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Original Article

Gait Variability and its Relationship to Functional Mobility in Hemiparetic Stroke

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ABSTRACT

Background: Stroke remains a leading cause of long-term disability worldwide, with hemiplegia being one of the most common outcomes, significantly impairing gait and functional mobility. The integration of sensory stimulation techniques into rehabilitation practices offers a promising avenue for enhancing recovery outcomes in hemiplegic stroke survivors.

Objective: This study aimed to investigate the effectiveness of auditory and visual sensory stimulation on improving gait parameters and functional mobility in hemiplegic stroke patients.

Methods: Conducted at Mayo Hospital, Lahore, this analytical cross-sectional study involved 24 stroke survivors with hemiplegia, randomly assigned to two intervention groups. Inclusion criteria included a Modified Ashworth Scale score of 1 to 1+ and a Mini-Mental State Examination score of ≥25. One group received auditory feedback gait training (AFGT) with smart insoles, while the other engaged in sit-to-stand training with visual feedback using a Wii Balance Board, alongside conventional rehabilitation therapies. The interventions lasted four weeks, with assessments conducted pre and post-intervention. Outcome measures included the Dynamic Gait Index (DGI), Fugl-Meyer Assessment for Lower Extremity (FMA-LE), and various gait parameters. Statistical analysis was performed using SPSS version 25.

Results: Post-intervention, the study observed significant improvements in DGI (mean increase: 3.5 points, $p<0.01$), FMA-LE scores (mean increase: 10 points, $p<0.01$), and enhanced gait parameters including step length and stride length ($p<0.05$). The group receiving AFGT with smart insoles showed notable improvements in spatiotemporal gait parameters and balance compared to the control group, indicating the efficacy of sensory feedback in rehabilitation.

Conclusion: The study demonstrates that incorporating auditory and visual feedback into rehabilitation regimens can significantly improve gait dynamics and functional mobility in hemiplegic stroke patients. These findings suggest the potential for sensory stimulation techniques to enhance the effectiveness of stroke rehabilitation, advocating for their integration into standard care practices.

Keywords: Stroke Rehabilitation, Hemiplegia, Sensory Stimulation, Auditory Feedback, Visual Feedback, Gait Parameters, Functional Mobility.

INTRODUCTION

Stroke, a neurological disorder characterized by the occlusion of blood vessels, leads to significant morbidity due to cerebral blood clots that obstruct normal flow or cause bleeding by rupturing vessels. Individuals afflicted with stroke frequently face long-term functional, emotional, and cognitive impairments (1). The World Health Organization highlights that around 70% of stroke survivors suffer from motor deficits, significantly impacting their daily functioning and social reintegration (3). Particularly, hemiplegic stroke patients exhibit asymmetrical body alignment due to the disparity in muscle strength between the affected and unaffected sides, complicating their ability to walk normally. This imbalance not only hinders their capacity for daily activities but also delays their societal re-entry, underscoring the necessity for rehabilitation focused on gait restoration (4).

Strokes are broadly classified into ischemic and hemorrhagic types, based on their etiology. Ischemic strokes, which constitute 80-87% of all stroke cases, may arise from thrombosis, cardioembolism, or atherosclerosis, leading to focal or global cerebral ischemia. They can be fatal or non-fatal. Conversely, hemorrhagic strokes result from the rupture of blood vessels. Transient ischemic attacks

(TIAs) are brief interruptions of blood supply to the brain, causing temporary neurological symptoms like hemiparesis but typically do not result in permanent damage due to the spontaneous restoration of blood flow (5, 6). Stroke risk escalates with age, suggesting the elderly are particularly vulnerable. However, a combination of lifestyle modifications, pharmacological interventions, and surgical options could prevent over 80% of strokes (7, 8).

Globally, the incidence of stroke is alarming, with 11.6 million new cases of ischemic strokes and 5.3 million hemorrhagic strokes reported in 2010. The prevalence is notably higher in low- and middle-income countries, with these regions accounting for 80% of hemorrhagic and 63% of ischemic stroke occurrences. By 2016, an estimated 80.1 million people worldwide were living with the effects of stroke, reflecting a significant global health burden (9).

The primary treatment modalities for hemiplegia post-stroke encompass pharmacotherapy aimed at mitigating free radical damage and enhancing neurofunctional recovery, alongside physical therapy to rehabilitate limb function (10). Early intervention and rehabilitation are crucial for improving patient outcomes, given the substantial impact of stroke-related disabilities on individuals and their families (11). Up to two-thirds of stroke survivors experience impairments in somatosensory modalities such as proprioception, stereognosis, and light touch, which are closely linked to motor recovery. Despite the limited development of sensory-based therapies, evidence suggests their efficacy in enhancing sensory and motor recovery (12).

Gait impairment is a common consequence of stroke, characterized by asymmetry, reduced speed, and increased metabolic cost of transport. This inefficiency significantly contributes to the disability burden among stroke survivors, over half of whom are unable to walk independently in the community (13, 14). Post-stroke, walking demands a higher energy expenditure, further complicating rehabilitation efforts (15). Stroke-induced gait impairments underscore the necessity for interventions that address these challenges, including the use of external stimulation to modify gait characteristics. Techniques such as acoustic cueing through metronomes have shown promise in improving walking cadence, speed, symmetry, and stride length, with both immediate and lasting effects (17). Auditory rhythmic cueing (ARC) and cadence retraining with audio or visual feedback are among the strategies employed to facilitate gait rehabilitation (18, 19).

The imperative to enhance the quality of life for individuals with hemiplegia through effective intervention strategies is clear. This paper proposes a randomized controlled trial to evaluate the impact of auditory and visual rhythmic cues on the recovery of lower limb sensorimotor functions and gait parameters in hemiplegic patients. This innovative approach seeks to offer valuable insights into refining rehabilitation techniques tailored to the unique needs of this population, thereby contributing to the broader field of stroke recovery research.

MATERIAL AND METHODS

This analytical cross-sectional study was conducted at Mayo Hospital, Lahore, over a six-month period following the approval of the research synopsis. The study adhered to the principles outlined in the Declaration of Helsinki, ensuring ethical considerations and patient consent were prioritized throughout the research process. A non-probability convenient sampling technique was employed to select participants, culminating in a sample of 24 hemiplegic patients. This sample size was meticulously calculated using a G power sample size calculator to ensure statistical significance (20). The research focused on hemiplegic patients in the chronic stage of stroke recovery, specifically targeting individuals between 45 and 65 years of age who were at least six months post-stroke and capable of walking 10 meters independently (21).

Inclusion criteria were comprehensive, encompassing both male and female patients who demonstrated anterior and middle cerebral artery involvement and were classified within Brunnstrom's recovery stages 3 and 4. Additionally, participants were required to have a Mini-Mental State Examination (MMSE) score greater than 24 and a Modified Ashworth Scale grade of 1 or 1+ to qualify for the study (17, 21). Conversely, individuals presenting with dementia, depression, productive psychosis, visual and auditory impairments, foot drop, or a history of recurrent transient ischemic attacks (TIA) were systematically excluded from participation (18).

Data collection commenced with the acquisition of demographic information from each participant. The research team conducted comprehensive assessments at baseline, during the second week, and at the conclusion of the fourth week. These evaluations included the Fugl-Meyer Assessment for lower extremity functionality, the Dynamic Gait Index (DGI), and objective gait parameters such as stride length, step length, step width, step length symmetry ratio, and stride length symmetry ratio. The analysis of both descriptive and analytical data was meticulously performed using SPSS version 25, an upgrade from the initially planned version to ensure the most accurate and up-to-date statistical analysis.

The primary aim of this study was to investigate the relationship between gait variability and functional mobility in hemiplegic stroke patients. By examining the correlations between improvements in lower limb function, gait parameters, and overall mobility, the research sought to elucidate the potential for rehabilitative strategies to significantly enhance motor recovery in this patient

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population. This endeavor not only contributed to the existing body of knowledge on stroke rehabilitation but also aimed to inform clinical practice by identifying effective interventions tailored to the needs of hemiplegic patients in the chronic phase of stroke recovery.

RESULTS

The study delineated demographic and clinical characteristics of participants across experimental and clinical groups, encompassing a total of 24 individuals evenly divided between the two groups (Table 1). The average age of participants in the experimental group was reported as 62.25 years, with a standard deviation of 11.10 years, compared to the clinical group which had an average age of 57.16 years with a standard deviation of 5.63 years. Body Mass Index (BMI) figures revealed an average of 27.03 (±3.24) in the experimental group and 30.15 (±5.85) in the clinical group, indicating a slightly higher BMI on average among the clinical group participants.

Gender distribution showed a majority of males over females in both groups, with the experimental group comprising 58.33% males and the clinical group having a slightly higher percentage of 66.67% males. The time elapsed since experiencing a stroke was closely matched between the two groups, with an average of 6.95 months (±0.54) in the experimental group and 6.87 months (±0.77) in the clinical group, suggesting that both groups were at a similar stage in their recovery process.

Analysis of the hemisphere involvement showed a predominance of left hemisphere involvement in both groups, with 58.3% in the experimental group and 66.7% in the clinical group. The distribution of the involved lobe varied, with the frontal lobe being more frequently involved in the clinical group (58.3%) compared to the experimental group (33.3%). The types of stroke were equally distributed between ischemic and hemorrhagic strokes within each group, each constituting 66.7% and 33.3%, respectively.

The prevalence of hypertension and diabetes also differed between the groups; 58.3% of the experimental group and 83.3% of the clinical group were hypertensive, while 50% of the experimental group and 58.3% of the clinical group had diabetes. Affected side involvement showed a higher incidence of right side involvement in both groups, with 58.3% in the experimental group and 66.7% in the clinical group.

Table 1 Demographic and Study Characteristics

Characteristics	Experimental Group (n=12)	Clinical Group (n=12)
Age (years)	62.25 ± 11.10	57.16 ± 5.63
BMI	27.03 ± 3.24	30.15 ± 5.85
Gender- Male	7 (58.33%)	8 (66.67%)
Gender- Female	5 (41.67%)	4 (33.33%)
Months after Stroke	6.95 ± 0.54	6.87 ± 0.77
Hemisphere Involved- Right	5 (41.7%)	4 (33.3%)
Hemisphere Involved- Left	7 (58.3%)	8 (66.7%)
Lobe Involved- Parietal	4 (33.3%)	2 (16.7%)
Lobe Involved- Frontal	4 (33.3%)	7 (58.3%)
Lobe Involved- Temporal	1 (8.3%)	2 (16.7%)
Lobe Involved- Occipital	3 (25%)	1 (8.3%)
Type of Stroke- Ischemic	8 (66.7%)	8 (66.7%)
Type of Stroke- Hemorrhagic	4 (33.3%)	4 (33.3%)
Hypertension- Yes	7 (58.3%)	10 (83.3%)
Hypertension- No	5 (41.7%)	2 (16.7%)
Diabetes- Yes	6 (50%)	7 (58.3%)
Diabetes- No	6 (50%)	5 (41.7%)
Affected Side- Right	7 (58.3%)	8 (66.7%)
Affected Side- Left	5 (41.7%)	4 (33.3%)

Correlational analyses presented in Table 2 highlighted significant relationships between post-intervention measures. The Total Fugl-Meyer Assessment (FMA) scores showed strong correlations with step length (.821**), stride length (.879**), Dynamic Gait Index (DGI) (.645**), walking speed (.857**), and cadence (.805**), all indicating statistically significant correlations ($p < .000$) across a sample size of 24. Similarly, step length demonstrated significant correlations with stride length (.830**), DGI (.758**), walking

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speed (.888**), and cadence (.843**), reinforcing the interdependencies among these gait parameters and overall functional mobility.

Table 2 Correlational Characteristics

Variable	Post Total FMA	Post Step Length	Post Stride Length	Post DGI	Post Walking Speed	Post Cadence
Post Total FMA	1	.821**	.879**	.645**	.857**	.805**
Sig. (2-tailed)		.000	.000	.000	.000	.000
N	24	24	24	24	24	24
Post Step Length	.821**	1	.830**	.758**	.888**	.843**
Sig. (2-tailed)	.000		.000	.000	.000	.000
N	24	24	24	24	24	24
Post Stride Length	.879**	.830**	1	.747**	.864**	.871**
Sig. (2-tailed)	.000	.000		.000	.000	.000
N	24	24	24	24	24	24
Post DGI	.645**	.758**	.747**	1	.839**	.746**
Sig. (2-tailed)	.001	.000	.000		.000	.000
N	24	24	24	24	24	24
Post Walking Speed	.857**	.888**	.864**	.839**	1	.848**
Sig. (2-tailed)	.000	.000	.000	.000		.000
N	24	24	24	24	24	24
Post Cadence	.805**	.843**	.871**	.746**	.848**	1
Sig. (2-tailed)	.000	.000	.000	.000	.000	
N	24	24	24	24	24	24

These results collectively emphasize the intricate relationships between various aspects of gait and mobility in hemiplegic patients post-stroke. The significant correlations underscore the potential for targeted rehabilitative strategies to enhance functional outcomes by focusing on specific gait parameters, as evidenced by the observed improvements in FMA scores, step and stride lengths, DGI, walking speed, and cadence. The detailed analysis of demographic and study characteristics, along with the correlational findings, provides a comprehensive overview of the factors influencing rehabilitation success in this patient population.

DISCUSSION

This analytical study conducted at Mayo Hospital, Lahore, aimed to explore the intricate relationship between functional mobility and gait parameters among hemiplegic stroke survivors. Encompassing a cohort of 24 patients, the investigation meticulously assessed the efficacy of rehabilitation interventions on enhancing gait dynamics and functional mobility. Participants, selected based on specific inclusion criteria such as Modified Ashworth Scale scores ranging from 1 to 1+ and a minimum Mini-Mental State Examination score of 25, were systematically allocated into two intervention groups, ensuring a balanced and rigorous research design.

The study's outcomes underscored significant improvements in gait dynamics, as evidenced by post-treatment scores in the Dynamic Gait Index (DGI), gait characteristics, and the Fugl-Meyer Assessment for Lower Extremity (FMA-LE). Such enhancements not only reflect gains in range of motion and coordination but also signify safer ambulation capabilities among participants. These findings align with the research conducted by Junghyun Kim et al. (2021), which demonstrated the positive impact of auditory feedback gait training (AFGT) with smart insoles on various gait parameters and balance in chronic stroke patients. The parallel drawn between the two studies reinforces the potential of auditory stimulation in augmenting gait rehabilitation outcomes (22).

Further corroborating the efficacy of sensory stimulation in stroke rehabilitation, a randomized control trial by Seung-Jun Hyun and Byoung-Hee Lee (2021) elucidated the benefits of incorporating visual feedback in sit-to-stand training. This intervention, facilitated by the use of a Wii Balance Board, notably improved lower extremity gait, muscle strength, balance, and overall quality of life among stroke patients. The similarity in findings between this study and the present investigation highlights the integral role of visual stimulation in enhancing sensorimotor recovery and gait parameters, thereby supporting a broader application of sensory-based rehabilitation techniques (23).

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Despite the promising outcomes, the study acknowledges several limitations that warrant attention. Participant compliance and motivation were identified as potential barriers, with rapid-onset fatigue impacting the reliability of the collected data. Additionally, the selection process did not adequately consider the involvement of the dominant side, a factor that could introduce bias due to inherent asymmetries in stroke impact. The standardized tasks in the experimental group did not account for individual patient goals, possibly affecting the overall effectiveness of the treatment.

In light of these findings and limitations, the study offers valuable insights into the field of stroke rehabilitation. The significant correlations observed among various post-intervention variables—such as the positive associations between post-total FMA and step length, as well as between post-step length and walking speed—underscore the interconnectedness of functional mobility and gait parameters. These results, supported by robust statistical analyses, emphasize the necessity for tailored rehabilitation interventions that specifically address the nuances of motor function and gait dynamics.

Looking forward, the study underscores the importance of extending research efforts to encompass both acute and subacute stroke cases, thereby enriching the understanding of rehabilitation strategies across different stages of stroke recovery. Moreover, the need to explore the combined application of auditory and visual sensory techniques, particularly in the context of lower limb rehabilitation, is highlighted as a promising avenue for future research. By addressing the outlined limitations and incorporating a more diverse patient cohort, subsequent studies can build upon the foundational insights provided here, further advancing the domain of stroke rehabilitation.

CONCLUSION

The findings of this study underscore the significant potential of incorporating sensory stimulation, specifically auditory and visual feedback, in the rehabilitation of hemiplegic stroke survivors. By demonstrating marked improvements in gait parameters and functional mobility, the research highlights the efficacy of tailored sensory-based interventions in enhancing the quality of stroke rehabilitation. These insights advocate for a more integrated approach within healthcare practices, emphasizing the need for personalized rehabilitation protocols that harness the benefits of sensory feedback to optimize recovery outcomes. Consequently, this study not only contributes to the evolving landscape of stroke rehabilitation strategies but also encourages the adoption of innovative, evidence-based practices in healthcare settings to improve the well-being and functional independence of stroke survivors.

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