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Effect of lower limb sensory training on postural stability in stroke patients: A randomized control trial

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***Abstract*---**Background: Cerebrovascular accident (Stroke) incidence is rapidly increasing and is considered to be one of the leading causes of death and physical impairment on a global level. These impairments aren't limited to motor weakness but can also include impairments in somatosensory functions essential for producing accurate and specific motor actions. Aim of the study: To determine the efficacy of lower limb sensory training on postural stability in stroke patients. Procedures: Thirty male ambulant patients with ischemic stroke in the distribution of anterior circulation with a modified Ashworth scale not exceeding 1+. The ages of the participants were between 50-65 years. They were recruited three to six months from the onset of their symptoms. Then, they were assigned randomly into two equal groups, study group (A) and control group (B). The patients in the study group (A) have been given a combination of a sensory-based intervention program for the affected lower limb and a carefully selected physical therapy program. Control group (B) patients were treated with the same selected physical therapy program. The treatment was executed three sessions per week

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for six weeks. Each session was done in a 90 minutes window. Postural stability was evaluated with the Berg Balance Scale (BBS) and the Biodex balance system indices (mediolateral stability index [MLSI]), anteroposterior stability index [APSI], and overall stability index [OASI]) in both eyes-open and eyes-closed circumstances before and after interventions. Results: A significant drop was noted in the indices of the Biodex balance system with eyes opened and eyes closed of both group A and group B post-treatment contrasted with pretreatment (P > 0.001) and there was a significant improvement in the BBS Index post-treatment in the group A and B contrasted with that pretreatment (P < 0.001). Between groups, there was a significant improvement in all measures of the study group (A) contrasted with the control group (B). Conclusion: Sensory-based interventions may be an effective intervention to improve postural stability in subacute stroke patients.

***Keyword*---**Stroke, Postural stability, Sensory training, Berg balance scale, Biodex balance system

Introduction

Stroke is a disturbance of cerebral functions that lasts more than 24 hours and appears to be vascular in origin. Ischemic strokes are the most common accounting for more than eighty percent of stroke cases in 2021 according to the American heart association[1]. The majority of stroke cases were able to be independently ambulant but this doesn't necessarily mean having a normal gait pattern as they tend to disuse their affected lower limb[2].

Postural instability, or impaired balance, is not uncommon amongst stroke survivors. It may get affected by disturbances in the associated systems of the process of Regulation of Posture or psychologically due to safety concerns and falling phobia. Stroke significantly alters the symmetry of weight bearing, with patients bearing between 61% and 80% of their weight on the less affected limb[3].

Less weight bearing on the more affected side may lead to further disuse atrophy. This can persist for years after injury encouraging more learned nonuse of the paretic side due to safety concerns and lack of sensory awareness of the affected side leading to more and more limitations in overall motor function and independence levels of stroke patients[4].

Different types of sensory-based interventions were mentioned in the literature, two main types were detected; active sensory training which is a method based on learning principles and graded re-education of sensory awareness, and passive sensory stimulation which is a method of stimulating afferent inputs by using electrical or thermal stimulation. It was noted that a greater focus was on methods of passive sensory stimulation than active sensory training[5].

Methods

Participants

Thirty male patients were recruited in the period between December 2020 to January 2022 with ischemic stroke in the anterior circulation three to six months from the onset, severity of lower limb spasticity on the modified Ashworth scale ranging from 1 to 1+, patients had adequate cognitive capacity and were ambulant. Patients were selected from the Faculty of Physical Therapy at Cairo University's outpatient clinic, and the stroke specialized clinic of the Faculty of Medicine, Cairo University. All participants were diagnosed based on careful history taking and neurological examination done by a neurologist and confirmed by a CT or an MRI of the brain. All participants agreed to participate in the study and signed a written consent form after being fully informed of its objectives, methods, potential advantages, and intended use of the collected data.

Patients with musculoskeletal disorders that can have a negative impact on their balance such as severe arthritis, lower limb fractures or contractures that led to a fixed deformity, patients with visual or auditory impairments, patients with cognitive impairments, patients with congestive heart failure, unstable angina, and shortness of breath were excluded from the study. The patients were randomly assigned using simple randomization methods such as coin-tossing or dice-rolling into two groups of equal numbers: study group (A) and control group (B) Fig (1).

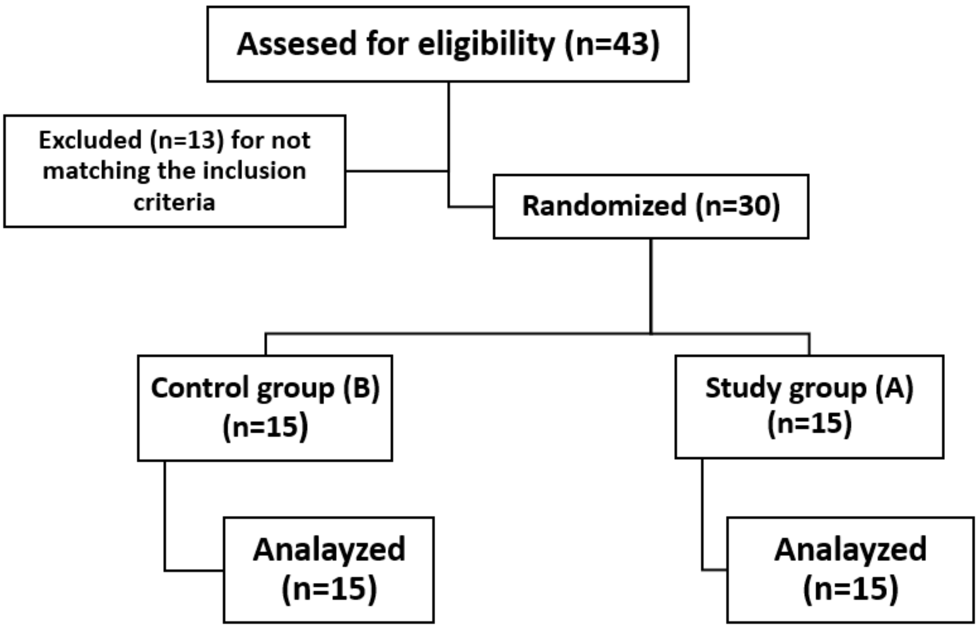

Fig. (1) A Flow chart of the study

Procedures

A selected physical therapy program was done for both groups which consisted of stretching exercises performed at the start of each session for a period of 30 seconds and repeated three to four times, facilitation for weak muscles, and strengthening exercises for the muscles exceeding grade three in the lower limbs such as straight leg raising exercises, clamshell exercises, and bridging. The exercises were done in three sets, each set consisted of 10 repetitions in a 90 minutes session three days per week for six weeks.

Sensory-based interventions were done only for the study group (A). 60 minutes of each session was dedicated to sensory-based interventions while the remaining 30 minutes were dedicated to the selected physical therapy program. Sensory-based interventions consisted of a method of passive sensory stimulation which was done using transcutaneous electrical neuromuscular stimulation (TENS) and delivered using a Chattanooga Primera TENS/NMES Unit with HAN waveform. The intensity of the stimulation delivered by the device was adjusted to be above the sensory threshold of each participant without inducing any visible nor palpable contraction in the calf muscle or causing the participant any pain. A pulse width of 200 μs was delivered at a frequency of 100 Hz for 30 mins[6]. Sessions were done three times per week for six weeks.

Active sensory training was done through a proprioceptive training program. The program consisted of three phases of training done in a step standing and standing position; the first phase was done using a soft stable surface (a block), and the second and third phases of training were done by using an unstable surface (a two-dimensional balance board). Each phase had a series of tasks done in both eyes opened and closed conditions. Five trials were done for each task, and they were considered a set, between each trial the patient was allowed to take a break for 10 seconds, and the patient was asked to perform five sets of each task to be considered completed and move on to the next.

Phase 1

Task 1: The patient assumed a step standing position with his affected limb on the block and the unaffected limb on the ground. The patient was asked to maintain the position for 20 seconds.
Task 2: The patient assumed a step standing position with his affected limb on the block and the unaffected limb on the ground and was asked to perform upper limb movement or reach in all directions for the purpose of weight shifting while maintaining stability
Task 3: The patient assumed a step standing position with his unaffected limb on the block and his affected limb on the ground and asked to maintain this position for 20 seconds.
Task 4: The patient assumed a step standing position with his unaffected limb on the block and his affected limb on the ground and was asked to perform upper limb movement or reach in different directions for the purpose of weight shifting while maintaining stability.

Phase 2

Task 1: The patient assumed a step standing position with his affected limb on the balance board and the unaffected limb on the ground. The patient was asked to maintain the position for 20 seconds.

Task 2: The patient assumed a step standing position with his affected limb on the balance board and the unaffected limb on the ground, reaching exercises and upper limb movements were done to encourage patients to shift their weight in all directions

Task 3: The patient assumed a step standing position with his unaffected limb on the balance board and his affected limb on the ground and asked to maintain this position for 20 seconds.

Task 4: The patient assumed a step standing position with his unaffected limb on the balance board and his affected limb on the ground. reaching exercises were done and upper limb movements to encourage patients to shift their weight in all directions.

Phase 3

Task 1: Patients were asked to assume a standing positing on the 2-dimensional balance board and remain stable for 20 seconds

Task 2: Patients were asked to assume a standing position on the 2-dimensional balance board while being asked to reach in multiple directions or perform upper limb movements to achieve weight shifting.

Measures

The berg balance scale (BBS) was used to assess static and dynamic balance pre and post-treatment. It consists of 14 items each item rated from 0 to 4 which leads to a maximum score of 56. The higher the score any patient gets the better. The items listed on the scale vary in difficulty. It had a significant validity and reliability in measuring balance and predicting falls in the elderly, it has also been used to evaluate the effectiveness of interventions and evaluation of overall functional level in clinical practice[7].

The Biodex Balance System (BSS) (Model 945-302, software version 3.12, New York) was used to assess postural stability objectively by calculating the mediolateral stability index (MLSI), the anteroposterior stability index (APSI), and, the overall stability index (OSI) in two different conditions (open and closed eyes) pre and post-treatment. The system includes a circular unstable platform that can tilt up to 20 degrees in all directions from the horizontal. The level of platform instability can be changed accordingly from level eight (minimally unstable) to level one (extremely unstable). The system is equipped with a 12.1″high resolution touch screen LCD with adjustable height display (53" to 68" above platform) to be suitable for each patient during assessment and adjustable support rails at the sides to provide maximum safety for patients. The Biodex balance system provides accurate testing with comprehensive, predictive, or bilateral comparison report formats[8].

Data Analysis

An independent t-test was done to compare participant characteristics among groups. Normal distribution of data was investigated by the Shapiro-Wilk test. Between groups homogeneity was examined by the Levene's test for homogeneity of variances. To assess the effects on APSI, MLSI, OASI, and BBS within and between groups, a mixed design MANOVA was carried out. For the following multiple comparisons, the Bonferroni correction was used to execute a post-hoc analyses. All statistical tests had a significance threshold of p 0.05. The statistical program for social studies (SPSS) version 25 for Windows was used for all statistical analysis (IBM SPSS, Chicago, IL, US).

Results

- Regarding basic characteristics of subjects:
Age, weight, height, and BMI did not significantly differ across groups (p 0.05). (**Table 1**)

Table 1.
Basic characteristics of subjects

	Group A Mean ± SD	Group B Mean ± SD	t- value	p-value
Age (years)	56.8 ± 4.36	55.86 ± 5.38	0.52	0.61
Weight (kg)	78.26 ± 9.6	77.6 ± 7.89	0.21	0.83
Height (cm)	166.73 ± 7.42	168.13 ± 9.79	-0.44	0.66
BMI (kg/m²)	28.26 ± 4	27.52 ± 2.61	0.59	0.55

SD, Standard deviation; p-value, Probability value

Regarding the Biodex balance system indices and BBS after treatent:
Interaction of great significance was noted of treatment and time ($F_{(7,22)} = 5.41$, $p = 0.001$, $\eta^2 = 0.63$). There was a significant main effect of time ($F_{(7,22)} = 113.51$, $p = 0.001$, $\eta^2 = 0.97$). The primary treatment effect was statistically significant ($F_{(7,22)} = 2.53$, $p = 0.008$, $\eta^2 = 0.44$).

- Within group differences
A significant decrease was found in all values of the Biodex balance system indices (APSI, MLSI, and OASI) with eyes open and eyes closed conditions of both groups post-treatment compared with pretreatment ($p < 0.001$). The BBS significantly improved in both groups after intervention, compared to baseline before treatment. ($p < 0.001$). The percent of change of the BBS in groups A and B was 10.07 and 5.51 respectively **(Table 2-3)**.

- Between groups differences
There was a significant decrease in all values of the Biodex balance system indices (APSI, MLSI, and OASI) in both eyes open and eyes closed conditions of group A compared with that of group B post-treatment ($p < 0.05$). There was a

significant increase in the BBS of group A compared with that of group B post-treatment (p < 0.001) **(Table 2-3)**.

Table 2.
Mean APSI, MLSI, OASI with eye opened and BBS pre and post treatment of the group A and B

Eye opened	Study group Mean ±SD	Control group Mean ±SD	MD	p-value
APSI				
Pre-treatment	2.74 ± 0.93	2.91 ± 0.79	-0.17	0.59
Post-treatment	1.61 ± 0.52	2.26 ± 0.61	-0.65	0.004
MD	1.13	0.65		
% of change	41.24	22.34		
	p = 0.001	***p = 0.001***		
MLSI				
Pre-treatment	2.71 ± 0.62	2.81 ± 0.55	-0.1	0.6
Post-treatment	1.73 ± 0.39	2.26 ± 0.45	-0.53	0.002
MD	0.98	0.55		
% of change	36.16	19.57		
	p = 0.001	***p = 0.001***		
OASI				
Pre-treatment	3.95 ± 0.97	4.15 ± 0.8	-0.2	0.55
Post-treatment	2.57 ± 0.65	3.08 ± 0.54	-0.51	0.02
MD	1.38	1.07		
of change	34.94	25.78		
	p = 0.001	***p = 0.001***		
BBS				
Pre-treatment	51.06 ± 2.12	50.8 ± 2.14	0.26	0.73
Post-treatment	56.2 ± 1.2	53.6 ± 1.88	2.6	0.001
MD (95% CI)	-5.14	-2.8		
% of change	10.07	5.51		
	p = 0.001	***p = 0.001***		

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, probability value

Table 3.
APSI, MLSI, and OASI with eye closed pre and post treatment of the group A and B

Eye closed	Group A Mean ±SD	Group B Mean ±SD	MD	p-value
APSI				
Pre-treatment	5.68 ± 1.35	6.39 ± 1.02	-0.71	0.11
Post-treatment	3.48 ± 0.98	4.81 ± 1.12	-1.33	0.002
MD	2.2	1.58		
% of change	38.73	24.73		
	p = 0.001	***p = 0.001***		
MLSI				
Pre-treatment	5.31 ± 1.15	5.69 ± 0.94	-0.38	0.33

Post-treatment	3.16 ± 0.78	3.83 ± 0.81	-0.67	0.02
MD	2.15	1.86		
% of change	40.49	32.69		
	p = 0.001	***p = 0.001***		
OASI				
Pre-treatment	5.97 ± 0.96	5.93 ± 0.85	0.04	0.9
Post-treatment	3.17 ± 0.57	4.03 ± 0.53	-0.86	0.001
MD	2.8	1.9		
% of change	46.90	32.04		
	p = 0.001	***p = 0.001***		

SD, Standard deviation; MD, Mean difference; p-value, probability value

Discussion

With this research, the berg balance scale was used as an outcome measure to assess postural stability for both groups. The berg balance scale was proven to have great reliability and validity in measuring changes In postural control in response to treatment[9].

The Biodex balance system was used to objectively measure postural stability in two different conditions; eyes opened, and eyes closed. It produced three indices; the anteroposterior stability index (APSI), the mediolateral stability index (MLSI), and, the overall stability index (OASI). The Biodex balance system indices were proven to have great validity and reliability in measuring postural control[10].

Patients enrolled in this study were recruited three to six months after their stroke onset. Every stage of recovery requires a different set of goals, the study was limited to patients in the subacute stage as this is the stage at which rehabilitation programs aim to treat several impairments and regain functional mobility[11].

The current study excluded patients with uncontrolled diabetes or diabetic neuropathy for two main reasons; first, it was pointed out that diabetic patients can benefit from balance training when the training focuses mainly on the muscular control of balance not the sensory aspect of postural control[12]. On the other hand, the adverse effects of diabetes on functional outcomes as it had been associated with many complications which can undeniably affect the ability of the patients to benefit from the rehabilitation process[13].

To measure the effect of sensory training of the lower limb on postural stability in patients with stroke the current work recruited 30 male patients and randomly allocated them to two groups: study group (A) and control group (B). group (A) was treated by selected physical therapy program in addition to sensory-based interventions (Proprioceptive training and T.E.N.S) while group B simply received the selected physical therapy program. The berg balance scale scores and the Biodex balance system indices in both open and closed eyes conditions were measured before and after treatment to measure the effectiveness of the interventions. The results revealed a significant improvement in all measures of the study group when contrasted to the control group.

Results from this study are consistent with those of Chae et al. (2017), who looked into the impact of proprioceptive training on balance function and measured berg balance scale scores for both a control group and a proprioceptive training group. They discovered a significant improvement in the berg balance scale score of the proprioceptive training group compared to the scores of the control group [14].

Results from this study supported the findings of Ng et al. (2016), who found that TENS use significantly improved the berg balance scale scores in both groups. When compared to the control group, the study group that received TENS treatment in addition to task-oriented balance training also showed a substantial improvement in berg balance scale scores.[15].

The effectiveness of sensory-based interventions can be explained by the following; first, the enhanced afferent input of the affected limb to the sensorimotor cortex when applying peripheral electrical stimulation or any kind of sensory stimulation enhances the motor output from the primary motor cortex and consequently improves motor function. The relationship between the primary motor cortex and the somatosensory cortex offers the anatomic basis for understanding how sensory-based interventions affect motor function. Second, by decreasing the reliance on visual input which requires the subject to look down which in turn affects their posture and therefore, decreases their postural stability. Other studies suggested that sensory stimulation can activate cutaneous and proprioceptive sensory fibers consequently promoting cortical reorganization and excitability[16].

In contradistinction, Lynch et al. 2007 investigated the impact of lower limb sensory retraining in acute stroke patients and assessed postural control using the Berg balance scale, proprioception by the Distal proprioception test. According to the study, there was no noticeable difference between groups in any of the outcome variables. Three factors can be used to explain this discrepancy: first, the study's poor power as a result of the small sample size (only 21 subjects were recruited compared to 30 patients in this study); second, the difference regarding the introduction of the intervention at the acute stage of recovery versus the current study's introduction of interventions at the subacute stage. Last but not least, in this work, the system of Biodex balance was used in addition to the Berg balance scale to give an additional, objective measurement of postural stability.[17]

Conclusion

This study concluded that sensory-based interventions might be an effective method of improving postural stability in patients with subacute stroke.

Ethical Clearance

All procedures acquired the approval of the Cairo university Research Ethical Committee with the registration number (P.T.REC/012/002940). A consent form was signed by all the participants in the study before enrollment. This study was also registered in the Pan African Clinical Trials Registry (PACTR202209909344807).

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