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RESEARCH ARTICLE

To evaluate and compare the Effectiveness of Sensorimotor Integration with that of Conventional Training for improving Balance and Gait in Stroke Hemiparesis: A Comparative Study

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ABSTRACT

Aim of the study: To evaluate and compare the effectiveness of sensorimotor integration with that of conventional training for improving balance and gait in stroke hemiparesis.

Materials and methods: The study design used for this research will be comparative study. Data will be taken from Mahatma Gandhi Hospital and Medical College, Jaipur and Mumbai.

Results: When both the groups were compared using unpaired t-test, sensorimotor group showed significant improvement in all outcome measures ($p < 0.0001$) except for MCTSIAB conditions 1 and 2 where the difference was not statistically significant.

Conclusion: Sensorimotor integration training is one of the novel treatment which can have a addictive effects along with the conventional training for balance.

Keywords: Balance and gait training, Sensorimotor integration.

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INTRODUCTION

Stroke is third common cause of death and also a major cause of long-term disability. Balance problem are thought to be common after stroke, and they have been implicated in the poor recovery of activities of daily living (ADL) and mobility and an increased risk of falls.

The specific causes of balance disorders in hemiparetic patients after stroke can be manifolded.[1] Balance can be affected in various ways which include joint motion limitation, weakness, altered muscular tone, sensory deficits, anomalous postural reactions and cognitive problems.[2] Balance is a prerequisite for all functional activities and depends on the integrity of the central nervous system. Impaired balance and increased risk of falling toward the paretic side is found to be significantly correlated with locomotor function, functional abilities and length of staying inpatients rehabilitation facilities.

Balance impairment in patients with stroke hemiparesis is frequently related to deficits of central integration of afferent inputs (somatosensory, visual, and vestibular). Three sensory modalities are mainly involved in postural control: Somatosensory, visual, and vestibular afferents. Integration of information from these systems is crucial for adequate postural control.[3] For instance, in the static standing position, healthy adults normally use somatosensory information which globally comes from the lower limbs (feet pressure receptors, ankle joint receptors and muscle proprioceptors) in order to build the main reference coordinates for balance.[4,5] Under this condition, somatosensory afferents account for 70% of the information required for postural control, while vestibular afferent accounts for 20% and visual input for 10%.[6]

Visual and vestibular inputs are likely to be more relevant sources of information when proprioceptive information is unreliable, for instance, during sway, [6-9] When lower limb somatosensory information is inadequate (e.g., under a compliant surface support condition), other sensory systems are involved. This central integration of sensory inputs allows potential sensory conflicts generated by inadequate afferent information to be overcome.

For example, vestibular and somatosensory information is in conflict with visual information when a stationary train creates the illusion of movement as another train begins to move. Under these very critical conditions, the ability to analyze, compare and select the pertinent sensory information is very important in order to avoid falling. The existence of a general neural process

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aimed at resolving sensory conflicts and synthesizing from disparate sensory inputs and combining efferent and afferent information has already been suggested in literature.[10]

Sensory information is regulated dynamically and modified by changes in environmental conditions.[6] Despite the availability of multiple sources of sensory information, in a given situation, the central nervous system (CNS) gives priority to one system over another to control balance in the orthostatic position.[11] The ability to choose and rely on the appropriate sensory input for each condition is called eweighting.[12,13]

When one is standing on an unstable surface, for instance, the CNS increases sensory weighting to vestibular and vestibular and visual information and decrease the dependence on surface somatosensory inputs for postural orientation. On the other hand, in darkness, balance control depends on somatosensory and vestibular feedback. Sensory reweighting is also important in the situation of sensory conflict that frequently occurs in daily activities; for example, when someone stands next to a bus in movement. In this situation, the visual system reports relative movement of the person in relation to an object, which conflicts with information from the somatosensory and vestibular systems. The CNS must reject visual information and use vestibular and somatosensory inputs. The ability to analyze, compare, and select the pertinent sensory information to prevent falls can be impaired in hemiparetic stroke patients.[14]

Abnormal interactions between the three sensory systems involved in balance could be the source of normal postural reactions.[14-16] In situation of sensory conflict, a patient with stroke can inappropriately depend on one particular system over another.[15] Laboratory measurements of sensory organization demonstrate that patients with chronic stroke perform worse in conditions of altered somatosensory information and visual deprivation or inaccurate visual input.[14] Excessive reliance on visual input may be a learned compensatory response that occurs over time.[14] Relying on a single system can lead to inappropriate adaptations and, hence, balance disturbances. Furthermore, sensory integration and reweighting can be impaired in patients with stroke, emphasizing visual input even when it provides inaccurate information.[14-16]

Several structures of the central nervous system seem to be involved in sensory integration such as the visual and vestibular cortex[17,18] the posterior parietal cortex,[19] the dorsoventral prefront al cortex,[19] the basal ganglia,[20] the limbic system,[21] the cerebellum,[22] and the reticular system.[23]

No general physiotherapy approach has been proven to be superior for promoting balance recovery from stroke.

More research is needed to identify effective and efficient interventions for improving functional balance and reducing the risk of falls among people living in the community after a stroke.

Although, a deficit of sensorimotor integration is now acknowledged as a major factor in balance disability after stroke, few studies[2,24,25] have been carried out to propose remediation programs for rehabilitation of the anomalous processing of afferent sensory input in hemiplegic patients. A pilot study by Nicola et al have proved significant improvement in balance after rehabilitation of sensorimotor integration deficits in chronic stroke patients. But, there has been no research done to compare the efficacy of these new interventions with those of conventional physiotherapy for balance in chronic stroke patients. So, the main purpose of the study was to compare the efficacy of sensorimotor integration approach with that of conventional physiotherapy program for improving balance and gait in chronic stroke patients.

AIM

To evaluate and compare the effectiveness of sensorimotor integration with that of conventional training for improving balance and gait in stroke hemiparesis.

OBJECTIVES

- To assess the efficacy of conventional training on balance and gait in stroke hemiparesis.
- To assess the efficacy of sensorimotor integration on balance and gait in stroke hemiparesis.
- To compare the efficacy of conventional training and sensorimotor integration on balance and gait in stroke hemiparesis.

MATERIALS AND METHODS

Nature of study: The study design used for this research will be comparative study.

Research settings: Data will be taken from Mahatma Gandhi Hospital and Medical College Jaipur.

Selection criteria: An ethical committee approval was taken starting with the intervention.

A sample size of 30 subjects with stroke hemiparesis who met with the inclusion criteria was chosen from Mahatma Gandhi Hospital and Medical College (Jaipur). Their informed consent was taken. They were randomly divided into two groups: The control group and the experimental group.

The control group was treated with conventional training and training group with sensorimotor integration.

Inclusion criteria

- First episode of stroke
- Stability of neurological severity
- Absence of any cognitive impairment according to mini mental scale
- Ability to stand and walk with/without an aid.

Exclusion criteria

- Perceptual and visual impairment
- Deficits of somatic sensation involving the paretic lower limb
- Vestibular disorders
- Paroxysmal vertigo
- Presence of neurological conditions such as neglect, hemianopia and controversies pushing syndrome
- Presence of orthopedic disease involving lower limbs.

Materials required

- Mat
- Ball
- Weight cuffs
- Foam surface (inclined wedge)
- Vestibular board
- Parallel bar
- Stool
- Mirror.

Variables of study

- Modified clinical test of sensory integration and balance (CTSIAB)
- 10 meters walk test
- Berg balance
- Dynamic gait index.

Modified clinical test of sensory integration and balance (CTSIAB)

The modified clinical test of sensory integration and balance is timed balance[27-29] test that evaluate somatosensory, visual, and vestibular function for maintenance of upright posture. This test requires that patients maintain standing balance during a combination of three visual and two supports surface conditions. Tasks were performed with the eyes open and with the eyes closed. It included a hard, flat floor and an 8 cm section of density foam rubber that reduces the quality of the surface orientation input. During the test, subjects stood barefoot in the upright position with their arms alongside the body and their feet on the predesigned site. If the subjects activated any postural reaction, the test was stopped immediately and the number of seconds standing prior to the violation constituted the trial score.

The test was performed under four conditions:

1. Eyes open: Stable surface
2. Eyes open: Compliant surface
3. Eyes closed: Stable surface
4. Eyes closed: Compliant surface.

Five trials were carried out for each test condition. Each trial lasted 30 seconds. Total scores for each condition were the sums of the scores of each trial.

Maximum score for each test condition: $30 \times 5 = 150$.

Ten Meters Walking Test

This is a validated test used for quantitative analysis of gait. Patients were required to walk on a flat hard floor at their most comfortable pace for 10 meters using their usual assistive device and orthoses. Scoring was their walking speed.

Berg Balance

The Berg balance scale is a performance-based assessment tool, that is, used to evaluate standing balance during functional activities. The patients are scored on fourteen different tasks. Functional activities, such as reaching, bending, transferring, and standing, are evaluated on the test to evaluate balance.

Scores for each item can range from 0 (cannot perform) to 4 (normal performance).

Overall scores can range from 0 (severely impaired balance) to 56 (excellent balance).

- 41–56 = low fall risk
- 21–40 = medium fall risk
- 0–20 = high fall risk.

The Berg is considered as the gold standard assessment of balance with good intraratter reliability and good internal validity.

Dynamic Gait Index

It is a useful reliable and clinical tool for evaluating dynamic balance in ambulatory people with chronic stroke.

Training Procedures

All the subjects underwent 4 weeks of balance training program which consisted of 1 hour session thrice a week. The exercises for the conventional group were as follows:

- Strengthening of trunk and lower limb muscles

- Weight shifts in different positions, such as standing, kneeling, etc. Perturbations were given in different positions.
- Activities in standing included:
  - Standing with feet close to each other
  - Tandem standing
  - Standing reach outs in all directions
  - One leg standing
  - Step up/down/forward/sideways
  - Passing a ball behind
  - Marching with head kept straight
  - Standing with progression from wide to narrow BOS and then perturbations.
- Activities in walking included:
  - Tandem walking
  - Use of parallel bar (lateral walking)
  - Walking over and around obstacles
  - Picking up object while walking
  - Carrying weights while walking
  - Change in direction while walking.

The exercises for the sensorimotor integration group were as follows:

- Standing (progression from eyes open to closed and floor to mat):
  - Weight shifts and reach outs:
  - Tandem standing
  - Tandem standing and reach outs
  - One leg standing
  - Standing with head turns to left and right as per commands and maintain balance with eyes closed.
- Standing on inclined wedge-progression with eyes closed and head turns:
  - Step up from floor to mat, step up from floor to inclined wedge and back to floor
  - Walking on mat (progression from eyes open to closed and head turns)
  - Vestibular ball-sitting on ball with feet on floor and weight shifts/reach outs
  - Progression with feet on mat and eyes closed and maintain balance in sitting and also head turns. With feet on mat and reach outs.
- Vestibular board—balancing on it in sagittal plane (progression from wide BOS to narrow, tandem)
- Use of scooter board—maintains standing balance while giving perturbations. Progression to eyes closed and then head turns.

DATA ANALYSIS AND RESULTS

There was significant improvement seen within both the groups on Berg balance ($p < 0.0001$). Dynamic gait index ($p < 0.0001$), 10 m walk test ($p = 0.0001$) and modified CTSIAB (all conditions) ($p < 0.0001$) (Table 1 and Graphs 1 to 7). When both the groups were compared using unpaired t-test sensorimotor group showed significant improvement in all outcome measures ($p < 0.0001$) except for MCTSIAB conditions 1 and 2, and the difference was not statistically significant.

- Condition 1; $p > 0.999$
- Condition 2; $p = 0.8562$

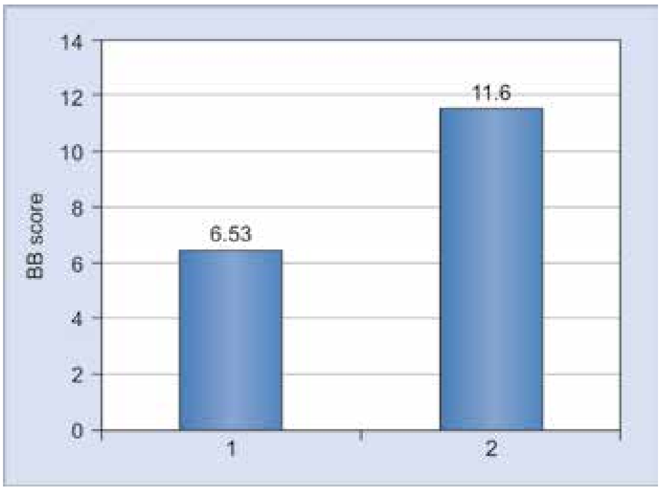
Table 1: Means and standard deviations of scores on outcome measures of conventional and experimental groups at baseline and 4 weeks

Measures *Conventional*	*Baseline (Pre)* *Mean (SD)*	*Post 4 weeks* *Mean (SD)*
Berg balance	38.66 (8.27)	45.46 (6.34)
Dynamic gait index	13.13 (3.77)	17.06 (4.26)
10m walk test	0.48 (0.19)	0.66 (0.18)
MCTSIAB-1	144.6 (6.39)	150 (0)
MCTSIAB-2	137.4 (7.8)	148.7 (3.7)
MCTSIAB-3	87.33 (15.79)	93.73 (13.22)
MCTSIAB-4	74.53 (21.17)	94.6 (21.68)
Experimental		
Berg Balance	32.933 (9.34)	45.866 (10.15)
Dynamic Gait Index	13.06 (3.283)	19.86 (2.85)
10m walk test	0.46 (0.15)	0.79 (0.16)
MCTSIAB-1	147.33 (5.936)	150 (0)
MCTSIAB-2	138 (13.2)	150 (0)
MCTSIAB-3	88.33 (14.59)	146 (8.28)
MCTSIAB-4	54 (12.42)	142.66 (14.37)

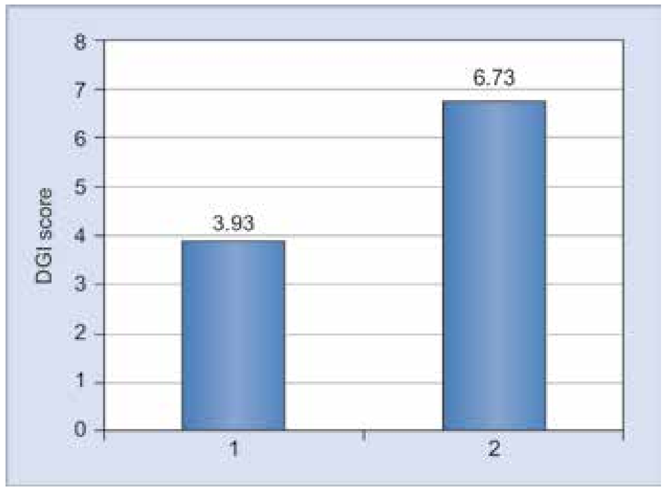
DISCUSSION

The present study shows that, following a specific training program based on weight transfer and balance exercises performed under different conditions of manipulation of sensory inputs, patients have achieved a significant improvement in their ability to maintain balance control. Gait ability, measured as walking speed, also showed a statistically significant improvement. These changes could not be ascribed to spontaneous recovery, because all the patients included in this study were at a chronic stage of illness. Thus, the improvement seen in the patients could be mainly ascribed to a change in sensory strategies used by patients in controlling their standing posture.

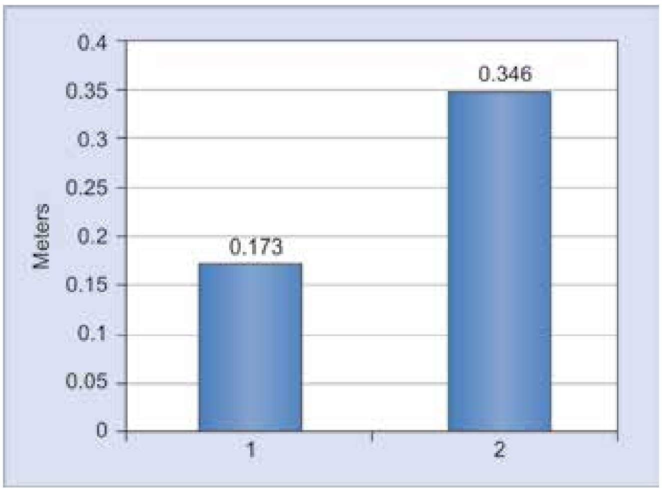
Balance is a complex process involving the reception and integration of sensory inputs and the planning and execution of movement to achieve a goal requiring upright posture. It is the ability to control the center of gravity (COG) over the base of support (BOS) in a given sensory environment. This biomechanical task of keeping COG over BOS is always accomplished within an environmental context which is detected by the sensory systems.



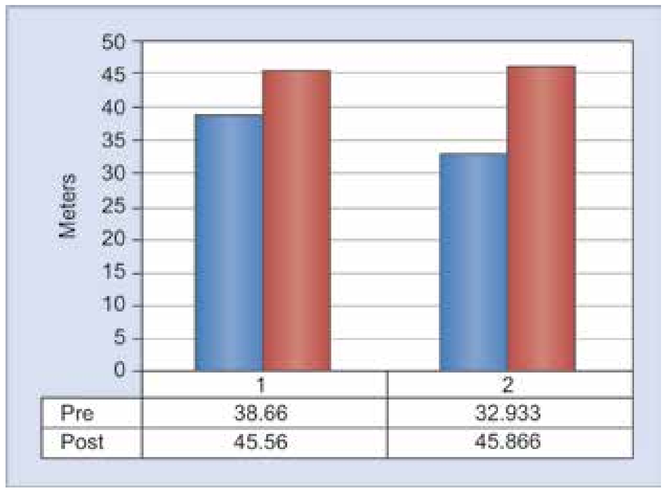
Graph 1: Improvement across conventional and experimental on Berg balance (BB) at 4 weeks



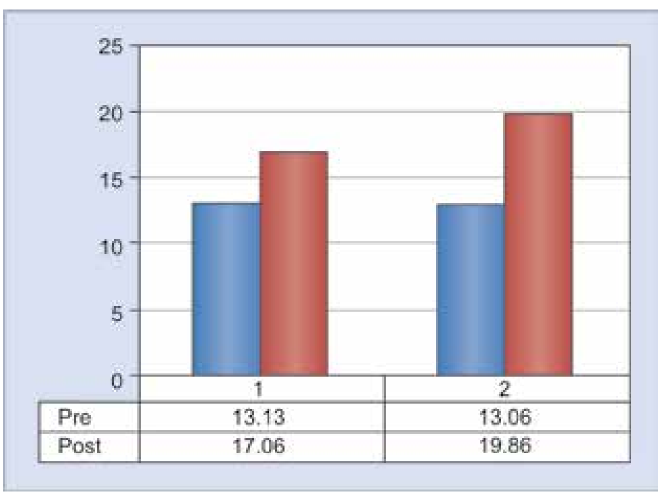
Graph 2: Improvement across conventional and experimental on Dynamic gait index (DGI) at 4 weeks



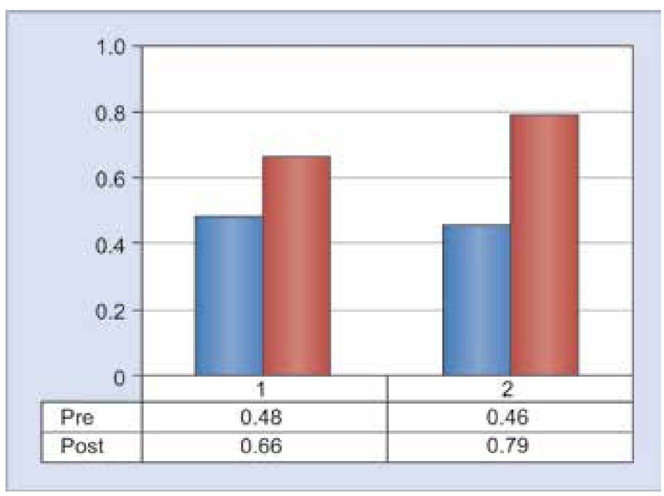
Graph 3: Improvement across conventional and experimental on 10m walk test at 4 weeks



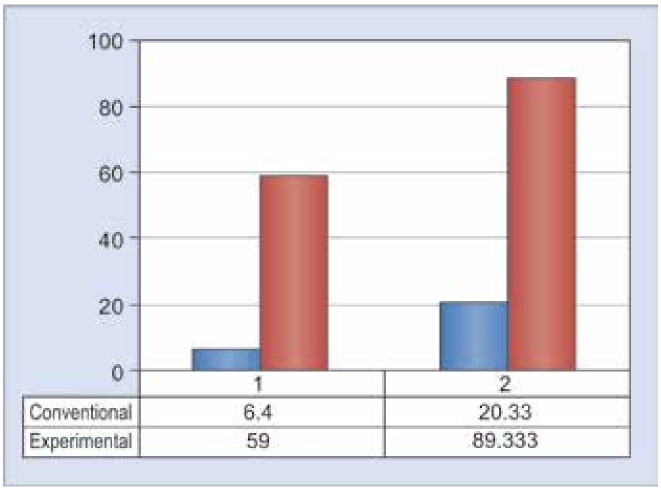
Graph 4: Berg balance in conventional and experimental: Baseline and at 4 weeks



Graph 5: Dynamic gait index in conventional and experimental: Baseline and at 4 weeks



Graph 6: 10m walk test in conventional and experimental groups: At baseline and after 4 weeks



Graph 7: Improvement in modified CTSIAB (conditions 3 and 4) in conventional and experimental groups

The sensory environment is the set of conditions that exist, or are perceived to exist in the external world that may affect balance. Peripheral sensory receptors gather information about the environment, body positions and motion in relation to the environment, and the body segments positions and motions in relation to self. Central sensory structures process this information to perceive body orientation, position and motion and to determine the opportunities and limitation present in the environment.

Both the groups showed significant improvement on Berg balance and dynamic gait index ($p < 0.001$). But sensorimotor group showed greater improvement than conventional group ($p < 0.001$).

Surface and visual conditions, however, may vary significantly and may be stable or unstable. Common unstable visual conditions are experienced on mass transit, in crowds or on a boat. Also, rapid head movement may render a stable visual environment unusable for postural cues, and darkness may preclude the use of vision.

As recently reported by Di Fabio and Badke[30] unlike normal subjects, patients with stroke tend to rely upon visual rather than somatosensory inputs in order to maintain the standing posture. This observation was confirmed by pretreatment MCTSIAB data which showed that postural stability was markedly decreased in all the somatosensory conflicts (complaint surface) conditions, and in particular during the blind conditions.

Thus, following exercise training aimed at progressively inducing to use lower limb somatosensory inputs for controlling standing stability, patients are able to improve their ability to stand even in conditions in which somatosensory input has been altered in several ways. Therefore, patients who received sensorimotor training performed better than conventional group in conditions 3 and 4 of MCTSIAB.

Human balance requires appropriate integration of many sensory and motor systems. The brain uses three main senses—visual, vestibular and somatosensory to determine where one is in space and how one is moving in relation to the environment, visual information provides a reference of our movement in relationship to the environment. Somatosensory information is used in at least two different ways. It is from the feet and lower extremity is used to determine movement of the body in relation to the support system. This information from the neck and trunk is used in conjunction with information from vestibular system to determine if movement is of entire body or head alone.

It is very relevant from a functional point of view that similar improvement was also seen in walking speed. This could be explained by improvement in postural adjustment mechanisms. Movements of the legs are a source of disturbance of balance because they are involved in body support, and thus a displacement of the center of gravity is observed immediately before and after movement onset. The center of gravity shift occurs, during the initiation and course of gait.[31] Control of the center of gravity shift toward a new position, compatible with equilibrium during movement, may be related both to anticipatory and responsive postural adjustments.[31] It is worth noting that sensory input integration is very important for maintaining equilibrium, especially during conditions of perturbed balance, such as during walking performance. Hence, the sensorimotor group showed improved walking speed than the conventional group.

Bonan et al[2, 24]assessed twenty patients with chronic hemiplegia after stroke (more than 12 months from onset). Patients were randomized to two groups both of which underwent a 4-week balance rehabilitation program.[32] Group I performed all the program exercises under vision deprivation while the same exercises were performed under free vision in group II. The results of this study showed that static and dynamic balance improved more after rehabilitation under visual deprivation than under free vision. They also recorded a significant improvement in gait ability after the training.

In the second study, by Bayouk et al,[25] sixteen patients with chronic hemiplegia after stroke (more than 12 months from onset) were randomized to an experimental and to a control group. The control group underwent an 8-week rehabilitation program aimed at improving balance, gait ability and movement coordination. These exercises were also performed in the experimental group but, in this case, the program also included exercises executed while the proprioception of the feet and ankles and/or vision was manipulated. As a whole, both groups received the same amount of therapy. As in the study by Bonan et al[2,24]a significant improvement in static and dynamic balance was recorded after rehabilitation training. In contrast, an improvement in walking speed was observed not only in the experimental but also in the control group.

This specific effect of rehabilitation could be ascribed to the fact that both groups performed walking exercises according to their training program:

The results of this study extended previous results[2,24] showing that a somatosensory integration training program can improve balance ability in patients with stroke and that this improvement is not transient but may persist for several days. As Perry et al[26] described, hemiparetic patients with a mean walking speed of 0.26 ± 0.11 m/s can be classified as those who are able to use walking for all household activities but unable to enter and leave their homes independently. On the other hand, patients with a walking speed of 0.4 ± 0.18 m/s are classified as being capable of entering and leaving their homes independently.[33-37]

Although the mechanism underlying the improvement in gait performance after a somatosensory integration training program are still subject to debate,[25] the results of the present study suggest that a balance rehabilitation program may lead to an improvement in postural control mechanism and consequently in gait performance.

LIMITATION

- The small sample size. Further studies with a larger subject population are needed to further validate the findings.

CONCLUSION

These results showed that the addition of a multisensory training component to the regular exercise program was required to obtain a significant improvement in standing balance of stroke subjects. In the absence of sensory training, very limited changes were observed for both static and dynamic balance tasks. Thus, it could be explained that sensorimotor integration training is one of the novel treatment which can have a addictive effects along with the conventional training for balance.

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