RESEARCH PAPER

Effect of Square Stepping Exercises Program on Functional Mobility in Hemiparetic Individuals

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ABSTRACT

Stroke is a major neurological condition that frequently results in hemiparesis, leading to impairments in functional mobility such as difficulty in bed mobility, transfers, standing, and walking. Reduced functional mobility limits independence and increases the risk of falls among hemiparetic individuals. Conventional physiotherapy interventions may not adequately address multidirectional stepping and dynamic balance required for functional mobility. Square Stepping Exercise (SSE) is a structured, task-oriented intervention that incorporates multidirectional stepping patterns and may enhance motor control, balance, and mobility.

Keywords: Hemiparesis, Stroke, Square Stepping Exercise, Functional Mobility, Rivermead Mobility Index, Rehabilitation

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1. INTRODUCTION

Hemiparesis is a common neurological consequence of cerebrovascular accidents. Stroke-related hemiparesis often disrupts the ability to maintain postural stability and execute coordinated gait, leading to functional limitations and a heightened risk of falls. These impairments are influenced not only by unilateral muscle weakness but also by deficits in movement sequencing, sensory feedback processing, and adaptive balance control. These impairments significantly compromise independence in activities of daily living and substantially increase the risk of falls. Restoration of balance and functional mobility therefore remains a fundamental objective of neurological rehabilitation. Rehabilitation strategies that focus solely on strengthening or repetitive gait practice may therefore fall short in restoring functional stability. Recent advances in neurorehabilitation highlight the importance of task-specific, repetitive, and cognitively engaging interventions to enhance motor learning and promote neuroplasticity. Exercise programs that integrate both physical and cognitive components have demonstrated superior outcomes in balance control, gait performance, and fall prevention when compared to isolated motor training.(1). Square-stepping exercise represents an innovative and structured balance training approach that involves performing multidirectional stepping sequences on a grid-based surface. structured stepping format in which individuals follow predetermined multidirectional patterns, requiring precise foot placement, controlled weight transfer, and sustained attention. The integration of cognitive engagement with purposeful movement distinguishes this approach from conventional balance training and supports active motor relearning. (1,2). Such multidimensional demands closely simulate functional mobility tasks encountered during daily activities, thereby enhancing the transfer of training effects to real-world performance. Evidence indicates that square-stepping exercise produces significant improvements in dynamic balance, postural stability, and gait parameters in individuals with neurological impairments, including stroke survivors(2,3).Beyond its well-established effects on motor recovery, square-stepping exercise demonstrates a broader therapeutic influence on cognitive and psychosocial domains(3). The structured yet progressively challenging stepping patterns require continuous attention, visuospatial processing, and decision-making, which collectively enhance cognitive engagement during movement (4,5). This integrated motor–cognitive demand has been linked to improvements in executive functions, emotional well-being, self-confidence, and reduced fear of movement, thereby promoting greater participation in rehabilitation. From a neurophysiological perspective, dual-task–oriented exercises such as square-stepping are believed to facilitate activity-dependent neuroplasticity by up-regulating neurotrophic factors and strengthening sensorimotor and cognitive neural networks(6). These adaptive neural changes may support cortical reorganization and functional recovery, contributing to sustained improvements over time. Furthermore, evidence synthesized from systematic reviews highlights consistent benefits of square-stepping exercise across physical performance, balance, and cognitive outcomes, underscoring its clinical relevance as a holistic and multidimensional rehabilitation approach rather than a purely motor-focused intervention(6,7).Although the accumulating evidence supporting the therapeutic advantages of square-stepping exercise, its targeted implementation in individuals with hemiparesis remains insufficiently examined(8). Hemiparetic individuals commonly experience persistent balance impairments and an increased risk of falls, which significantly restrict functional independence and participation in daily activities. Consequently, there is a critical need for rehabilitation strategies that are not only effective but also cost-efficient, adaptable, and feasible within routine physiotherapy settings(8,9). The present study is undertaken to evaluate the effects of a structured square-stepping exercise program on balance and functional performance in individuals with hemiparesis. By focusing on this underrepresented population, the study aims to bridge an important gap in existing neurorehabilitation literature. Furthermore, the findings are expected to provide evidence-based insight into the clinical applicability of square-stepping exercise as an adjunct to conventional physiotherapy(9). Establishing its therapeutic relevance may support informed clinical decision-making and encourage the adoption of innovative yet practical interventions that address balance deficits and functional limitations in hemiparetic rehabilitation(10).

2. MATERIALS AND METHODOLOGY

2.1. Study Protocol: The present experimental study was conducted to investigate the effect of a Square Stepping Exercise (SSE) program on functional mobility in hemiparetic individuals following stroke. The study was carried out at the Department of Physiotherapy, Krishna College of Physiotherapy and KVV Hospital, Karad, Maharashtra, India. Participants were recruited from the outpatient neuro-physiotherapy department. The study procedures were explained to all participants in simple language and written informed consent was obtained prior to enrolment. Participation was voluntary and confidentiality of participant data was maintained throughout the study.

2.2. Study Design: This research was designed as an experimental pre-test and post-test study. The aim of the study was to determine whether a structured Square Stepping Exercise program could improve functional mobility in individuals with hemiparesis following stroke. Baseline measurements were taken before the intervention and repeated after completion of the exercise program to determine changes in mobility and spasticity.

2.3. Sélection Criteria Participants were included in the study if they met the following criteria:

Clinical diagnosis of hemiparesis due to stroke
Age group between 55 and 70 years
Ability to ambulate with or without assistive devices
Medically stable and cleared for participation in therapeutic exercise
Adequate cognitive ability to understand and follow instructions
Willingness to participate and provide written informed consent.

2.4. Exclusion Criteria :

Participants were excluded if they had:
Severe cognitive impairment preventing participation
Progressive neurological disorders
Severe musculoskeletal or orthopedic conditions affecting lower limb movement
Significant visual or vestibular impairments interfering with balance
Any medical condition contraindicating participation in exercise programs.

2.5. Procedure: Participants who fulfilled the eligibility criteria were recruited from the outpatient physiotherapy department. After obtaining written informed consent, baseline assessment of functional mobility and muscle tone was performed using standardized clinical outcome measures.

Following the initial assessment, participants underwent a structured physiotherapy intervention program consisting of Square Stepping Exercise training along with conventional physiotherapy rehabilitation. The Square Stepping Exercise was performed on a 2 × 2 meter mat divided into equal squares. Participants were required to follow predetermined stepping patterns demonstrated by the therapist. These patterns included forward, backward, lateral, and diagonal stepping movements. Each session began with a short warm-up period including breathing exercises and lower limb range-of-motion activities. After the warm-up, participants performed stepping sequences on the mat while maintaining balance and accurate foot placement. The exercises were initially simple during the familiarization phase and gradually progressed to more complex multidirectional patterns based on the participant's performance and balance ability. The exercise sessions were conducted five days per week for a period of six weeks under the supervision of a physiotherapist. Each stepping sequence was repeated multiple times to reinforce coordination, weight shifting, and balance control. Rest intervals were provided whenever necessary to prevent fatigue.Therapists provided verbal cues, visual guidance, and safety support throughout the sessions to ensure proper execution of movements and reduce the risk of falls. After completion of the six-week intervention period, post-intervention assessments were performed using the same outcome measures to evaluate the effect of the training program.

3. OUTCOME MEASURES

3.1. Rivermead Mobility Index (RMI):

The Rivermead Mobility Index was used to evaluate functional mobility in hemiparetic individuals. The scale consists of 15 functional tasks, including bed mobility, transfers, standing, and walking activities. Each item is scored as 0 (unable) or 1 (able), with a maximum score of 15, where higher scores indicate better functional mobility.

3.2. Modified Ashworth Scale (MAS):

The Modified Ashworth Scale was used to assess muscle spasticity of the affected limb. It measures the resistance encountered during passive movement of a joint. The scale ranges from 0 to 4, with higher scores indicating greater muscle tone or spasticity.

4. STATISTICAL ANALYSIS

The collected data were analyzed using appropriate statistical methods to determine the effectiveness of the intervention on participants ' functional performance. A total of 20 participants were included in the study. The variables analyzed included age, pre-test scores, post-test scores, and improvement scores.Descriptive statistics were calculated to summarize the data. The mean age of the participants was 54.25 ±12.6 years, with ages ranging from 30 to 77 years. The mean pre-test score was 6.05 ±1.93, whereas the mean post-test score increased to 11.15 ± 2.13 out of a maximum score of 15. The average improvement observed was 5.10 ±1.59 points, indicating a considerable increase in performance after the intervention.To determine whether the change between pre-test and post-test scores was statistically significant, a paired t-test was applied since the same participants were assessed before and after the intervention. The results showed a statistically highly significant difference between the scores ($t(19) = 14.38$, $p < 0.001$). This indicates that the intervention had a meaningful impact on improving the participants 'performance.The 95% confidence interval for the mean improvement ranged from 4.36 to 5.84 points, suggesting that the true improvement in the population is likely to fall within this range.The effect size was calculated using Cohen's d and was found to be 3.22, which represents an extremely large effect. This suggests that the intervention produced not only statistically significant results but also a strong practical impact on the participants.To further validate the findings, a Wilcoxon signed-rank test was performed as a non-parametric alternative. The test also indicated a significant improvement ($p < 0.001$), confirming the robustness of the results. Additionally, the relationship between age and performance scores was explored using correlation analysis. A moderate negative correlation was observed between age and pre-test scores ($r = -0.43$), suggesting that older participants tended to have slightly lower baseline scores. However, this relationship did not reach statistical significance ($p = 0.059$). No significant association was observed between age and post-test scores or improvement levels. Overall, the statistical analysis demonstrates that the intervention significantly improved functional performance among the participants.

5. RESULT AND DISCUSSION

5.1. Data summary

Sample size: 20 participants

5.2. Variables analyzed:

- Age
- Pre-test score out of 15
- Post-test score out of 15
- Improvement = Post-test − Pre-test

Table 1: Descriptive statistics

Variable	Mean	SD	Median	Minimum	Maximum
Age	54.25	12.6	58	30	77
Pre-test score	6.05	1.93	6	2	9
Post-test score	11.15	2.13	11	7	14
Improvement	5.1	1.59	5	2	8

5.3. Score Improvement :

- Mean pre-test score: 6.05 out of 15
- Mean post-test score: 11.15 out of 15
- Mean improvement: 5.10 points

Percentage form

- Pre-test mean = 40.33%
- Post-test mean = 74.33%
- Mean gain = 34.00 percentage points

This shows a substantial rise in functional performance after the intervention/training/program.

5.4. Paired t-test:

Since the same 20 participants were tested before and after, the correct test is a paired t-test.

Result

- $t(19) = 14.38$
- $p < 0.001$

Interpretation

The difference between pre-test and post-test scores is statistically highly significant. Therefore, the intervention appears to have produced a real improvement in performance.

5.5. 95% confidence interval for mean improvement:

- Mean improvement = 5.10

- 95% CI = 4.36 to 5.84

Interpretation: we can be 95% confident that the true average improvement in the population lies between 4.36 and 5.84 points.

5.6. Effect size

For paired data, Cohen's *d* was calculated using the difference scores.

- Cohen's d = 3.22

Interpretation

This is an extremely large effect size, indicating that the improvement is not only statistically significant but also practically very strong.

5.7. Non-parametric confirmation

To support the result, a Wilcoxon signed-rank test was also considered.

- Wilcoxon p < 0.001

This confirms that the improvement remains significant even without relying on normality assumptions.

5.8. Individual improvement pattern :

All 20 participants improved from pre-test to post-test.

- Smallest improvement: 2 points
- Largest improvement: 8 points

This indicates a very consistent positive effect across participants.

5.9. Age and score relationship:

Correlation with age was explored:

- Age vs Pre-test score: r = -0.43, p = 0.059
- Age vs Post-test score: r = -0.30, p = 0.194
- Age vs Improvement: r = 0.11, p = 0.631

Interpretation

- Older participants tended to have slightly lower pre-test scores, but this was not statistically significant at the 5% level.
- Age was not significantly related to improvement.
- So, the improvement appears to occur across ages rather than being limited to a specific age group.

6. DISCUSSION

The present study was conducted to evaluate the effectiveness of the intervention program in improving the functional performance of participants. The results of the study demonstrated a clear and statistically significant improvement in post-test scores compared with pre-test scores, indicating that the intervention had a positive impact on the participants 'functional abilities.

At baseline, the participants demonstrated relatively low levels of performance, with a mean pre-test score of 6.05 ±1.93 out of a maximum possible score of 15. This suggests that many participants experienced limitations in performing the functional activities included in the assessment. Following the implementation of the intervention program, the mean post-test score increased to 11.15 ±2.13, representing a substantial improvement in functional ability. The average improvement of 5.10 ±1.59 points reflects a considerable change in performance after the intervention period.

The statistical analysis confirmed that the difference between pre-test and post-test scores was highly significant. The paired t-test results showed t(19) = 14.38 with p < 0.001, indicating that the improvement observed in the participants was unlikely to be due to chance. This finding supports the effectiveness of the intervention in enhancing functional performance.

In addition to statistical significance, the magnitude of improvement was also evaluated using effect size analysis. The calculated Cohen's d value of 3.22 represents an extremely large effect size. This indicates that the intervention had a strong practical impact on the participants 'functional performance. Large effect sizes suggest that the observed improvement is not only statistically meaningful but also clinically relevant, highlighting the practical importance of the intervention program.

Another important observation in the study was the consistent improvement among all participants. Each participant demonstrated some level of progress between the pre-test and post-test assessments. The range of improvement varied from 2 points to 8 points, indicating that although the degree of improvement differed among individuals, the overall direction of change was positive for every participant. This consistent pattern suggests that the intervention program was broadly beneficial and applicable to individuals with varying baseline functional abilities.

The study also explored the possible relationship between age and performance outcomes. The results indicated a moderate negative correlation between age and pre-test scores, suggesting that older participants tended to have slightly lower initial performance levels. However, this relationship did not reach statistical significance. Furthermore, age did not show a significant association with post-test scores or with the amount of improvement achieved during the intervention period. This finding suggests that the benefits of the intervention were observed across different age groups and were not limited to younger participants.

The improvement observed in the present study may be attributed to several factors related to the intervention program. Structured training or therapeutic programs are known to enhance functional performance by improving physical capacity, coordination, strength, and overall activity tolerance. Regular participation in such interventions can also improve confidence and independence while performing daily functional activities. These factors collectively contribute to better functional outcomes, which may explain the significant improvement observed in post-test scores.

The findings of this study are consistent with previous research indicating that structured intervention programs can significantly improve functional performance and daily activity levels. Improvements in functional ability are often associated with better mobility, enhanced independence, and improved quality of life. Therefore, interventions that target functional performance can play an important role in rehabilitation and health promotion.

Despite the encouraging findings, certain limitations of the study should be acknowledged. The sample size was relatively small, which may limit the generalizability of the results to a larger population. Additionally, the study focused on a specific group of participants, and variations in demographic or clinical characteristics were not extensively examined. Future studies involving larger sample sizes, diverse populations, and longer follow-up periods would provide more comprehensive evidence regarding the long-term effectiveness of the intervention.

Another limitation is that the study primarily evaluated changes over a short duration. Long-term follow-up assessments could help determine whether the improvements observed are sustained over time. Further research may also explore additional variables such as lifestyle factors, physical activity levels, or comorbid conditions that could influence functional performance outcomes.

Overall, the findings of the present study provide strong evidence supporting the effectiveness of the intervention program in improving functional performance. The significant increase in post-test scores, large effect size, and consistent improvement across all participants highlight the potential value of this intervention as a beneficial strategy for enhancing functional abilities.

7. CONCLUSION

The statistical analysis demonstrated a clear and meaningful improvement in participants ' functional activity scores following the intervention. The mean score increased from 6.05 ±1.93 in the pre-test to 11.15 ±2.13 in the post-test out of a maximum score of 15, indicating a substantial enhancement in functional performance. The average gain in score was 5.10 ±1.59 points, which was found to be highly statistically significant according to the paired t-test analysis ($t(19) = 14.38$, $p < 0.001$). Furthermore, the calculated effect size was very large (Cohen's $d = 3.22$), suggesting that the intervention had a strong impact on improving functional activity. Notably, all participants demonstrated improvement in their post-test scores compared to the pre-test values, indicating consistent benefits of the intervention across the sample. Additionally, the analysis revealed that age did not have a significant influence on the degree of improvement, suggesting that the intervention was effective regardless of age differences among participants. Overall, these findings confirm that the intervention led to a highly significant improvement in functional activity levels among the participants.

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