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Original Article

Effects of 8 weeks of mat-based Pilates exercise on gait in chronic stroke patients

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Abstract. [Purpose] The purpose of this study was to investigate the effects of an 8-week program of Pilates exercise on gait in chronic hemiplegia patients and to determine whether or not it can be used for rehabilitation in postsrtoke patients. [Subjects and Methods] Twenty individuals with unilateral chronic hemiparetic stroke (age, 66.1 ± 4.4 yrs; height, 162.3 ± 8.3 cm; weight, 67.4 ± 12.3 kg) participated in this study and were randomly allocated equally to either a Pilates exercise group or a control group. To identify the effects of Pilates exercise, a 3-D motion analysis with 8 infrared cameras was performed. [Results] For the gait parameters, improvements were found in the Pilates exercise group for all variables, and statistical significance was observed for stride length, gait velocity, knee range of motion and hip range of motion. For the asymmetry indexes, insignificant improvements were found for all variables in the Pilates exercise group. [Conclusion] In conclusion, an 8-week program of Pilates exercise had a positive influence on improving the gait ability of poststroke patients, and the intervention could be applied to poststroke patients with various levels of physical disability by adjusting the intensity of training.
Key words: Stroke rehabilitation, Pilates exercise, Hemiplegic gait

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INTRODUCTION

Stroke refers to cerebrovascular bleeding and a neural disease caused by nontraumatic reasons and is accompanied by brain damage or functional loss of lower body muscles on the paretic side[1, 2)]. Despite the development of modern medicine, economic growth, and widening interests in health, its occurrence is increasing quickly due to unbalanced lifestyles, environmental pollution, and excess stress in fast-paced societies[1, 2)]. It has been reported that loss of motor ability and balance due to stroke can limit some daily living activities such as walking and may lead to secondary injury like falls. Generally, gait in stroke patients is characterized by reduced gait parameters[3–5)], and decreased gait function following stroke in particular is known as the fundamental reason why patients fail to safely return to society[6–8)].

Yang et al.[9)] reported that because hemiplegia patients with lesions support more than 60% of the load on the non-paretic limb during standing, it could result in an asymmetric gait pattern. They also reported that a stroke patient group showed lower gait velocity, stride time, stride length, and cadence compared with a group of healthy elderly. Grasies[10)] and Vattanasilp et al.[11)] showed that patients with stroke tend to reduce the range of motion (ROM) of paretic lower limb joints during walking, while Fonseca et al.[12)] reported that increased stiffness of the hip joint can reduce energy efficiency, which results in limited walking and running movement. In addition, Turnbull et al.[13)], who analyzed the gait cycles of eight elderly hemiplegia patients for ten years, reported that the patients showed increased double support time and decreased single support time during walking, indicating that patients tended to walk as slowly and stably as possible to secure stability.

As reported from previous studies, the predominant characteristic of hemiplegia patients with stroke is the difficulty with walking due to weakened lower limb muscles and imbalance. Therefore, many researchers have conducted studies focusing

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on the recovery of gait ability as the ultimate purpose of rehabilitation of patients with stroke[14–16].

Recently, Pilates exercise has been introduced[17–23]. Pilates exercise is also called Contrology and it is based on the idea of muscle control. It focuses to make a neutral spine of body to prevent excess flexion and extension of the spine when walking upright[17, 18]. Since Pilates exercise has been shown to have positive effects on development of muscular strength and endurance and improvement of flexibility, it has been used not only for exercise programs for healthy adults but also for rehabilitation for the elderly[19, 21]. Moreover, unlike other exercise programs, Pilates exercise can be performed with various tools to adjust the fitness level for the elderly, who have weaker physical strength and it can be performed at home without having to visit a rehabilitation center[22, 23]. As Pilates is reported to develop the deep core muscles, which helps to improve the stability of spine, reduce back pain, and control the pelvis and hip joints[24–30], it is thought to have a positive influence on gait ability, and many researchers have actually reported the effectiveness of Pilates exercise on gait ability for the elderly[17, 18, 21].

Despite the various positive effects of Pilates, however, it is still not widely applied to stroke patients. Therefore, the purpose of this study was to investigate the effects of an 8-week program of Pilates exercise on gait in chronic hemiplegia patients and to determine whether or not it can be used for rehabilitation in poststroke patients.

SUBJECTS AND METHODS

Twenty poststroke participants (age, 66.1 ± 4.4 yrs; height, 162.3 ± 8.3 cm; weight, 67.4 ± 12.3 kg) were recruited for this study. The exclusion criteria for the poststroke participants included moderate/severe chronic white matter disease on MRI or orthopedic and other gait-influencing diseases such as arthrosis or history of lower-extremity joint replacement. Participants who were involved in other studies or rehabilitation programs were also excluded from this study. The objective and requirements of this study were explained to all participants, and written informed consent was obtained from each participant prior to participation. The university's institutional review board approved the study protocol.

After completing participants selection, the participants were randomized into two matched number groups: the Pilates exercise group (EG) and control group (CG). During the intervention period, the EG performed Pilates exercise, while the CG did not perform any kind of exercises or receive any treatment.

The Pilates exercise program used in this study was conducted by two certified Pilates instructors and one physical therapist three times a week, 60 minutes per session, for 8 weeks. The exercise was composed of warm-up exercise, the main exercise, and cool-down exercise. For improving core muscles stability, breathing exercises were conducted in a sitting posture before and after the main exercise. The details of the program are provided in Table 1.

In order to investigate the effects of the 8 weeks of Pilates exercise, a 3-D motion analysis with 8 infrared cameras (Oqus, Qualisys, Sweden) was performed twice (a week before and after the Pilates exercise period). The subjects were required to wear black spandex shorts, a dark T-shirt, and a pair of walking/running shoes during data collection. To identify lower limb movements, 12 reflective markers were attached to the lower body. After sufficient warm-up, each subject was asked to

Table 1. Pilates exercise program

	Program
Warm-up exercise 10 min	1. Breathing: 8 sets 2. Chin up & down: 8 sets 3. Spine stretch forward: 8 sets
Main exercise 40 min	1. Spine stretch side: 8 sets 2. Draw a sword: 8 sets 3. Deltoid lift: 8 sets 4. Foot and ankle strengthener: 8 sets 5. Abdominals with head support: 8 sets 6. Top leg pulse-downs: 8 sets 7. Bottom leg pulse-ups: 8 sets 8. Deep abdominal cue: 8 sets - between the leg - around the leg 9. Prone glute series-Charlie Chaplin: 8 sets 10. Prone glute series-swimming: 8 sets 11. Bridge: 8 sets 12. Prone glute series-heel squeeze: 8 sets
Finishing exercise 10 min	1. Breathing: 8 sets 2. Swan: 8 sets

walk on a treadmill (Instrumented Treadmill, Bertec, USA), and his/her walking trials were captured with sampling rate of 100 Hz. The cameras were positioned around the treadmill for sufficient tracking redundancy and were calibrated using the NLT (non-linear transformation) method. The treadmill speed was set at each subjects' preferred speed which was measured before the experiment. Each subject was recorded while walking for 30 seconds, and five strides from the middle of the recording were used for analysis.

To evaluate the asymmetric pattern of gait parameters, the asymmetry index proposed by Robinson et al.[31] was used.

$$\text{Asymmetry}(\%) = \frac{\left|X_{\text{paretic}} - X_{\text{non-paretic)}}\right|}{\frac{1}{2} \times \left(X_{\text{paretic}} + X_{\text{non-paretic}}\right)} \times 100$$

$X_{paretic}$ and $X_{non\text{-}paretic}$ are the values of a gait parameters recorded for the paretic and non-paretic limbs, respectively.

To verify the effect of the 8-week Pilates exercise on the gait of poststroke patients, the two-way ANOVA with repeated measure was used, and statistical significance was set at α=0.05.

RESULTS

The gait parameters and asymmetry indexes before and after the 8 weeks of exercise are presented in Tables 2 and 3. For the gait parameters, increased patterns were found for all variables and statistical significances were found for stride length, gait velocity, knee ROM, and hip ROM (Table 1, $p<0.05$). For the asymmetry indexes, insignificant improvements were found for all variables (Table 2, $p>0.05$).

DISCUSSION

The main purpose of this study was to examine the effectiveness of an 8-week Pilates exercise on walking in poststroke patients and to provide guidance for physical therapy whether or not the exercise can be used for rehabilitation in poststroke patients. Gait in stroke patients is characterized by reduced temporospatial variables, reduced ROM of lower extremity joints, and asymmetry in the lower extremities[3–5]. In this study, it was proved that an 8-week Pilates exercise program effectively

Table 2. Kinematic gait parameters between exercise periods

Variables		Control	Training
		Pre-training	Post-training
Stride length (cm)		33.25 ± 12.90	43.91 ± 19.35*†
Stride time (s)		1.52 ± 0.36	1.40 ± 0.32
Stride velocity (cm/s)		21.54 ± 3.41	31.48 ± 12.81*†
Step length (cm)	Paretic	17.22 ± 4.24	24.63 ± 8.25
	Non-paretic	16.03 ± 8.69	19.28 ± 11.28
Hip ROM (deg)	Paretic	22.55 ± 5.91	22.77 ± 6.84
	Non-paretic	26.01 ± 10.43	30.61 ± 5.47*
Knee ROM (deg)	Paretic	25.30 ± 12.55	20.38 ± 3.08
	Non-paretic	48.39 ± 8.89	52.03 ± 8.72*
Ankle ROM (deg)	Paretic	12.14 ± 2.83	11.67 ± 6.76
	Non-paretic	14.69 ± 2.39	19.96 ± 6.07

Values are group mean ± standard deviation. *Significant difference between pre- and post- Pilates training. †Significant difference between groups ($p<0.05$)

Table 3. Asymmetry indexes of kinematic gait parameters between training periods (Unit: %)

Variables	Control		Training	
	Pre-training	Post-training	Pre-training	Post-training
Step length	28.2 ± 25.7	33.1 ± 35.0	39.3 ± 29.2	37.2 ± 33.5
Hip ROM	42.4 ± 37.9	44.8 ± 34.7	35.5 ± 24.3	31.9 ± 20.0
Knee ROM	67.6 ± 51.0	68.1 ± 40.8	71.4 ± 48.7	65.9 ± 45.4
Ankle ROM	52.1 ± 40.1	50.9 ± 47.7	52.2 ± 36.1	48.4 ± 21.0

Values are group mean ± standard deviation.

improved patients' gait parameters.

Since gait speed is easy to measure and a reliable outcome of rehabilitation, it has been widely used in studies on stroke patients[3, 30]. Gait speed is increased when stride length is increased or stride time is decreased. In this study, the Pilates exercise group showed a statistically significantly improved gait speed, whereas the control group did not (Table 1, $p<0.05$). The subjects in the Pilates exercise group seem to have increased their gait speed by increasing their stride length after the exercise period (Table 1, $p<0.05$). This is probably because the Pilates exercise developed the deep muscles, such as the transverse abdominis and internal oblique that take charge of the stability of the body and this may have helped to improve the stability of spine and the muscular strength and flexibility of the pelvis and hip joints[24–29]. Unlike general Pilates exercise, the Pilates exercise used in the present study included lower limb strengthening exercise. This exercise may strengthen the quadriceps, gluteus medius, adductor magnus, gastrocnemius, and anterior tibialis, which can help to increase stride length. The effect of strengthening the deep muscles is also seen in the increased ROM of the lower extremity joints in the Pilates exercise group after the exercise period (Table 1, $p<0.05$).

Another gait characteristic of stroke patients is that over 60% of weight is loaded on the lower limb on the non-paretic side during walking, so they show asymmetrical gait in temporospatial parameters[9]. The present study showed no statistical differences in the asymmetry indexes of variables in either group. In the case of the exercise group, however, insignificantly improved symmetric patterns were found (from 5.3% to 10.1%) after the exercise period (step length, 5.3%; Hip ROM, 10.1%; Knee ROM, 7.7%; Ankle ROM, 7.3%; $p>0.05$, Table 2). The lack of statistically significant improvements in asymmetry indexes was probably the result of a limited number of subjects or a short exercise period. In this study, we chose eight weeks as the exercise period because many previous intervention studies for elderly have shown the effectiveness of 8-week interventions. As Pilates exercise strengthens the deep muscles, however, it is thought to require a longer exercise period compared with resistance training, cardiovascular exercises, or underwater exercises, which strengthen the superficial muscles. This issue should be examined in a follow-up study.

In conclusion, this study proved the effect of Pilates exercise, which has not been used as a means of intervention to rehabilitate motor functions of poststroke patients. The 8-week program of Pilates exercise had a positive influence on improving the gait ability of poststroke patients, and the intervention could be applied to poststroke patients with various levels of physical disability by adjusting the intensity of exercise.

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