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Effect of gait training with additional weight on balance and gait in stroke patients

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Objective: To study the effects of gait training with additional weight and gait training with non-additional weight on balance ability and gait ability in patients with chronic stroke through comparative analysis.
Design: Randomized controlled trials.
Methods: The subjects were divided randomly into two groups: additional weight group (AWG, n=12), and non-additional weight group (NAWG, n=10). Both groups received general physical therapy for 30 min in 1 session, 5 sessions per week during 6 months. The AWG practiced gait training with additional weight of 0.1 and 0.5 kg for 20 min a day, 3 days per week for 6 months and the NAWG practiced gait training with non-additional weight for 20 min a day, 3 days per week for 6 months. Patients in both groups were instructed to walk as fast as they could along a 35 m long track (straight for 20 m and curved for 15 m). Patients walked with their hemiplegic side on the inside of the track while a physical therapist followed along to instruct patients to maintain a straight posture. Balance ability was tested with the Functional Reach Test, the Timed Up and Go test, and the Berg Balance Scale, and gait ability was tested with GAITRite. The results of balance and gait ability were analyzed before and after interventions.
Results: A significant increase in FRT, TUG, BBS was seen in both groups after intervention ($p<0.05$). A significant increase in gait ability was seen in the AWG after intervention ($p<0.05$). For balance and gait ability, the results from the AWG was significantly improved compared with the NAWG ($p<0.05$).
Conclusions: Gait training with additional weight improves balance ability and gait ability in stroke patients, this gait training method is effective and suitable for stroke patients to increase the ability of functional performance.

Key Words: Gait, Postural balance, Stroke, Weight

Introduction

A stroke is a cerebrovascular condition where blood supply is interrupted or a hemorrhage occurs in the cerebral tissues, and leads to a loss of motor and sensory function in the brain [1]. Stroke is one of the three leading causes of death. According to the statistics from the American Heart Association an average of 1 stroke occurs every 40 seconds in the United States amounting to approximately 795,000 people experiencing a new or recurrent stroke, per year [2]. Furthermore, post-stroke hemiplegic patients have neurological impairments, such as, motor, sensory, cognition and speech deficits, and also exhibit various motor dysfunctions, such as, hemiparesis, muscle weakness, reduced selective motor control, and abnormal reflexes, all of which limit daily activities, and increase the risk of falls [3]. In particular, the gait of hemiplegic patients are characterized by a shorter step and stride length, a wider base of support, a shorter stance phase, and a longer swing phase, which reduce walking speed and encourage abnormal gait patterns, and result in instability that limits mobility [4]. The most important purpose of rehabilitation in stroke patients is to maximize

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functional independence and increase participation in daily activities [5].

Rapid muscle activation is vital for walking on a daily basis after a stroke, and proprioceptive reflex is a neurological mechanism that maintains weight load, posture and balance [6]. Inputs from the Golgi tendon organs (receptors of stimuli) run through Ib afferent nerve fibers and activate leg extensor muscles to control gait balance [7]. During the past few years, several experiments have been performed, such as, water immersion walking, walking with a backpack, and walking without gravity, to determine how load changes affect the body, and the results of these experiments showed that load changes affect muscle activations in limbs, reflex activities, and posture control [8].

Research on animals has shown that afferent inputs of ankle plantar flexors during the stance phase excite limb extensors, inhibit flexors, and prolong the stance phase while delaying initial swing. On the other hand, the unloading of ankle plantar flexors decreases extensor activation. Furthermore, a rapid decrease in afferent firing appears to trigger the stance-to-swing transition [9]. Griffin *et al*. [10] reported that the energy required to generate muscle force to support body weight was largely increased during the stance phase while walking with loads. Stephens and Yang [11] reported that soleus activity increased up to 40% during the entire stance phase and activity of the quadriceps femoris increased by up to 134% during the initial stance phase when healthy adult volunteers carried loads secured closely around a well-padded hip belt (thereby near the body's center of mass) and were asked to walk on a treadmill. Of the methods used to provide more load, an approximation therapeutic technique that increases pressure on joints through compression has been advocated as an effective means of improving muscle control [12].

Bearing weight on the upper limbs was found to increase muscle activity in the upper limb and shoulder area, and approximation at the pelvis while standing increased hip activity and knee extensor musculature, and improved balance [13]. Ratliffe *et al*. [14] reported that effects of the manual approximation technique on balance while standing can be achieved with a weight jacket. Liao *et al*. [15] measured the maximum load that a child with spastic cerebral palsy is capable of carrying while standing up once from a sitting posture. Patients were asked to stand from a sitting position while wearing a weight jacket at up to 50% of maximum load, and this resulted in a significant increase in Gross Motor Function Measure scores [15].

However, although various studies have shown improvements in functional abilities using additional loads, little research has been undertaken on the effects of gait training with extra weight on stroke patients in terms of improving walking posture and balance. Therefore, the purpose of this study was to investigate the effectiveness of additional weight on gait and balance in stroke patients.

Methods

Thirty patients with hemiplegia (caused by cerebrovascular accident) initially participated in this study. All experimental protocols and procedures were explained to each subject and approved by the institutional review board of Sahmyook University, South Korea. All subjects provided written informed consent prior to study enrollment. The inclusion criteria were as follows: an ability to follow verbal instructions; an Korean version of Mini-Mental State Examination score of >21; no obvious limitation in passive range of motion of ankle joints; and an ability to walk 10 meters without any form of assistance. Patients with brain stem and/or cerebellum damage or any other disease/condition that could affect gait were excluded. After explaining the purpose of this study, 4 patients decided not to participate while 26 patients agreed to participate in the pre-test. Patients who met the study criteria and agreed to participate were randomly assigned to either additional weight group (AWG, n=13) or non-additional weight group (NAWG, n=13). However, one in the AWG and three in the NAWG were excluded because their program participation rate was less than 80%. Accordingly, the study cohort comprised 22 subjects: 12 in the AWG and 10 in the NAWG (Figure 1, Table 1).

Patients in the AWG received general physical therapy and gait training while wearing weighted jackets. Patients in the NAWG received general physical therapy and gait training without weighted jackets. Patients in both groups performed gait training for 20 minutes a day, 3 times a week for 6 weeks. All 22 subjects completed the 6-week training schedule.

Two devices (weights and jacket) and two different weights (0.1 kg and 0.5 kg) were used during gait training. The weights were placed in jacket pockets [15]. Each patient wore a jacket with 7% of body weight loaded in front and back pockets to maintain balance [10]. Sponges were placed on the shoulders under the jackets to prevent neck and shoulder pain. Patients in the AWG walked along the track

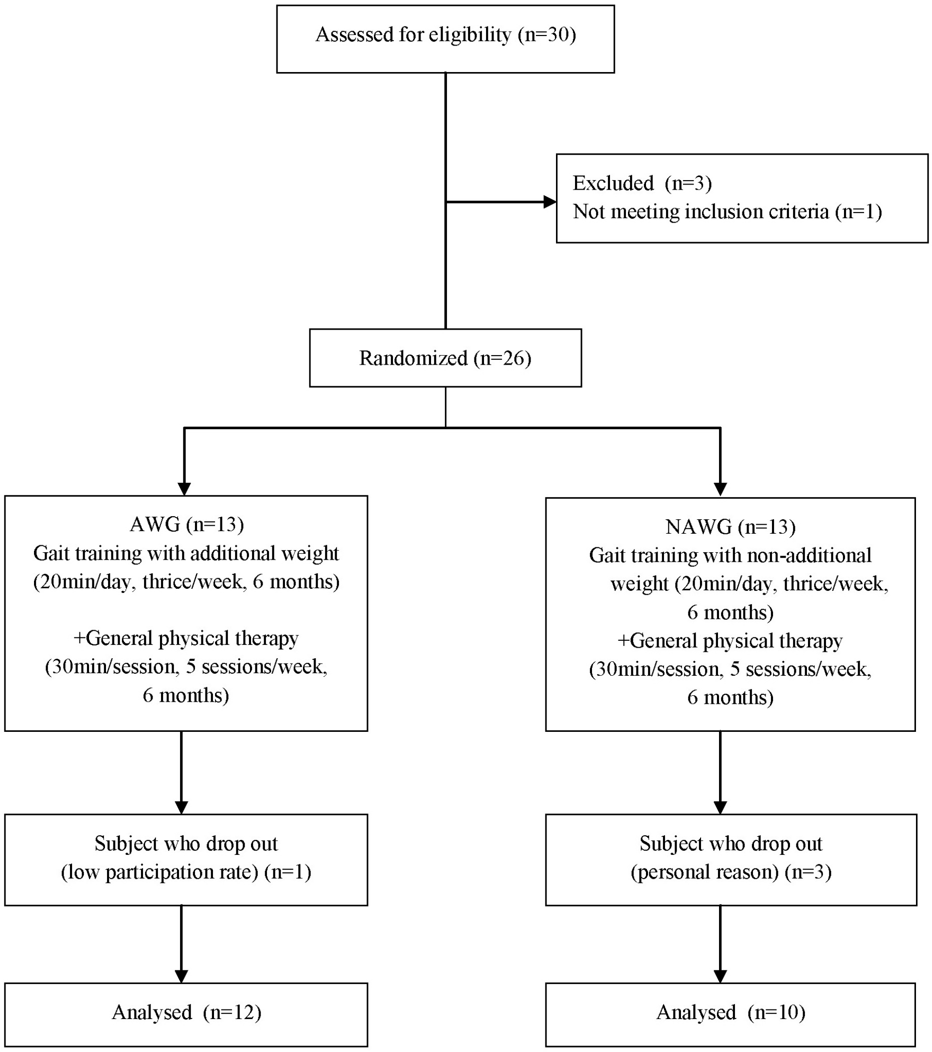

Figure 1. Flow diagram of total experimental procedure. AWG: additional weight group, NAWG: non-additional weight group.

Table 1. General characteristics of the subjects (N=22)

Classification	AWG (n=12)	NAWG (n=10)	X^2/t	p
Gender (male/female)	9 (75)/3 (25)	8 (80)/2 (20)	1.000	1.000
Paretic side (left/right)	5/7	6/2	1.474	0.158
Etiology (infarction/hemorrhage)	9/3	7/1	0.657	0.519
Age (y)	53.25 (4.41)	51.75 (4.97)	1.001	0.323
Height (cm)	165.16 (4.84)	162.00 (5.56)	1.909	0.064
Weight (kg)	62.75 (4.60)	60.50 (4.53)	1.523	0.136
Period (mo)	19.91 (2.37)	20.75 (2.40)	−1.081	0.297
MMES-K (score)	26.41 (3.04)	24.50 (3.14)	1.925	0.062

Values are presented as n (%) or mean (SD).
AWG: additional weight group, NAWG: non-additional weight group, MMES-K: Korean version of Mini-Mental State Examination.

as fast as they could while maintaining their balance and an upright posture, and patients in the NAWG did the same but without a weighted jacket [15].

Patients in both groups were instructed to walk along a track as fast as they could. Total length of the track for gait training was 35 m (straight for 20 m and curved for 15 m). Patients walked with their hemiplegic side on the inside of the track. A physical therapist followed the patients to provide verbal instructions to ensure a straight posture was maintained and that the patients walked as fast as they could

Figure 2. Gait training with additional weight jacket.

(Figure 2).

Training consisted of a warm-up followed by gait training. The warm-up involved a 1-minute walk without a weighted jacket, whereas gait training involved a 20-minute walk with a weighted jacket in AWG, and a 20-minute walk without a weighted jacket in NAWG. After 10 minutes of gait training, patients were allowed a 1-minute break. Gait training was performed 3 times a week for 6 weeks [6].

General physical therapy included neuro-developmental treatment, mat exercise and gait training for 10 minutes each, and was given one by one to 4 patients by each of the 5 physical therapists after the degree of difficulty was adjusted for each patient's condition.

Five physical therapists met 6 times (twice the week before, and 4 times during general physical therapy) to decide on exact techniques, times, and other restrictions that might increase the uniformity of therapy.

Functional Reach Test (FRT) is useful for evaluating dynamic balance related to maintaining postural stability during movement. Subjects were asked to stand 10 cm apart from the wall so that their shoulders were perpendicular to the reach measurement device. Subjects extended their arm horizontally and placed a closed fist against the sliding handle. Individuals were asked to the slide measurement bar as far forward as they could without losing balance. Test-retest reliability and interrater reliability were r=0.89, r=0.98 respectively [16].

The Timed Up and Go test (TUG) was used to evaluate dynamic balance. This test is a widely used clinical test to evaluate balance and mobility [17]. Subjects were asked to complete 3 trials of TUG. When performing the TUG, subjects were given verbal instructions to stand up from a chair (seat height 45 cm), walk 3 meters as quickly and as safely as possible, cross a line marked on the floor, turn around, walk back, and sit down [17]. The TUG is considered a reliable test with an intra and interrater reliability of r=0.99 and r=0.98 respectively [18].

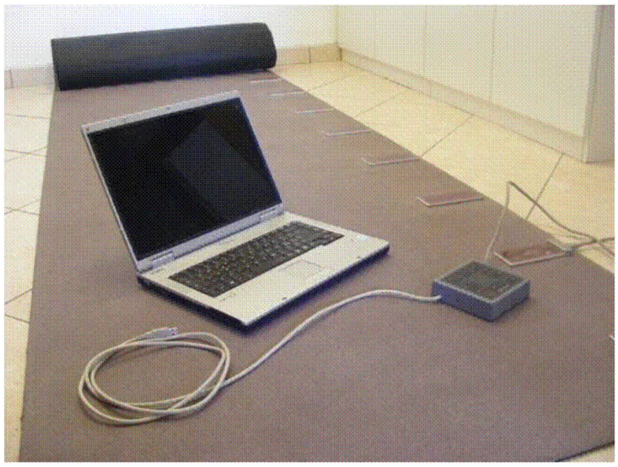

Figure 3. GAITRite system.

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairments in balance function by assessing the performance of functional tasks [19]. The BBS comprises of 14 tasks. The 14 tasks are graded on a 5 points ordinal scale from 0 to 4 in accordance with detailed description. The total score for all tasks consists of 56 scores [20]. As intrarater reliability and interrater reliability were each r=0.99, r=0.98, this test was reliable and valid to assess balance ability [19].

GAITRite system (CIR Systems Inc., Clifton, NJ, USA) was used in order to assess temporal-spatial characteristics of the patient's gait [21]. The walkway's active measurement area was 61 cm wide and 5 m long with 16,128 pressure sensors. Sensors were arranged in a grid pattern and placed 1.27 cm in the center. This system supplied the clinician with quantitative information about the patient's gait. The GAITRite system was used to process the data and provide the mean temporal and spatial parameters. Interclass correlation coefficients for all gait measurements at a preferred walking speed were over 0.96 [22] (Figure 3).

Statistical analyses were performed using IBM SPSS Statistics 19.0 (IBM Co, Armonk, NY, USA). Results are presented as mean±standard deviation. Prior to training, data normality was assessed using the Shapiro-Wilk test. Chi-square analysis and the independent samples t-test were used to calculate the frequency of differences for categorical variables. The independent samples t-test was performed to determine the significances of differences between groups and the paired t-test was used to compare before and after gait training with a weighted jacket. Statistical significance

Table 2. Changes in balance ability (N=22)

Classification	AWG (n=12)	NAWG (n=10)	t^b	p
Functional Reach Test (cm/s)				
Pre-test	28.39 (3.16)	26.71 (1.70)	1.668	0.107
Post-test	36.05 (3.08)	29.75 (2.80)		
Difference	7.66 (1.61)	3.03 (1.30)	8.19	<0.001
t^a	19.55	−8.023		
p	<0.001	<0.001		
Berg Balance Scale (score)				
Pre-test	41.14 (2.17)	39.60 (3.02)	1.456	0.160
Post-test	48.57 (2.20)	42.60 (3.62)		
Difference	7.42 (0.75)	3.00 (1.15)	11.382	<0.001
t^a	36.77	−8.216		
p	<0.001	<0.001		
Timed Up and Go test (second)				
Pre-test	26.57 (17.0)	32.92 (14.40)	−0.855	0.404
Post-test	12.00 (4.01)	27.39 (10.13)		
Difference	14.56 (14.49)	5.52 (4.94)	−2.446	0.019
t^a	3.481	4.47		
p	0.005	<0.001		

Values are presented as mean (SD).
AWG: additional weight group, NAWG: non-additional weight group.
[a]Paired t-test, [b]Independent t-test.

Table 3. Changes in gait ability (N=22)

Classification	AWG (n=12)	NAWG (n=10)	t^b	p
Velocity (cm/s)				
Pre-test	37.19 (18.18)	27.70 (8.62)	1.362	0.190
Post-test	82.08 (34.31)	33.03 (7.73)		
Difference	44.89 (25.07)	5.33 (2.22)	6.560	<0.001
t^a	−6.203	−9.612		
p	<0.001	<0.001		
Cadence (steps/min)				
Pre-test	70.43 (22.50)	64.93 (19.21)	0.745	0.462
Post-test	107.8 (22.95)	76.43 (19.87)		
Difference	37.42 (15.64)	11.50 (5.40)	5.930	<0.001
t^a	−10.696	−7.959		
p	<0.001	<0.001		
Step length (cm)				
Pre-test	30.37 (9.15)	24.96 (4.46)	1.535	0.142
Post-test	47.23 (12.32)	25.21 (9.27)		
Difference	16.86 (8.66)	0.24 (5.18)	6.998	<0.001
t^a	−6.738	−0.192		
p	<0.001	0.851		
Stride length (cm)				
Pre-test	58.52 (18.79)	52.32 (8.46)	0.868	0.868
Post-test	91.56 (25.48)	53.87 (8.35)		
Difference	33.03 (18.95)	1.55 (5.19)	6.596	<0.001
t^a	−6.037	−1.197		
p	<0.001	0.250		
Single support percentage (%)				
Pre-test	23.51 (6.01)	21.03 (6.61)	0.855	0.404
Post-test	31.33 (6.24)	24.91 (7.53)		
Difference	7.81 (5.39)	3.87 (5.05)	2.352	0.024
t^a	−5.015	−3.067		
p	<0.001	0.008		

Values are presented as mean (SD).
AWG: additional weight group, NAWG: non-additional weight group.
[a]Paired t-test, [b]Independent t-test.

was set below 0.05 for p-values.

Results

FRT, TUG, and BBS scores improved significantly in both the AWG and NAWG after intervention, with the AWG being significantly greater than the NAWG ($p < 0.05$; Table 2).

In both groups, there was a significant increase in gait velocity, cadence, and single support percentages after intervention, with significantly greater increases seen in the AWG compared with NAWG ($p < 0.05$). In addition, there was a significant increase in average step length and stride length in the AWG ($p < 0.05$; Table 3).

Discussion

Fall incidence rates between 23%-50% have been reported in studies on people with chronic stroke [23], and this rate is much higher than the 11-30% rate reported for older community-dwelling adults without stroke [24]. Fall incidence is related to impaired balance in people with stroke, and thus, the recovery of balance in stroke patients is an important aim [5].

This study examined changes in balance abilities using the FRT, TUG and BBS after 6 weeks of gait training with weights. The average increase during the FRT with additional weight was 7.74 cm, a 27% improvement. The average decrease in the time required during TUG with additional weight was 14.57 s, a 55% improvement. The average increase shown on BBS of AWG was 7.43, a positive change of 18%. Thus, balance abilities were found to be significantly improved by gait training with additional weight. In addition, the results of the AWG confirmed the effectiveness of training as they were significantly different from the NAWG, which underwent only general physical therapy for the same duration.

The standing posture of stroke patients is characterized by large amplitude postural sway associated with a lack of balance [25], and decreased muscle activation can lead to a disproportionate reaction in postural sway, and thus, an improvement in balance is affected by elevated levels of muscle activation [26].

Lee *et al*. [27] reported that sway path length decreased an average of 5.44 cm after placing a secured 12 kg load on 10 patients with chronic stroke, which equals a 10% improvement in balance ability. Sway path velocity showed a 10% negative change and decreased by 0.18 cm/s. Muscle activity as determined by EMG increased by 3.67%-4.35% in terms of % maximal voluntary contraction of the lower limbs.

Liu *et al*. [28] reported that muscle activation increased as load increased, and Adler [29] reported that muscle activation around the hip and knee was increased by forward and downward manual approximation on the pelvic area and not by adding additional weight. Even though amplitudes of muscle activation were not examined in this study, muscle activation of lower limbs resulting from additional weight might improve balance ability based on the results of a previous study that muscle activation and balance ability increased with additional weight.

In the present study, in accord with a previous study, weight application increased muscle activation in the affected lower limb, muscle contraction to support body weight against gravity, and shifted weight load toward the affected side. Weights loaded on both lower limb improved postural symmetry after training, which led to a decreased center of mass sway and improved balance.

Gait is an essential part of daily activity and allows participation as a member of a community [30]. Even though many patients have experienced some restoration of independent gait when they leave rehabilitation centers, many gait problems persist. Decreased gait velocity is a major limitation of community-dwelling activity [24]. Therefore, the restoration of gait independence in stroke patients is as important as restoring balance.

In the present study, spatial and temporal gait variables were studied using a gait analysis system in stroke patients after 6 weeks of gait training. Regarding, temporal variables, mean gait velocity in AWG increased from 37.19 cm/s to 82.08 cm/s after training; an average improvement of 44.89 cm/s. Mean cadence in AWG increased from 70.43 steps/min to 107.80 steps/min after training, an average improvement of 37.37 steps/min.

Published gait speed results for community-dwelling stroke patients vary from 0.3 to 0.8 m/s [31], which compares with 1.3 m/s in healthy elderly [30]. Gait velocity is related to many motor function factors in stroke patients, especially weakness in the affected lower limb, which is a manifestation of a decreased number of motor units and activation [32]. This is one of the reasons why gait velocity of stroke patients is slower [5]. Bohannon [30] reported that the activations of hip extensors, knee extensors, and ankle plantar flexors on the affected side are significantly related to maintaining or increasing movement velocity, and thus, an increase in gait velocity reflects an improvement in overall gait abilities.

Perry *et al*. [33] conducted a correlational research on gait velocity and daily activities and showed that less than 40 cm/s indicated severe gait impairments and limitations to indoor activities. Moderate gait impairments resulted in a walking speed of 40 to 80 cm/s, at which patients had a limited social life. However, those who could walk faster than 80 cm/s had mild impairments and an independent social life [33]. Compared with these results, the 82.08 cm/s gait velocity achieved by the AWG means that these patients were likely to be socially independent.

In this study, step length, stride length, and single support percentage of the affected side were measured to determine the average change of spatial gait variables before and after 6 weeks of gait training. Gait in stroke patients is characterized by a decrease in stride length, duration of stance phase of the affected side, single support percentages, and by an increase in duration of the swing phase of the affected side [4].

Mean step length in AWG increased from 30.37 cm to 47.23 cm after training; an improvement of 16.86 cm ($p < 0.05$). Mean stride length in AWG increased from 58.52 cm to 91.56 cm after training; an improvement of 33.04 cm ($p < 0.05$). Mean single support percentage of affected side in AWG increased from 23.51% gait cycle (GC) to 31.33% GC after training; an improvement of 7.82% GC.

According to the results of this study, all spatiotemporal variables of gait demonstrated the effectiveness of additional weight load in stroke patients, and these improvements are due to neurological responses in response to additional weight training.

Loading afferent feedback on the lower limb was found in research on cats with separated brain and spinal cords, which supports evidence of the activity of lower limb extensors during gait [34].

Griffin *et al*. [10] reported that energy generated by ground reaction force against the floor while standing increases with load. Harkema *et al*. [35] study on individuals with incomplete and complete spinal cord injury showed that gait patterns are established by flexion and extension of lower limbs resulting from appropriate proprioceptive feedback and repetitive alternating extra weight stimuli. Afferent feedbacks from lower limb arise from Ib afferent fibers activated plantar flexors [36], which activate lower limb extensors during the stance phase but inhibit flexors. Therefore, the stance phase is prolonged and initiation of the swing phase is delayed [9]. Thus, additional loads induce changes in lengths of Golgi tendon organs, activate lower limb extensors to support body weight, and maintain posture and balance [10].

Activation of lower limb extensors is connected to the stability of stance phase, and directly influences forward propulsion of the center mass at ankle, knee, and hip joints, so increased activation of lower limb extensors is essential for daily activities such as walking and climbing stairs. Since the results of this study are similar to those of a previous study on weight stimulation, the activations of lower limb extensors by loading seems to lead to an increased percentage of single support and improve forward propulsion on the affected side. These prolong the swing phase and extends step and stride length on both the affected and unaffected sides, and thus, increase overall gait speed.

Gait training with additional weight improves balance ability and gait ability in stroke patients, this gait training method is effective and suitable for stroke patients to increase the ability of functional performance

Acknowledgements

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