannot exercise more vigorously due to injury or poor health.

As strength-based exercises are directly connected to health, they can be an effective method to improve balance ability and can also be used to correct postural deviations for a flexible and balanced body[11, 12].

A recent study on balance and Pilates demonstrated that Pilates can be effective for enhancing both static and dynamic equilibrium capacity in university students in a 16-week mat exercise course[13]. In another study, by Changgiun[14], balance ability was again improved through a Pilates exercise program.

Based on these findings, we hypothesized that Pilates exercise training could be an effective post-stroke rehabilitation method to address impairments frequently encountered by patients with stroke, such as flexibility, somatosensory loss, muscular strength, and balance[15–18].

Currently, most of the studies on Pilates training programs have focused on orthopedic remedial exercise[19–21] or balance improvement in the elderly[16, 21, 22]. Rydeard et al. reported that patients with low back pain described a lower level of functional disability after 4 weeks of Pilates intervention[21]. Bird et al. reported that a 5-week Pilates training course for the elderly contributed to greater benefits in static and dynamic balance compared to usual activity[16]. Fewer studies have investigated the effects of Pilates in patients with neurologic conditions. Of these, the majority have focused on patients with multiple sclerosis[22–26], and no studies have been conducted on the rehabilitation of patients with chronic stroke.

Therefore, the purpose of this study was to investigate the effects of an 8-week mat-based Pilates exercise training program on the static and dynamic balance abilities of patients with chronic stroke.

## SUBJECTS AND METHODS

Thirty participants were initially recruited from the Rehabilitation Center for the Disabled located in Uijeongbu, Gyeonggi Province, Korea. The inclusion criteria stated that each participant must be at least 2 years post stroke, medically stable with a physician release granting approval to initiate and complete an exercise program, able to walk independently without an assistive device, and willing to participate in a Pilates exercise class. Participants were excluded if they had visual impairment, hearing damage, uncontrolled high blood pressure, or were unable to understand the nature of the experiment. Participants who were receiving physical therapy separately were also excluded from this study.

In total, 10 participants were excluded because they were participating in individual physical therapy sessions, and one participant dropped out of the control group due to hospital admission during the intervention period. Finally, nineteen individuals with chronic hemiparetic stroke participated in the study (age, 64.7 ± 6.9 years; height, 161.7 ± 7.9; and weight, 67.0 ± 11.1). Written informed consent was obtained from each participant after explaining the study. The research protocol was approved by the institutional review board of Sahmyook University.

Following participant selection, they were randomized into two groups, a Pilates exercise training group (PG) and a control group (CG). During the intervention period, the PG was given Pilates exercise training, while the CG was not given any exercises or treatment at the Center for the Disabled.

The Pilates training program was based on mat classes lasting one hour per class, three times a week for 8 weeks. In this study, two certified Pilates instructors and one physical therapist were in charge of the class. One instructor demonstrated movements for patients to follow and the other instructor and the physical therapist assisted patients with the exercise. All movements included in the Pilates training was based on 8 1 set of 8 repetitions per exercise. To improve core stability, breathing exercises were conducted in a sitting position before and after all training sessions. The mat based Pilates training was composed of spine mobility exercises, upper limb exercises, and lower limb strengthening exercises. The exercises were composed of the following detailed movements: 1) Spine mobility- chin up and down, forward spine stretch, and side spine stretch in sitting with theraband; 2) Upper limb exercise- draw a sword, and deltoid lift in sitting with theraband; and 3) Lower limb strengthening exercise- top leg pulse-down and bottom leg pulse-up in sidelying using the magic circle, and foot and ankle strengthening in sitting with theraband. Unlike general Pilates training, lower limb strengthening exercises help to strengthen the quadriceps, gluteus medius, adductor magnus, gastrocnemius, and anterior tibialis. Additionally, for gluteal activation, a gluteal series including Charlie Chaplin exercises, swimming, and a heel squeeze in prone with a ball under the chest were performed, along with a prone bridge.

To verify the effects of the 8-week Pilates training course on the static and dynamic balance of patients with chronic stroke, two data collection protocols were conducted one week before and after the training. The variables assessed were center of pressure (COP) sway and velocity.

To measure static balance, participants wore familiar shoes, and were asked to stand on an instrumented treadmill (FIT, Bertec Corp., USA)with their eyes open and arms at their sides comfortably for 30 seconds. Each foot was placed on a separate force plate located under the treadmill belts and foot position was measured and maintained for each evaluation.

To measure dynamic balance, participants were asked to walk on the instrumented treadmill at their self-selected velocity. The over-ground self-selected velocity was determined for each participant beforehand and the treadmill belt speed was set to match that velocity during the evaluation. When it was determined that subjects were exhibiting natural walking movements (after about 3–5 seconds), data for 5 consecutive strides were collected.

A total of 5 static and dynamic trials were conducted for each subject, and average values from the trials were used for data analysis. Original COP data were collected at 1,000 Hz, and anterior-posterior (A-P) and medial-lateral (M-L) directional COP sway, as well as velocity with time series, were computed and evaluated.

Independent samples t-test and $\chi^2$ analysis were used for homogeneity testing. The 8-week Pilates training effects were assessed using a paired t-test, and an independent samples t-test was conducted to compare the differences in subordinate variables between the groups. The level of significance for all comparisons was set as $\alpha=0.05$.

# RESULTS

No significant differences in general characteristics were noted between the groups ($p>0.05$, Table 1). For static balance, COP sway significantly decreased in the PG in both the A-P and M-L directions ($p<0.05$, Table 2). All dynamic balance parameters for both legs improved significantly in the PG after training ($p<0.05$, Tables 3 and 4). For all static and dynamic balance parameters, significant differences after training were found between the PG and the CG, although there were no significance differences at baseline ($p<0.05$, Tables 3 and 4).

# DISCUSSION

We examined the effects of Pilates exercise training on static and dynamic balance in patients with chronic stroke. To our knowledge, this investigation is the first to show improvements in static and dynamic balance following Pilates training in this population. One of the important purposes of this study was to determine whether training that had been performed for balance improvement in the elderly could be effectively applied to patients with chronic stroke[16, 18, 22, 23, 27, 28].

In this study, the PG demonstrated 26% and 34% improvement in static balance in the A-P and M-L directions, respectively (Table 2, $p<0.05$). The results of this study support the findings of studies conducted on the effects of Pilates training in the elderly. In a study by Newell et al., an 8-week Pilates training course contributed to a 40% improvement in A-P COP sway in the elderly[28]. Further, Bird et al. reported that a 5-week Pilates training course led to a 16–22% improvement in M-L COP sway ($p<0.001$) during challenging balance tasks[16]. In our study, the improvement in static balance was attributed to the

**Table 1.** General characteristics of subjects

| | PG (n=10) | CG (n=9) |
|---|---|---|
| Gender (male/female) | 10 (5/5) | 9 (5/4) |
| Age (years) | 66.80 ± 5.7 | 61.11 ± 6.6 |
| Height (cm) | 159.75 ± 8.9 | 163.57 ± 10.4 |
| Weight (kg) | 65.01 ± 12.6 | 66.43 ± 10.9 |
| Duration (years) | 12.80 ± 3.0 | 13.20 ± 6.3 |
| Stroke type (hemorrhage/Infarction) | 10 (4/6) | 9 (5/4) |
| Paretic side (left/right) | 10 (6/4) | 9 (5/4) |

PG: Pilates training group; CG: control group.
Values are expressed as mean ± standard deviation (SD).

**Table 2.** Changes in static balance ability

| Variables | PG (n=10) | CG (n=9) |
|---|---|---|
| M-L COP range (mm) | | |
| Pre | 10.85 ± 5.0 | 11.72 ± 5.4 |
| Post | 7.11 ± 2.2 | 16.10 ± 6.1 |
| Pre-Post | −3.74 ± 3.3* | 1.61 ± 3.0† |
| A-P COP range (mm) | | |
| Pre | 14.75 ± 8.0 | 16.10 ± 6.1 |
| Post | 10.47 ± 3.7 | 16.82 ± 5.0 |
| Pre-Post | −4.28 ± 4.9* | 0.72 ± 4.6† |
| M-L COP velocity (mm/s) | | |
| Pre | 83.94 ± 42.1 | 84.24 ± 45.0 |
| Post | 66.48 ± 26.6 | 86.69 ± 41.9 |
| Pre-Post | −17.46 ± 24.4* | 2.45 ± 4.8† |
| A-P COP velocity (mm/s) | | |
| Pre | 122.00 ± 47.6 | 130.48 ± 45.8 |
| Post | 104.55 ± 42.0 | 135.78 ± 43.2 |
| Pre-Post | −17.45 ± 11.9* | 5.30 ± 7.2††† |

A-P COP: anterior-posterior center of pressure; M-L COP: medial-lateral center of pressure.
Values are expressed as mean ± standard deviation (SD).
*Means significant difference within group; †Means significant difference between groups

8-week Pilates training course that improved muscle control of the deeper abdominal muscles (i.e., transversus abdominis, lumbar multifidus, and the respiratory and pelvic diaphragms). Conversely, Bird et al. found no significant training effects on balance performance while standing on a firm surface[16]. The reason our results differ may be due to the difference in training period and frequency. In the present study, stroke survivors were trained for 3 times/week for 8 weeks, while patients in the study by Bird et al. were trained 2 times/week for 5 weeks[16]. This suggests that there may be a dose response effect that should be verified in future studies.

In this study, the PG demonstrated significant improvements (15–22%) in dynamic stability in the A-P and M-L directions for both the paretic and nonparetic foot after training (Tables 3 and 4, $p<0.05$). The results of this study are similar to other intervention studies. Sator et al. reported that polyneuropathy patients demonstrated a 20% reduction in COP velocity of the midfoot during walking after a 12-week ankle strengthening program ($p<0.05$)[29] and Lim and Yoon revealed that the elderly exhibited a 32% decrease in COP sway during obstacle walking as a result of a 12-week underwater training program ($p<0.05$)[30]. It has been reported that in dynamic situations (i.e., walking), COP velocity is directly related to center of mass (COM) acceleration, which represents human movement along with COP sway, and that the reduction of COP variables represents increased balance during walking[31]. Unlike general Pilates training, lower limb strengthening exercises were added to our Pilates program. This could help patients increase muscles force production and subsequently improve their dynamic balance. Given that COP variables in the M-L direction are closely related to the risk of falls[32, 33], the improvement of COP variables in this direction increases the expectation that Pilates training may have an influence on the reduction of fall risk in patients with chronic stroke.

To our knowledge, this is the first study using Pilates training as an intervention to improve static and dynamic balance in patients with chronic stroke. Despite the documented effects on balance, Pilates training has not yet been applied to the rehabilitation of patients with chronic stroke. However, as a result of this study, the 8-week Pilates training program has been proven fully effective for the treatment of static and dynamic balance in patients with chronic stroke.

However, in using this intervention for the rehabilitation of patients with chronic stroke, careful attention will be needed on several points. First, unlike general muscular strength training or aerobic exercises, maintaining the correct posture is very important in Pilates training, and it should only be carried out by qualified instructors supervising a small number of participants per session. In this study, the number of participants in a class was restricted to 8[11], and the same class was offered 6 times a week so that patients would not be inconvenienced by attending classes 3 days a week. Second, given the previous finding that a 5-week Pilates training program for the elderly did not influence balance on firm surfaces[15], a minimum of 8-weeks is suggested as a suitable training period.

As Pilates training for patients with chronic stroke has not been reported, this study could only be compared to studies of Pilates training for the elderly. Moreover, this study did not include other variables (e.g., gait parameters or EMG activity)

**Table 3.** Changes in dynamic balance ability on the paretic side in stance phase

| Variables | PG (n=10) | CG (n=9) |
|---|---|---|
| M-L COP range (mm) | | |
| Pre | 15.0 ± 2.1 | 16.0 ± 2.4 |
| Post | 12.0 ± 1.4 | 16.3 ± 2.4 |
| Pre-Post | −3.0 ± 2.4** | 0.4 ± 1.0† |
| A-P COP range (mm) | | |
| Pre | 27.0 ± 3.2 | 26.2 ± 3.7 |
| Post | 22.4 ± 2.7 | 26.5 ± 2.9 |
| Pre-Post | −4.6 ± 1.2*** | 0.3 ± 1.2††† |
| M-L COP velocity (mm/s) | | |
| Pre | 88.6 ± 33.5 | 91.8 ± 39.8 |
| Post | 76.5 ± 25.6 | 92.6 ± 38.8 |
| Pre-Post | −12.1 ± 8.4* | 0.7 ± 2.2††† |
| A-P COP velocity (mm/s) | | |
| Pre | 114.8 ± 31.2 | 117.0 ± 30.6 |
| Post | 98.3 ± 25.2 | 117.1 ± 29.1 |
| Pre-Post | −16.5 ± 6.6** | 0.1 ± 2.7††† |

A-P COP: anterior-posterior center of pressure; M-L COP: medio-lateral center of pressure.
Values are expressed as mean ± standard deviation (SD).
*Means significant difference within group; †Means significant difference between groups

**Table 4.** Changes in dynamic balance ability on the non-paretic side in stance phase

| Variables | PG (n=10) | CG (n=9) |
|---|---|---|
| M-L COP range (mm) | | |
| Pre | 12.7 ± 1.2 | 13.7 ± 2.2 |
| Post | 10.4 ± 0.8 | 14.2 ± 1.9 |
| Pre-Post | −2.4 ± 0.6*** | 0.44 ± 0.62††† |
| A-P COP range (mm) | | |
| Pre | 23.2 ± 2.4 | 22.1 ± 3.6 |
| Post | 18.2 ± 1.2 | 22.9 ± 3.3 |
| Pre-Post | −5.0 ± 1.6*** | 0.77 ± 1.1††† |
| M-L COP velocity (mm/s) | | |
| Pre | 79.0 ± 28.3 | 86.04 ± 27.2 |
| Post | 66.5 ± 21.2 | 87.16 ± 26.3 |
| Pre-Post | −12.5 ± 7.5* | 1.12 ± 2.6††† |
| A-P COP velocity (mm/s) | | |
| Pre | 89.7 ± 28.8 | 96.9 ± 27.5 |
| Post | 73.2 ± 17.9 | 97.0 ± 25.1 |
| Pre-Post | −16.6 ± 11.3* | 0.1 ± 3.3†† |

A-P COP: anterior-posterior center of pressure; M-L COP: medial-lateral center of pressure.
Values are expressed as mean ± standard deviation (SD).
*Means significant difference within group; †Means significant difference between groups

that may be used to assess static and dynamic balance improvements after Pilates training. Therefore, follow-up studies should be performed to investigate the impact of Pilates training on gait parameters or lower limb EMG activity related to balance measures.

This study proved that an 8-week Pilates training program improved the static and dynamic balance of patients with chronic stroke. If Pilates training that strengthens the deeper abdominal muscles is sustained for this duration, than these results can be obtained. Therefore, if these training parameters are used in the clinic when it becomes appropriate for the patient, a Pilates program can be an effective treatment for the recovery of walking ability, which is the highest objective of rehabilitation for patients with chronic stroke. Given these results, Pilates training should be considered as a rehabilitation intervention for balance improvement in patients with chronic stroke.

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