PILOT STUDY

The Effect of Gait Training on a Sandy Beach in Patients with Chronic Stroke: A Randomized Controlled Pilot Study

Junekyung Lee, MD; Min Ho Chun, MD, PhD; Jiyeon Lee, PT, MSc; Jieun Kim, PT

ABSTRACT

Background • A sandy beach provides an unstable support surface and may influence walking ability in patients with stroke.
Primary Study Objective • To investigate the effect of gait training on a sandy beach in patients with chronic stroke.
Methods/Design • This was a randomized controlled trial.
Setting • Patients were recruited from a community center.
Participants • A total of 28 patients with chronic stroke participated in the study.
Intervention • Patients were randomly assigned to receive gait training either on a sandy beach (sand group) or firm ground (control group). All patients received gait training for 30 minutes per session, 2 sessions every day for 5 days.
Primary Outcome Measures • Primary outcomes were 10-minute walk test (10MWT) and Berg Balance Scale (BBS) scores. Secondary outcomes were Functional Ambulatory Category (FAC), Timed Up and Go (TUG) and spatiotemporal parameters of gait evaluated with a wearable inertial sensor. Psychological parameters, including the Beck Depression Inventory (BDI) and State-Trait Anxiety Inventory (STAI), were also measured. Outcome measurements were evaluated at baseline and after the intervention.
Results • The 10MWT and BBS scores were significantly improved in the sand group ($P < .05$). Compared with the changes from pre- to post-treatment between the groups, 10MWT showed a large effect size and BBS score showed a medium effect size. Regarding spatiotemporal parameters, cadence and gait velocity were significantly higher after training than before training in the sand group ($P < .05$). Compared with the changes from pre- to post-treatment between groups, cadence and gait velocity showed large effect sizes and affected-side stride length showed a medium effect size. There was no difference in the changes from pre- to post-treatment in BDI and STAI between the 2 groups ($P > .05$). No adverse events occurred during the study.
Conclusion • Gait training on a sandy beach may be beneficial for improving walking ability and balance in patients with stroke (*Altern Ther Health Med.* 2023;29(3):97-103).

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INTRODUCTION

Stroke is a main cause of disability, and neurologic deficits due to stroke can be sustained, resulting in chronic disability.[1] In many patients with stroke, gait disturbance occurs due to a combination of muscle weakness, impaired motor control, proprioceptive deterioration and decreased balance. Recovery of gait function is achieved within the first 11 weeks.[3] After this time, a small amount of additional improvement in gait may be acquired, and the remaining abnormalities persist into the chronic phase.[1] This limits activities of daily living and independence and eventually restricts social activities.[4] Thus, gait recovery is the main goal of rehabilitation therapy in patients with stroke.[1,2,5]

Common approaches to improving gait recovery include high-intensity therapy, task-based training, neurodevelopmental techniques and muscle strengthening.[5] Recently, research has been conducted on gait rehabilitation that takes place in different environments, including on sand and in water.[6-8] Walking on sand requires more mechanical work and energy than walking on a hard floor because of the decreased efficiency of muscle-tendon work; however, the stress on joints, muscles and tendons is reduced.[9,10] Sand provides an uneven and continuously unstable support surface, which increases the muscle activity of the lower limbs and requires greater balance. It also alleviates the impact during a fall to help prevent injuries.[11] Exercising on sand improves lower-limb muscle strength, walking ability, balance and aerobic fitness.[11-14]

A sandy beach provides an unstable support surface and may influence the walking abilities of patients with stroke. A previous study demonstrated the effect of walking exercise on a sandy beach in sedentary elderly women.[13] In patients with stroke, sand walking in specially designed settings that are similar to sandy ground has been shown to improve dynamic balance ability and gait endurance.[12,14] The sand ground used in these studies was not a natural sand surface, but a specially prepared surface (1 m wide, 5 m long, and 30 cm deep) inside a treatment room. However, no study has investigated gait training on a sandy beach in patients with stroke. Thus, the aim of this study was to investigate the effect of gait training on a sandy beach in patients with chronic stroke.

METHODS

Study Participants

Inclusion criteria. A total of 28 patients with stroke were recruited through a poster advertisement in a community center. The inclusion criteria were that patients were: (1) more than 6 months post-stroke; (2) age 18 to 74 years; (3) of Functional Ambulatory Category (FAC) ≥3; and (4) independent walkers prior to stroke.

Exclusion criteria. Patients were excluded if they had: (1) severe communication disorder due to aphasia or cognitive impairment; (2) severely limited joint range of motion, such as joint contracture; (3) difficulty walking due to a musculoskeletal disorder, such as severe deformity or pain in the lower extremities; (4) skin disorder, open wound, pressure ulcer or uncontrolled ulcer; (5) evidence of infection; (6) high risk of compression fracture with severe osteoporosis; (7) uncontrolled hypertension or orthostatic hypotension.

All patients provided informed consent and signed a consent form before enrolling in the study. This study was approved by the Institutional Review Board (ethical committee/board, no. 2018-0683) of our hospital.

Study Design

This study was a randomized controlled trial conducted between July 2018 and August 2018 in the Republic of Korea.

Patients were randomly assigned to the sand group or the control group by a computer-generated random-number table. All patients performed gait training for 30 min per session, 2 sessions every day for 5 days. The gait training consisted of 3 phases: warm-up, main exercise and cool-down. The warm-up phase consisted of 2 min of weight shifting on the bilateral lower limbs followed by 3 min marching in place, for a total of 5 min. The main exercise phase consisted of 10 min of straight walking,[15,16] 5 min of S-pattern walking,[17] and 5 min of sideways walking,[15,16] for a total of 20 min. The cool-down phase consisted of 3 min of marching in place followed by 2 min of weight shifting on the bilateral lower limbs, for a total of 5 min. Patients in the sand group performed the training on a sandy beach with shallow seawater waves where the seawater level was below the knee (Uljin-gun, Gyeongsangbuk-do, Republic of Korea). The average temperature was 25.5°C, the average humidity was 84.0%rh, and the average wind speed was 1.9 m/s during the study period. With regard to the seawater, the average temperature was 25.02°C, salinity was 32.25‰ and the pH was 7.88. In the sand group, to ensure safety, gait training was conducted within a 45-m distance (Figure 1). To mark the distance and present the boundaries of the test area, flags were set every 15 m on the sand away from the water. Flags were also set up every 3 m on the shallow seawater side, and patients walked along these boundaries. In the sea, a safety line was installed using buoys. Patients wore life jackets for safety and water shoes to keep their feet safe as they walked in the water.

Patients in the control group performed this training on a firm floor in an indoor facility (Guri-si, Gyeonggi-do, Republic of Korea). The average temperature in the treatment room was 26°C, and the average humidity was 40%rh during the study period. Patients in the control group wore comfortable shoes.

The group exercise program was led by experienced physical therapists who were in charge of training both groups. For safety, experienced physical therapists provided assistance to patients when needed, and patients were closely monitored

Figure 1. Gait training in the sand group. (**1A**) Schematic diagram of the training site setting. Gait training was conducted within a 45-m distance, and blue flags were set every 15 m on the sand away from the water. Red flags wereset up every 3 m on the shallow seawater side, and patients walked along the flags with both straight walking and sideways walking (blue arrow, dotted line) and S-shaped walking (green arrow, dotted line). A safety line was installed in the sea using buoys (yellow). (**1B**) Picture of gait training in the sand group.

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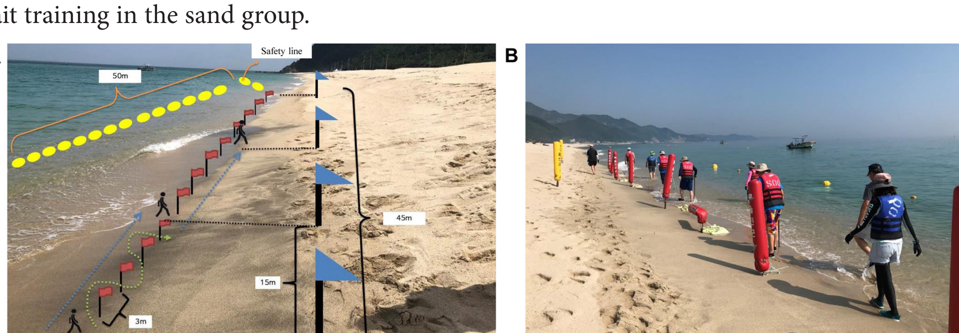

for adverse events (AEs) or risks during the training. Patients were allowed to use a walking aid such as a cane (mono cane or quad cane) during training if needed. The patients' caregivers did not participate during the program. All patients were prohibited from engaging in walking activities and exercises except for basic daily activities during the study period.

Outcome Measures

The primary outcomes were 10-m walk test (10MWT) and Berg Balance Scale (BBS). The secondary outcomes were FAC, Timed Up and Go (TUG) and spatiotemporal parameters of gait evaluated with a wearable inertial sensor. Psychological parameters including the Beck Depression Inventory (BDI) and State-Trait Anxiety Inventory (STAI) were also measured.

10MWT. The 10MWT test is commonly used to evaluate gait velocity. Patients walked 10 m, and walking speed was calculated using the middle 6 m, excluding the first and last 2 m. Patients were instructed to walk at a comfortable speed. The test was conducted twice, and the average of both results was used for the analysis.[18]

BBS. The BBS measures static and dynamic balance on a 14-item scale. Each item is scored from 0 to 4, with 0 indicating inability to perform the task and 4 indicating independent task completion. The global score ranges from 0 to 56; the higher the score, the better the balance ability.[19]

FAC. The FAC evaluates walking ability and has good reliability and validity.[20] Patients are categorized into one of six levels based on the physical assistance that they require to keep walking.[21]

TUC. The TUG test is a valid and reliable tool for measuring functional mobility. The participants stand up from a chair with an armrest, walk about 3 m, turn around, walk back to the chair and sit down. The time taken to perform this procedure is measured.[22]

Spatiotemporal parameters of gait including cadence, gait velocity, stride length and stance and swing duration were quantified using a wireless inertial device (G-Sensor®, BTS Bioengineering SpA, Italy). The G-sensor was fixed to the waist of the patient at the level of the L5 spinous process using a semi-elastic belt, and the patient was instructed to walk 10 m in a straight line on a flat surface at a comfortable speed. The BTS G-Walk® system (BTS Bioengineering SpA, Italy) with built-in G-Sensor transferred the collected data to a computer via Bluetooth, and the dedicated software program automatically analyzed and provided the spatiotemporal data.[23,24] Gait analysis was evaluated at the same time point as physical function measurements.

BDI. The BDI is a self-report questionnaire comprised of 21 items related to symptoms of depression. Each item was rated on a scale ranging from 0 to 3 according to the severity of symptoms, and the total score ranged from 0 to 63, with higher scores indicating severe depression.[25]

STAI. The STAI a 40-item self-report questionnaire for measuring state anxiety and trait anxiety, with 20 items each. Each item is rated on a 4-point scale. Higher scores indicate severe anxiety.[26]

Safety was evaluated based on AEs, including musculoskeletal disorders, falls and injuries, all of which were monitored during the study period.

All outcomes were measured before and immediately after the intervention. Outcome measurements were obtained by skilled physiotherapists who were blinded and not involved in any randomization or training.

Statistical Analysis

Because this was a pilot study, we did not perform sample size calculations. Data were analyzed statistically using the Statistical Package for Social Sciences software, version 22.0 (SPSS Inc., Chicago, IL, USA). The normality assumption was evaluated using the Shapiro–Wilk test before statistical analysis, and all data were normally distributed. To compare patient characteristics and pretraining physical function and spatiotemporal parameters between the 2 groups, Fisher's exact tests and two-sample *t* tests were used. Paired t-tests were used to compare physical function and spatiotemporal parameters before and after treatment in each group. Two-sample *t* tests and Cohen's d statistic (effect size) were used to compare all changes from pre- to post-treatment between the 2 groups. An effect size value of 0.2 corresponds to a small effect, 0.5 corresponds to a medium effect and 0.8 corresponds to a large effect.[27] A $P < .05$ was considered statistically significant.

RESULTS

Figure 2 presents the study flowchart. A total of 34 stroke patients was screened for study eligibility. A total of 3 patients were excluded based on the inclusion and exclusion criteria, and 3 declined to participate. Of 34 patients who were screened, 28 were enrolled in the study, resulting in a recruitment rate of 82%. The remaining 28 patients were recruited and randomly assigned to the sand group or the control group. No patients dropped out during the study period, so the dropout rate was 0%. With regard to safety, no AEs occurred during the study.

There were no statistically significant differences in patient characteristics between the 2 groups before treatment and no significant differences in any outcome measure (see Table 1).

Table 2 shows the outcome measure of physical function. In the sand group, the 10MWT and BBS scores were significantly improved post-treatment compared with pre-treatment ($P = .002$ and $P = .002$, respectively), but not in the control group ($P = .80$ and $P = .42$, respectively). In the comparison of changes from pre- to post-treatment between the 2 groups, the 10MWT showed a large effect size (0.899), the BBS score showed a medium effect size (0.734) and the TUG showed a small effect size (0.277).

Table 3 shows the spatiotemporal parameters of gait. Spatiotemporal parameters were not available for 1 patient in the sand group because of mechanical errors. In the remaining patients in the sand group, cadence and gait velocity were significantly higher after treatment than before treatment ($P = .02$ and $P = .01$, respectively). In the control group, there

Figure 2. Study flowchart

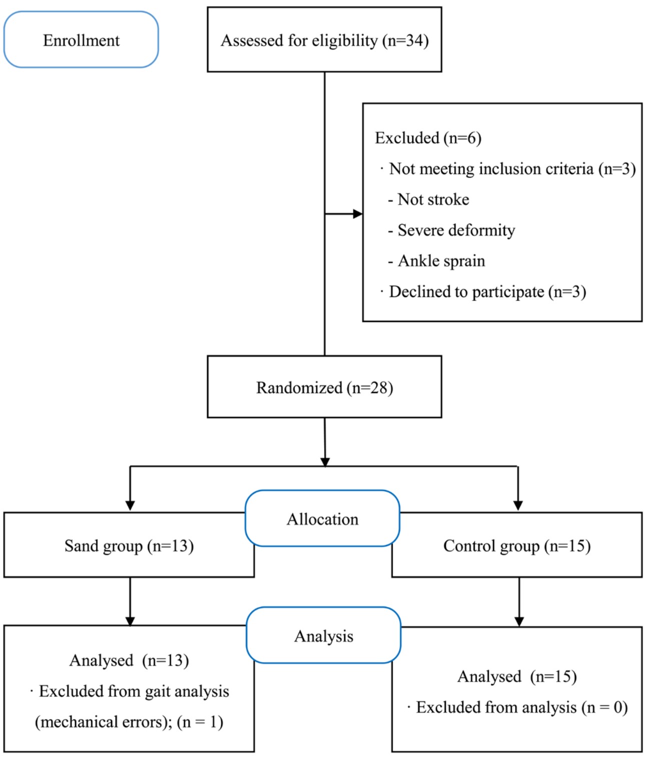

Table 1. Baseline Demographics and Clinical Characteristics of the Sand and Control Groups

	Sand group (n = 14)	**Control group** (n = 14)	***P* value**
Age (years)	65.15 ± 5.34	67.07 ± 5.82	.376
Gender (n)			
Male	9	13	.372[a]
Female	4	2	
Stroke etiology (n)			
Infarction	9	10	1.000[a]
Hemorrhage	4	5	
Side of hemiparesis (n)			
Left	7	7	1.000[a]
Right	6	8	
Time post-stroke (years)	13.25 ± 5.87	13.90 ± 7.38	.876
10MWT (m/s)	0.71 ± 0.25	0.62 ± 0.24	.349
BBS	48.23 ± 4.13	48.73 ± 4.96	.775
FAC	4.69 ± 0.48	4.73 ± 0.46	.819
TUG (s)	17.06 ± 6.58	19.78 ± 9.37	.390
Spatiotemporal parameters			
Cadence (steps/min)	92.96 ± 31.16	98.29 ± 20.84	.600
Velocity (m/s)	1.03 ± 0.33	1.05 ± 0.38	.885
Affected-side stride length (m)	1.42 ± 0.34	1.39 ± 0.34	.815
Affected-side stance phase (% of GC)	62.95 ± 7.50	57.46 ± 10.40	.138
Affected-side swing phase (% of GC)	37.05 ± 7.50	42.54 ± 10.40	.138
BDI	18.46 ± 11.60	14.80 ± 6.69	.308
STAI	88.08 ± 25.65	100.13 ± 17.2	.151

Note: Values are presented as mean ± standard deviation or number.

[a]Fisher's exact test; otherwise, two-sample *t* test.

Abbreviations: 10MWT, 10-m walk test; BBS, Berg Balance Scale; BDI, Breck Depression Inventory; FAC, Functional Ambulatory Category; GC, gait cycle; STAI, State-Trait Anxiety Inventory; TUG, Timed Up and Go.

Table 2. Outcome Measures Before and After the Treatment Program

	Sand group (n = 14)				**Control group (n = 14)**						**95% CI**	
	Pre-	**Post-**	**Difference (Post–Pre)**	***P* value[a]**	**Pre-**	**Post-**	**Difference (Post–Pre)**	***P* value[a]**	***P* value[b]**	**Effect Size[c]**	**Lower**	**Upper**
10MWT (m/s)	0.71 ± 0.25	0.84 ± 0.31	0.13 ± 0.11	.002	0.62 ± 0.24	0.63 ± 0.26	0.01 ± 0.10	.80	.006	0.899	0.800	0.998
BBS	48.23 ± 4.13	50.77 ± 4.99	2.54 ± 2.26	.002	48.73 ± 4.96	49.2±4.26	0.47 ± 2.17	.42	.02	0.734	-1.360	2.828
FAC	4.69 ± 0.48	4.85 ± 0.55	0.15 ± 0.38	.17	4.73 ± 0.46	4.8 ± 0.41	0.07 ± 0.26	.33	.48	0.196	-0.108	0.499
TUG (s)	17.06 ± 6.58	19.35 ± 12.85	2.29 ± 7.86	.31	19.78 ± 9.37	19.98 ± 8.7	0.21 ± 3.42	.82	.39	0.277	-5.310	5.863

Note: Values are presented as mean ± standard deviation.

[a]Paired *t* tests, for intragroup analysis.
[b]Two-sample *t* test, for the difference (post-pre) in the sand group vs the control group.
[c]Cohen's d for the difference (post-pre) in the sand group vs the control group.

Abbreviations: 10MWT, 10-m walk test; BBS, Berg Balance Scale; FAC, Functional Ambulatory Category; TUG, Timed Up and Go.

Table 3. Spatiotemporal gait parameters before and after the treatment program.

	Sand group (n = 14)				Control group (n=14)			
	Pre-	Post-	Difference (Post-Pre)	*P* value[a]	Pre-	Post-	Difference (Post-Pre)	*P* value[a]
Cadence (steps/min)	92.96 ± 31.16	110.64 ± 27.43	17.68 ± 21.31	.02	98.29 ± 20.84	95.77 ± 14.41	-2.52±16.62	.57
Velocity (m/s)	1.03 ± 0.33	1.27 ± 0.39	0.24 ± 0.28	.01	1.05 ± 0.38	0.95 ± 0.30	-0.09±0.22	.12
Affected-side stride length (m)	1.42 ± 0.34	1.47 ± 0.34	0.06 ±0.15	.22	1.39 ± 0.34	1.30 ± 0.36	-0.09±0.18	.07
Affected-side stance phase (% of GC)	62.95 ± 7.50	61.04 ± 9.08	-1.91 ± 8.33	.44	57.46 ± 10.40	67.77 ± 11.64	10.31±18.74	.05
Affected-side swing phase (% of GC)	37.05 ± 7.50	38.96 ± 9.08	1.91 ± 8.33	.44	42.54 ± 10.40	32.23 ± 11.64	-10.31 ± 18.74	.05

	P value[b]	Effect Size[c]	95% CI	
			Lower	Upper
Cadence (steps/min)	.01	0.837	-17.085	18.759
Velocity (m/s)	.002	1.038	0.801	1.274
Affected-side stride length (m)	.03	0.705	0.547	0.863
Affected-side stance phase (% of GC)	.03	-1.121	-9.219	6.977
Affected-side swing phase (% of GC)	.03	1.121	-6.977	9.219

Note: Values are presented as mean ± standard deviation.

[a]Paired t-tests for intragroup analysis.
[b]Two-sample *t* test for the difference (post-pre) in the sand group vs the control group.
[c]Cohen's d for the difference (post-pre) in the sand group vs the control group.

Abbreviations: GC, gait cycle.

Table 4. Psychological parameters before and after the treatment program

	Sand group (n = 14)				Control group (n = 14)				
	Pre-	Post-	Difference (Post–Pre)	*P* value[a]	Pre-	Post-	Difference (Post–Pre)	*P* value[a]	*P* value[b]
BDI	18.46 ± 11.60	14.80 ± 6.69	-2.46 ± 7.02	.230	14.80 ± 6.69	9.87 ± 8.42	-4.93 ± 7.46	.023	.377
STAI	88.08 ± 25.65	100.13 ± 17.2	-8.54 ± 20.08	.151	100.13 ± 17.2	99.07 ± 11.25	-1.07 ± 21.4	.850	.352

Note: Values are presented as mean ± standard deviation.

[a]Paired *t* tests for intragroup analysis.
[b]Two-sample *t* test for the difference post-analysis in the sand group vs the control group.

Abbreviations: BDI, Beck Depression Inventory; STAI, State-Trait Anxiety Inventory.

was no significant change in any spatiotemporal parameter from pre- to post-treatment ($P > .05$). In the comparison of changes from pre- to post-treatment between the 2 groups, cadence and gait velocity showed large effect sizes (0.837 and 1.038, respectively) and affected-side stride length showed a medium effect size (0.705).[27]

With regard to psychological parameters, there was no difference between the 2 groups with regard changes in BDI and STAI from pre- to post-treatment ($P > .05$; see Table 4).

DISCUSSION

This was a randomized controlled trial investigating the effects of gait training on a sandy beach in patients with chronic stroke. The results suggested that gait training on a sandy beach improved walking speed, balance and spatiotemporal parameters such as cadence and walking velocity in patients with chronic stroke.

Our results showed that gait training on a sandy beach improved 10MWT and BBS scores in patients with stroke to a greater extent than gait training on firm ground. Cadence and walking velocity measured by the BTS G-Walk system were significantly increased in the sand group after training, and the changes from pre- to post-training were greater than those observed in the control group. Previous studies have shown that the BBS, which reflects balance, is related to walking speed.[2,28] In patients with chronic stroke, balance is positively correlated with walking ability and speed.[29,30] In this study, the improvement in BBS scores in the sand group might have affected the increase in gait speed. In terms of spatiotemporal parameters, walking velocity is related to many other factors, including cadence and stride length.[2]

Previous studies have reported that gait training on sand was more effective at improving walking ability than gait training on firm ground in patients with chronic stroke.[12,14]

Training on sand was shown to improve cardiovascular function and walking ability by increasing muscle endurance and strength.[12] The results of previous studies are consistent with the results of our study on walking ability and balance.[12,14] However, those studies were conducted using specially made sand ground inside a treatment room, not a natural sand surface. In this study, we provided a beach environment for the rehabilitation of patients with stroke and proved the effects of gait training on a sandy beach compared with firm ground, which is commonly used for gait rehabilitation in patients with stroke. Walking on sand increased the muscle strength of the lower limbs, balance due to greater proprioceptive input and aerobic fitness in elderly women.[13] Walking on sand also enhanced ankle proprioception through changes in ankle movements, thereby improving ankle strength, balance and the walking ability of patients with chronic hemiplegic stroke.[31] Lower extremity sensitivity and proprioception may be related to the results of the current study. Future studies that evaluate lower extremity sensitivity and proprioception are required.

van den Berg, et al. reported that hip flexion, knee flexion and ankle dorsiflexion during the swing phase were significantly greater when patients with multiple sclerosis (MS) walked on the sand.[32] Similar to patients with multiple sclerosis, hip and knee flexion and ankle dorsiflexion on the hemiplegic side are limited during the swing phase of gait in patients with stroke.[2,33] Although kinematics were not analyzed in this study, walking on a sandy beach may have had a similar effect of increasing lower-limb flexion in patients with stroke, and this might have affected their gait pattern. Further study is needed on the kinematic changes that underlie the observed effects of our gait-training program.

Although walking on a sandy beach with shallow seawater does not exert a large buoyant force on the human body, it provides a drag force.[34,35] This resistance induces isokinetic muscular contraction and balanced development of agonist and antagonist muscles.[36] The water provides proprioceptive and sensory feedback and affects balance.[37] It is likely that the intensity of walking training on the beach was higher than that of indoor gait training on a firm floor in the present study. This is consistent with the principle of stroke rehabilitation in that high-intensity training promotes recovery.[38]

Study Limitations

This study had some limitations. First, the number of participants was relatively small, and the results may not be generalizable to all patients with stroke. Second, we measured outcomes only at baseline and at the end of the rehabilitation program, and it is unclear whether there were any long-term benefits. Third, the study was carried out for 2 sessions per day for 5 days, which can be considered a short intervention. A longer exposure time will be needed in future studies. Fourth, we did not directly identify the mechanisms underlying the effects of gait rehabilitation at the beach. All of these issues will require further consideration in future research. A further study with a larger sample size and longer duration is needed. Finally, it is difficult to take patients to the beach, especially in bad weather, as it would increase spasticity. Hence, during the study period, the patients had to stay near the beach. Moreover, there was a risk of bias in the interventions that were compared in the study. Some confounding factors, such as emotional well-being, can be expected when comparing therapy administered in the sand/sea with therapy in an indoor training facility. Considering emotional well-being, psychological parameters, including the BDI and STAI, were also measured. There was no difference in the changes in the BDI and STAI from pre- to post-treatment between the sand group and the control group. Further research is warranted to compare the sand group with a group in which exercises were conducted outside (eg, on the boulevard, near the sea).

CONCLUSIONS

We found that patients with stroke who trained on a sandy beach showed improvements in walking ability and balance. This study suggests considering gait training on the beach in the treatment of patients with stroke and also demonstrated that gait training on a sandy beach may have potential as a beneficial complementary and alternative treatment in patients with stroke. Future studies on this topic should measure the long-term effects in a large sample size.

CONFLICT OF INTEREST

None.

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CLINICAL TRIAL REGISTRATION

This study was registered on Clinical Research Information Service (KCT0003681).

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