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Original Article

Effects Of Forward & Backward Walking on Gait Parameters of Patients with Chronic Stroke: A Preliminary Trial

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Abstract

Background: Gait training after stroke is of paramount importance for independent living and quality of life. Objectives: The purpose of this study was to examine the effects of forward and backward walking over a firm level and a sandy surface on gait parameters among stroke patients. **Methods:** A total of 20 subjects randomly assigned to four groups were evaluated on various gait parameters while walking on a firm level surface and on sand. Baseline evaluation of temporal and spatial parameters of gait was conducted through stride analysis and final measurement after 3 weeks of intervention. **Results:** Backward walking on sand showed a statistically significant improvement in walking velocity, cadence, step/stride length, and gait symmetry among chronic stroke patients. **Conclusion:** The results of this study support the use of backward walking on sand as a new tool to improve functional walking among stroke patients. Such enhanced improvement can be attributed to the fact that backward walking on sand is more challenging than forward walking.

Keywords: Gait Training; Stroke; Backward Walking; Stroke Rehabilitation; Physical Therapy Interventions, Innovative Rehabilitation Techniques

Introduction

Stroke is a leading cause of disability that results in a variety of impairments affecting the quality of life. Restoration of independent walking is the most cited goal among stroke patients. [1] Walking ability in stroke patients does not only refer to the movement of the body but should also be assessed by integrating disability, activity, participation, and quality of life.[2] The majority of patients with stroke eventually recover their independent walking ability over time; however, they lack the ability to make necessary adjustments when walking on uneven surfaces, which would increase the risk of falls or limits their ability to walk outdoors[3]. Hence, in conventional gait re-education programs it is not sufficient to improve gait performance alone as this does not focus on the individual movement components comprising the synergic pattern in stroke patients. The decreased velocity observed in hemiplegic gait compared to normal gait has also been repeatedly reported, along with the associated limitations in cadence, stride length, and gait cycle[4].

Forward, backward and lateral walking training is widely used in various situations as a form of balance training and muscle strengthening exercises for the lower limbs, in addition to serving as a preventive measure for falls [5–9]. Learning to walk backwards correctly is recommended for improving the movement components required for forward walking (FW)[10]. It has also been suggested that backward walking (BW) may offer some benefits beyond those provided by FW alone.

In stroke rehabilitation, the current trends emphasize gait patterns of stroke patients in a variety of experimental environments, which may be essential to increase activity levels and social participation, through which the quality of life can be improved [11]. Therefore, there are several strategies aimed at enhancing walking ability in patients with stroke. Most previous studies have reported on intervention strategies focusing on conventional walking environments experienced by patients in everyday life. Thus, gait training interventions that involve a heterogeneous ground environment is necessary.

Gait training on uneven ground instead of firm level ground requires more diverse movement at the ankle joint as well as precise muscle activation [12]. Using such environmental attributes can influence greater ankle mobility and improvement in proprioception. The improved proprioceptive signals are essential for achieving the ability for effective walking on an uneven ground [13].

There have been no studies that required subjects to walk backward on the sand. Based on the above background, the present study aimed to compare the effects of forward and backward gait on sand and on a firm level surface on gait parameters of patients with chronic stroke. We hypothesize that backward walking on sand will cause significant change in gait parameters compared with forward walking on sand and on a firm level surface.

Materials and Methods

The subjects included in our study were recruited randomly from the Rehabilitation Department of various hospitals Riyadh, Hota Sudair, Almajmaah and Zulfi region of Saudi Arabia. Demographic data were obtained through interview and by screening medical records. The sample size was calculated with the formula: $n = (Z\alpha/2+Z\beta)2 * (p1(1-p1)+p2(1-p2)+p3(1-p3)+p4(1-p4)) / (p1-p2-p3-p4)2$, where $Z\alpha/2$ is the critical value of the Normal distribution at $\alpha/2$ (e.g. for a confidence level of 95%, a is 0.05 and the critical value is 1.96), $Z\beta$ is the critical value of the Normal distribution at β (e.g. for a power of 80%, β is 0.2 and the critical value is 0.84) and p1, p2, p3 and p4 are the expected sample proportions of the four groups.

The study included patients who had experienced a stroke for the first time, with unilateral involvement, demonstrating motor stage 3 or 4 on the Brunnstrom motor recovery scale. These patients were able to walk 12 meters with or without ambulatory devices, were medically stable, and could follow simple commands. Exclusion criteria involved patients with co-morbid diseases other than stroke that could affect gait, conditions contraindicating exercises, cardio-pulmonary or orthopedic disorders affecting walking ability, and severe visual impairments not corrected by usual means, such as corrective glasses.

Procedure

Ethical approval for the study was obtained from the Deanship of Scientific Research, Majmaah University. Prior to randomization of the stroke population (n=73), written consent was obtained from the patients after explaining the purpose and procedure of the study. Forty-three subjects met the inclusion criteria and remaining 30were excluded due to various reasons. Our study conforms to the CONSORT Guidelines (Figure 1).

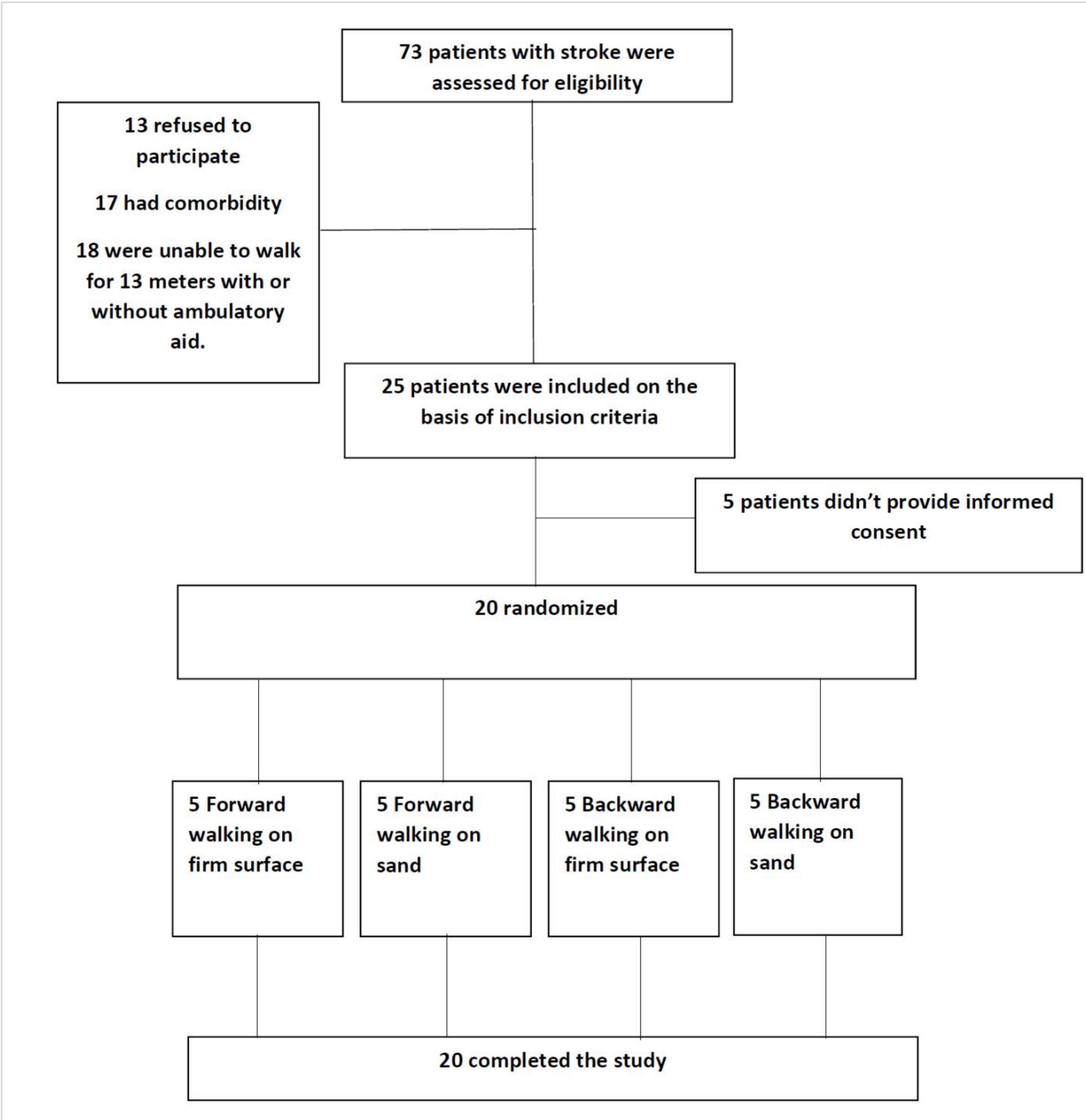


Figure 1: CONSORT Diagram for experimental study.

Twenty subjects volunteered to participate in this study and signed the written informed consent form. Out of 20 participants, 17 suffered from middle cerebral artery ischemic (7 female and 8 males) and 3 had middle cerebral artery hemorrhagic stroke (3 males). 12 out of 20 participants (3 female and 9 male) suffered a stroke on the dominant side and remaining 8 (4 male and 4 female) on the non-dominant side.

Participants were randomly allocated to 4 groups by lottery method. 20 participants were assigned a unique number. These numbers are put in a jar and thoroughly mixed. Blinded researcher picked numbers randomly to allocate participants into 4 groups. All participants underwent assessment of gait parameters before the start of training (pre-intervention) and at the end of the three weeks of training (post-intervention). The participants were allocated to four groups of five participants each. All participants received conventional treatment along with additional forward and backward walking exercises on a firm level surface and on sand.

Intervention

Participants in each group underwent 45 minutes of a conventional treatment program, which included modified constrain induced movement therapy, mat activities, balance training, and functional training of upper limb additionally every participant were given gait training on a firm level surface and on sand three times per week. The gait training required 25–35% of the total treatment session. All interventions were performed by an experienced physical therapist. 3 participants (1 male and 2 female) wore a modified shoe with AFO and 7 (5 male and 2 female) used cane regularly. The therapist closely guarded the subjects while backward walking to avoid falls. Backward walking was performed as described by Davis[15]. Initially, backward walking was practiced within the parallel bars: the individual was asked to hold (both hands) the railings of the parallel bar while walking backward for the first time .The therapist aided, such as when required to align the foot in correct position. Once the patient learned the correct pattern for backward walking, assistance was reduced. Lastly, the speed and distance of backward walking gradually progressed on a firm level surface and then moved onto the sand outside the parallel bars. All training sessions were closely monitored by a qualified and experienced therapist in the field of stroke rehabilitation.

Outcome Measure

Stride Analyzer (B/L Engineering, USA) was used to measure temporal and spatial parameters of gait. The Analyzer consists of a pair of insoles that sense pressure as well as all the parameters of the gait cycle. There are different sizes of innersoles available. Moreover, the anterior and posterior portion of the innersole can be folded to accommodate the shoe without causing any disruption of data. The data was wirelessly transferred to the computer via a recorder.

A 13-m alley of the Department of Physiotherapy, King Khalid Hospital, was used to calculate the baseline data and the final data. The floor of the alley was marked at start 3-m, 10-m, and 13-m points. The data were obtained from the middle of the marked alley between 3-m and 10-m points, thus circumventing the acceleration at start and deceleration at the end while walking. The testing instruments were standardized and the test-retest coefficient between investigators for gait outcome ranged from 0.89 to 0.99. All the data obtained from the patient was stored in the computer with a coding to blind assessors. All participants wore comfortable shoes and were instructed to walk at their own pace. An average of three trials was recorded for each participant. For safety reason, participants were closely monitored while walking, although no physical assistance was provided. Participants were seated between the trials for 1min[16,17].

All instruments including innersoles and foot switches were calibrated before the trials.

Participants were allowed to take a short walk to be familiar with the innersoles of their shoes. Assistive devices like canes and ankle-foot orthosis were allowed to be used while training.

Temporal-spatial parameters were measured such as velocity (m/min), cadence (steps/min), stride length (m), gait cycle (s), normal single-limb support (% of gait cycle) and affected single-limb support (% of gait cycle). The temporal symmetry index was calculated with a formula:

$$SI = \frac{(X_R - X_L)}{0.5(X_R + X_L)} * 100\%$$

Result

A total of 20 subjects, including 13 males and 7 females with a mean age of 61.4 ± 4.1 years and a mean stroke onset of 9.7 ± 2.3 months, participated in the study. Among the participants, 8 were graded 3 and 12 were graded 4 on the Brunnstrom Stages of Recovery. The percent differences between baseline and post-test scores for all outcome variables were calculated for further analysis. To determine the effect of the treatment protocols, a paired sample t-test was conducted (see Tables 1).

Table 1. Effect of different treatment protocol

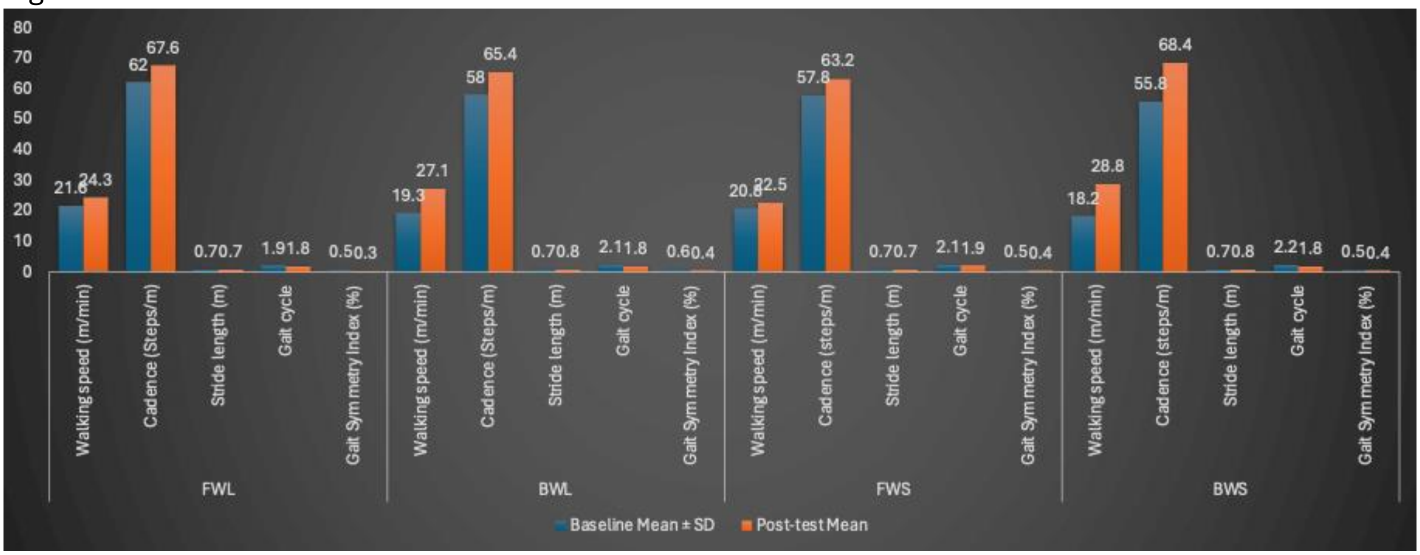
EP	Outcomes	Baseline	Post-test	Paired t-test	
		Mean ± SD	Mean ± SD	t	p
FWL	Walking speed (m/min)	21.6 ± 2.9	24.3 ± 3.3	−1.326	0.256
	Cadence (Steps/m)	62 ± 2	67.6 ± 3.6	−3.725	0.020*
	Stride length (m)	0.7 ± 0.1	0.7 ± 0.1	−0.439	0.683
	Gait cycle	1.9 ± 0.1	1.8 ± 0.1	1.826	0.142
	Gait Symmetry Index (%)	0.5 ± 0.1	0.3 ± 0.1	10.587	0.000*
BWL	Walking speed (m/min)	19.3 ± 1.5	27.1 ± 3.1	−5.638	0.005*
	Cadence (Steps/m)	58 ± 4.8	65.4 ± 4.5	−3.290	0.030*
	Stride length (m)	0.7 ± 0.1	0.8 ± 0	−6.595	0.003*
	Gait cycle	2.1 ± 0.2	1.8 ± 0.1	2.269	0.086
	Gait Symmetry Index (%)	0.6 ± 0.1	0.4 ± 0.1	4.964	0.008*
FWS	Walking speed (m/min)	20.8 ± 1.2	22.5 ± 2.3	−1.244	0.281
	Cadence (steps/m)	57.8 ± 1.6	63.2 ± 4	−2.557	0.063
	Stride length (m)	0.7 ± 0	0.7 ± 0	0.221	0.836
	Gait cycle	2.1 ± 0.1	1.9 ± 0.1	2.828	0.047*
	Gait Symmetry Index (%)	0.5 ± 0.1	0.4 ± 0	2.418	0.073
BWS	Walking speed (m/min)	18.2 ± 0.9	28.8 ± 1.1	−14.697	0.000*
	Cadence (steps/m)	55.8 ± 3.3	68.4 ± 3.3	−9.000	0.001*
	Stride length (m)	0.7 ± 0.1	0.8 ± 0	−8.728	0.001*
	Gait cycle	2.2 ± 0.2	1.8 ± 0.1	4.185	0.014*
	Gait Symmetry Index (%)	0.5 ± 0.1	0.4 ± 0.1	3.613	0.022*

Key: EP-Experimental Protocol; FWL-Forward Walking on Level Surface; BWL-Backward Walking on Level Surface; FWS-Forward Walking on Sand & BWS- Backward Walking on Sand

A paired t-test was conducted to evaluate the effect of different walking protocols on various gait parameters. For Forward Walking on Level Surface (FWL), there was a significant improvement in cadence ($t = −3.725$, $p = .020$) and Gait Symmetry Index ($t = 10.587$, $p < .001$), though changes in walking speed, stride length, and gait cycle were not significant. For Backward Walking on Level Surface (BWL), significant improvements were observed in walking speed ($t = −5.638$, $p = .005$), cadence ($t = −3.290$, $p = .030$), stride length ($t = −6.595$, $p = .003$), and Gait Symmetry Index (t =

4.964, p = .008), with no significant change in the gait cycle. For Forward Walking on Sand (FWS), there was a significant decrease in gait cycle (t = 2.828, p = .047), but changes in walking speed, cadence, stride length, and Gait Symmetry Index were not significant. For Backward Walking on Sand (BWS), significant improvements were found in walking speed (t = −14.697, p < .001), cadence (t = −9.000, p = .001), stride length (t = −8.728, p = .001), gait cycle (t = 4.185, p = .014), and Gait Symmetry Index (t = 3.613, p = .022). These results indicate that different walking protocols can significantly affect various aspects of gait, with notable improvements observed in backward walking on both level surfaces and sand.

Figure 1:



Key: FWL-Forward Walking on Level Surface; BWL-Backward Walking on Level Surface; FWS-Forward Walking on Sand & BWS-Backward Walking on Sand

To determine the effect of training across the four different protocols, the percentage difference between the baseline and post-test scores for all conditions was calculated. A one-way analysis of variance (ANOVA) was then conducted with Bonferroni post hoc comparisons. The results of this analysis are presented in Table 2.

The one-way ANOVA revealed statistically significant differences between the treatment protocols for walking speed (F = 9.306, p = .001), cadence (F = 3.572, p = .038), stride length (F = 7.002, p = .003), and the gait symmetry Index (F = 5.649, p = .008). However, there was no significant difference in the gait cycle among the treatment protocols. For all variables that showed a statistically significant difference, Bonferroni post hoc comparisons were performed.

Table 5. Between-group comparison for finding the efficacy of four different training protocol.

Variable	EP	Mean ± SD	One way ANOVA		FWL vs BLS	FWL vs FWS	FWL vs BWS	FWS vs BWL	FWS vs BWS	BWL vs BWS
			t	p						
Walking speed	FWL	14.3 ±23.2	9.306	0.001	0.16	1	0.005*	0.057	0.002*	0.690
	BWL	40.5 ±16.3								
	FWS	8.8 ±15.2								
	BWS	58.5 ±11.1								
Cadence	FWL	9.1 ±5.5	3.572	0.038	1	1	0.066	1	0.079	0.369

	BWL	13.2 ±9.5							
	FWS	9.5 ±8.4							
	BWS	22.8 ±6.1							
Stride length	FWL	4.51 ±7.7	7.002	0.003	0.137	1	0.035*	0.035*	0.009*	1
	BWL	24.1 ±9.6							
	FWS	−0.64 ±11.3							
	BWS	29.2 ±8.7							
Gait cycle	FWL	−7.2 ±9.4	2.438	0.102	-	-	-	-	-	-
	BWL	−16.4 ±15.4							
	FWS	−16.8 ±10.4							
	BWS	−26.8 ±9.7							
Gait Symmetry Index	FWL	−42.2 ±11.3	5.649	0.008	1	0.021*	0.025*	0.240	1	0.282
	BWL	−33.4 ±12.3							
	FWS	−17.0 ±13.5							
	BWS	−17.6 ±8.9							

Key: EP-Experimental Protocol; FWL-Forward Walking on Level Surface; BWL-Backward Walking on Level Surface; FWS-Forward Walking on Sand & BWS- Backward Walking on Sand

The Bonferroni post hoc comparison revealed statistically significant differences between subjects who underwent Forward Walking (FW) training on land and those who underwent Backward Walking (BW) training on land in three outcome variables: walking speed (p = .005), stride length (p = .035), and the Gait Symmetry Index (p = .025). Additionally, subjects in the FW training protocol showed a statistically significant difference compared to subjects in the BW training protocol in walking speed (p = .002) and stride length (p = .009). All other comparisons were not significantly different.

Discussion

Our study assessed the effects of forward and backward walking on sand and on a firm level surface among chronic stroke patients. The results of our study compared four different groups (Forward walking on Leveled surface (FWL), backward walking on Leveled surface (BWL), forward walking on sand (FWS), and backward walking on sand (BWS). The different walking parameters of cadence, stride length, and the Gait Symmetry Index showed significant changes in the pre- and post-sessions. The results of the study indicated that BWS is an effective intervention for chronic stroke patients.

A study by Lee et al.[18] showed a significant reduction in BW speed and cadence compared to FW, even though, gait cycle, and stride time were significantly increased during BW. Moreover, there was a significant change in stride length between BW and FW. A recent review and meta-analysis[19] revealed that the mean walking speed in stroke patients varied from 0.11 to 1.20m/s as compared to healthy elderly adults which ranged from 1.20 to 1.46 m/s. In our study, the mean walking speed of the BWS group improved from 0.30m/s (pre-intervention) to 0.48 m/s (post-intervention) (Figure 1). Another study [20] reported that backward walking velocity was a better prognosticator of the risk of falls than FW. Furthermore, they determined that all the fallers in their study had a gait speed of less than 0.60 m/s.

Balance has been shown to positively correlate with physical mobility and independent living. The BWS group indirectly showed an improvement in balance specific activity (% of single leg stance and step symmetry index).

Abnormal gait pattern is recognized by the asymmetrical pattern of limbs in terms of time spend on one limb[21]. Usually, stroke patients prefer to spend less stance time on the affected side[22].One goals of rehabilitation is to restore the symmetrical physiological pattern.[23]. Temporal gait asymmetry was observed at baseline in all the four groups. After three weeks of training, the BWS group showed results that were twice better (47% change in SI) than the FWS group (17.6% change SI) followed by BWL patients (33.4% change in SI). Similar results were found in a study in which subjects were trained on backward walking on a firm level surface[24].

Furthermore, a study by Yang et al.[25] suggested that BW walking would improve asymmetric gait patterns of post-stroke patients. In FW walking, gait velocity and cadence significantly increased but the gait cycle significantly decreased. Moreover, their study was in accordance with our results, as BW walking significantly improved gait velocity, cadence, stride length, and symmetry; however, the gait cycle (Figure 1) was reduced.

Our study revealed a 58.5% change in walking speed in the BWS group compared to the 14.3% change in the FWL group. These results are similar to a previous study, which reported that backward walking on the treadmill[26]improved cadence and walking speed better than FW on a treadmill. Moreover, walking speed increased by using a BW treadmill compared to that with over ground walking.

Many studies[26–29] have sustained that BW walking improved gait parameters, muscle strength, and endurance in stroke patients either on a firm level surface or on a treadmill. Studies have shown that backward walking limits visual cues and challenges neuromuscular control to maintain balance. Therefore, backward walking works two-fold: it reverse-trains the muscles of forward locomotion and influences dynamic walking balance. Moreover, sand adds to the demand of the balance component of walking. Backward walking on sand may cause enhanced proprioceptive input and greater muscle activation,[30] which may have contributed to the improved gait outcome in our study. In addition, the enhanced cerebral activation intrinsic[31]to backward walking may have involved damaged cerebral circuits better, leading to improved neural plasticity. Future studies should investigate the activation of cerebral activity during backward walking on difference surfaces. Sand is inexpensive and is available everywhere. It provides a cushioning effect in case a patient falls while walking. The chances of being injured are notably less than on a firm level surface. Sand improves confidence in patients as they feel safe. Although walking backwards sufficiently challenges the motor and postural control of stroke patients, similar findings have been reported in a study evaluating FW on sand[32].

A recent study reported a positive agreement between perceptions about the change in their walking ability with measured changes in the walking ability among stroke patients[33]. In our study, we also identified a self-perceived change in walking ability among subjects walking on sand (FWS and BWS), which was better than perceived by patients walking over firm level ground. (FWL and BWL).

Limitations and future recommendations

The results from this study were obtained from a small group of subjects; therefore, the results must be interpreted with caution. In addition, this study did not examine the kinetic changes occurring during backward walking for stroke patients and thus failed to determine a potential mechanism for the effectiveness of backward walking on sand. Future studies should also evaluate the influence of the strength of the major muscle groups in improving backward walking in stroke patients.

Our study also encourages researchers to explore the effect of backward walking on sand on ankle proprioceptive among stroke patients. Furthermore, our results suggested that BWS training on sand could be made safer in the clinical setting by using an over-head harness.

Conclusions

Our study suggests that the use of sand for gait training after stroke is beneficial and is more effective when a challenge component is introduced, such as for backward walking.

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