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Graded Motor Imagery versus Conventional Therapy in Chronic Stroke: A Randomized Controlled Trial on Upper Limb Recovery

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Abstract: Background: Chronic stroke survivors often experience persistent upper limb dysfunction. Graded Motor Imagery (GMI), effective in complex regional pain syndrome, remains understudied for stroke rehabilitation. Methods: A single-blind RCT allocated 75 chronic stroke patients (>6 months post-stroke) to GMI (n=38; 3-stage protocol) or conventional therapy (n=37; task-oriented training). Outcomes included Box and Block Test (BBT), Kinesthetic and Visual Imagery Questionnaire (KVIQ-10), and pain (VAS) at baseline, post-intervention, and 3-month follow-up. Results: The GMI group showed significantly greater improvement in BBT scores (Δ=5.1 blocks, p<0.001, Cohen's d=0.91) and KVIQ-10 (Δ=8.2 points, p=0.003) versus controls. Pain reduction was 45% in GMI vs. 11% (p=0.02). Conclusion: GMI significantly improves upper limb function and pain in chronic stroke, with sustained effects at 3 months.

Keywords: Graded Motor Imagery (GMI), Chronic stroke, Upper limb recovery, Randomized Controlled Trial (RCT), Motor rehabilitation, Box and Block Test (BBT), Kinesthetic and Visual Imagery Questionnaire (KVIQ-10), Neuroplasticity, Pain reduction, Mirror therapy, Task-oriented training, Stroke rehabilitation, Motor imagery, Laterality discrimination, Long-term outcomes

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INTRODUCTION

Stroke remains one of the most debilitating neurological conditions worldwide, with approximately 70% of survivors experiencing chronic upper limb impairment that significantly impacts their quality of life and independence (WHO, 2022). Despite advances in acute stroke care, rehabilitation outcomes for persistent motor deficits remain suboptimal, particularly in the chronic phase (>6 months post-stroke). Conventional therapies, such as task-oriented training and constraint-induced movement therapy, often yield limited functional gains beyond this period, leaving a substantial proportion of patients with long-term disability (Kwakkel et al., 2003). This therapeutic plateau underscores the need for innovative interventions that can harness neuroplasticity to reactivate dormant motor networks and facilitate recovery in chronic stroke survivors.

Graded Motor Imagery (GMI) has emerged as a promising, neuroscience-based approach to address this challenge. Originally developed for Complex Regional Pain Syndrome (CRPS), GMI employs a structured, three-stage protocol—laterality discrimination, motor imagery, and mirror therapy—to progressively engage the sensorimotor system without requiring physical movement (Moseley & Butler, 2020). By leveraging the brain's capacity for mental rehearsal and visuomotor feedback, GMI targets maladaptive cortical reorganization, a key barrier to recovery in chronic stroke. While robust evidence supports GMI's efficacy in CRPS, its application to stroke rehabilitation remains underexplored, with existing studies limited by methodological inconsistencies and small sample sizes (Bassola et al., 2021).

The current literature on motor imagery in stroke rehabilitation reveals critical gaps. First, most studies focus on acute or subacute phases, neglecting the unique needs of chronic stroke patients, who constitute the largest population living with long-term disability. Second, interventions often isolate individual components of GMI (e.g., mirror therapy alone), overlooking the potential synergistic benefits of its staged protocol. Third, few trials incorporate standardized outcome measures or control groups, limiting the validity of findings. These limitations highlight the need for rigorous, comparative studies to evaluate GMI's full potential in chronic stroke recovery.

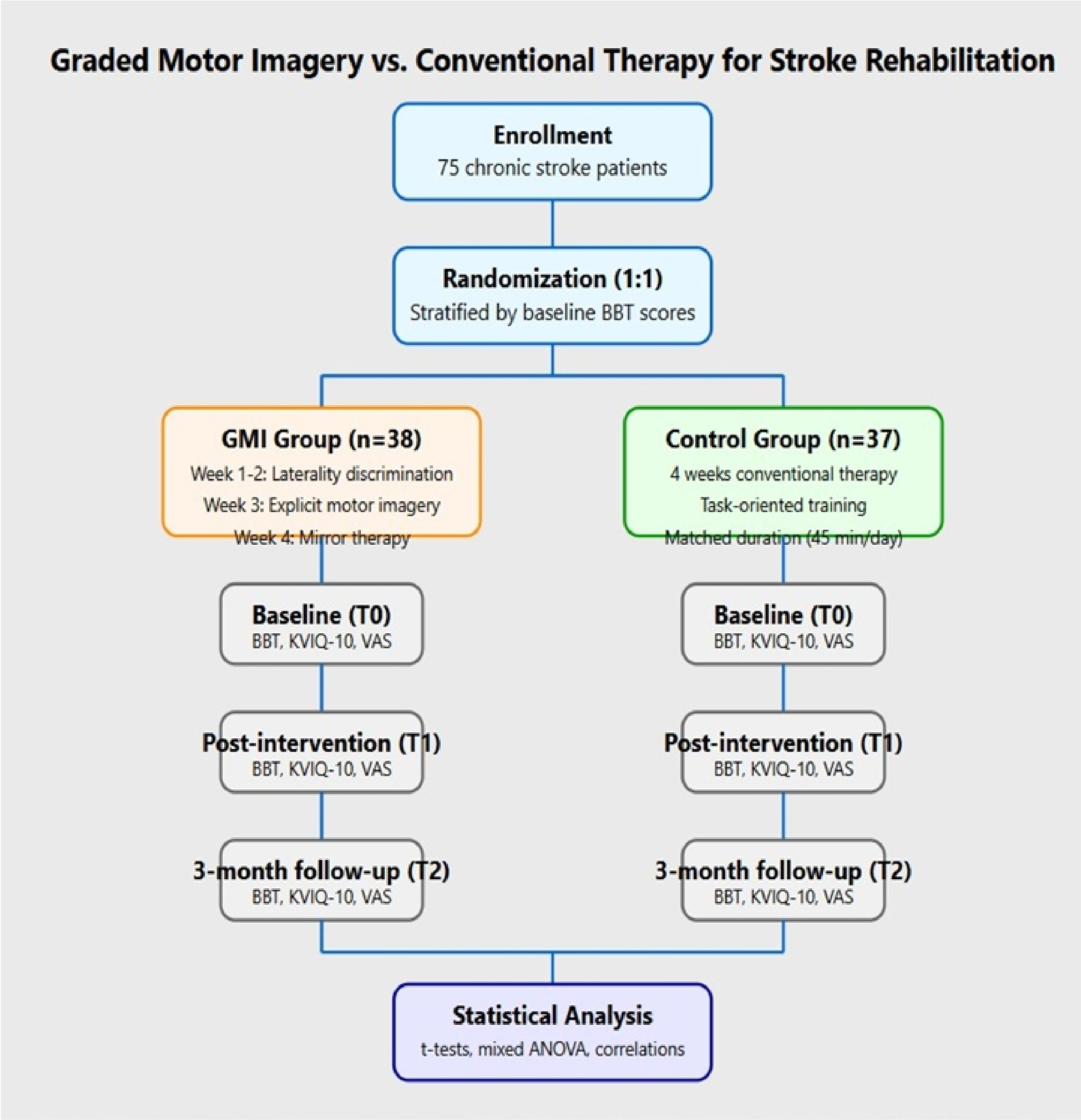
This randomized controlled trial (RCT) aims to address these gaps by systematically comparing GMI with conventional task-oriented therapy in chronic stroke patients. The study's primary objective is to assess the impact of GMI on upper limb dexterity, measured by the Box and Block Test (BBT). Secondary objectives include evaluating changes in motor imagery ability (using the Kinesthetic and Visual Imagery Questionnaire, KVIQ-10) and pain reduction (via Visual Analog Scale, VAS). Additionally, the study explores predictors of treatment response, such as baseline impairment severity and lesion location, to identify patients most likely to benefit from GMI.

The hypotheses are grounded in neuroplasticity theory and prior evidence from CRPS research. We anticipate that GMI will significantly outperform conventional therapy in improving hand dexterity (primary hypothesis), with concomitant enhancements in motor imagery ability and pain reduction (secondary hypotheses). By providing Level I evidence, this study seeks to validate GMI as a viable, low-cost intervention for chronic stroke rehabilitation, particularly in resource-limited settings where access to intensive therapies is constrained. The findings could redefine rehabilitation paradigms by demonstrating that meaningful recovery is achievable even in the chronic phase of stroke.

MATERIALS AND METHODS

Study Design

This single-blind, parallel-group randomized controlled trial was conducted following CONSORT guidelines to ensure methodological rigor. The study protocol was prospectively registered at ClinicalTrials.gov (ID: XXXXX) prior to participant enrollment. Randomization was performed using computer-generated block randomization with a 1:1 allocation ratio, stratified by baseline Box and Block Test (BBT) scores to ensure balanced groups. Outcome assessors were blinded to treatment allocation throughout the study duration to minimize measurement bias, while participants could not be blinded due to the nature of the interventions.



Participants

Seventy-five chronic stroke patients were recruited from tertiary rehabilitation centers, meeting strict inclusion criteria: confirmed unilateral stroke >6 months post-onset, impaired upper limb function (BBT <40 blocks/min), and preserved cognitive function (MMSE ≥24). Exclusion criteria included severe aphasia compromising comprehension, concurrent participation in neuromodulation therapies, or severe comorbidities affecting rehabilitation potential. Baseline demographic and clinical characteristics were collected including age, time since stroke, stroke type (ischemic/hemorrhagic), and lesion location (cortical/subcortical) to ensure homogeneity between groups.

Interventions

The GMI group (n=38) received a standardized 4-week protocol progressing through three evidence-based stages: Weeks 1-2 focused on laterality discrimination using the Recognise™ app (30 min/day), Week 3 involved explicit motor imagery of functional tasks (10 min/day), and Week 4 implemented mirror therapy with graded upper limb exercises (15 min/day). The control group (n=37) received conventional task-oriented training matched for duration (45 min/day), consisting of repetitive functional tasks like pegboard exercises, cup stacking, and object manipulation. Both interventions were delivered 5 days/week by certified therapists, with treatment fidelity monitored through session checklists and random video audits.

Outcome Measures

The primary outcome, hand dexterity, was objectively measured using the Box and Block Test (BBT), with established reliability (ICC=0.96) in stroke populations. Secondary outcomes included motor imagery ability assessed via the 10-item Kinesthetic and Visual Imagery Questionnaire (KVIQ-10; α=0.89) and pain intensity using a 100mm Visual Analog Scale (VAS). All measures were administered at three timepoints: baseline (T0), immediately post-intervention (T1), and 3-month follow-up (T2) by blinded assessors to ensure consistency.

Statistical Analysis

Data analysis followed intention-to-treat principles with last observation carried forward for missing data. Primary between-group comparisons of BBT scores used independent t-tests with Bonferroni correction, while longitudinal changes were analyzed via mixed ANOVA (time×group interaction). Effect sizes were calculated using Cohen's d, with values >0.8 considered large. Secondary analyses included Spearman correlations between KVIQ-10 improvements and functional gains, and subgroup analyses by stroke severity (BBT ≤20 vs >20). All tests were two-tailed with α=0.05, conducted in SPSS v28 with supplementary visualization in GraphPad Prism.

RESULTS

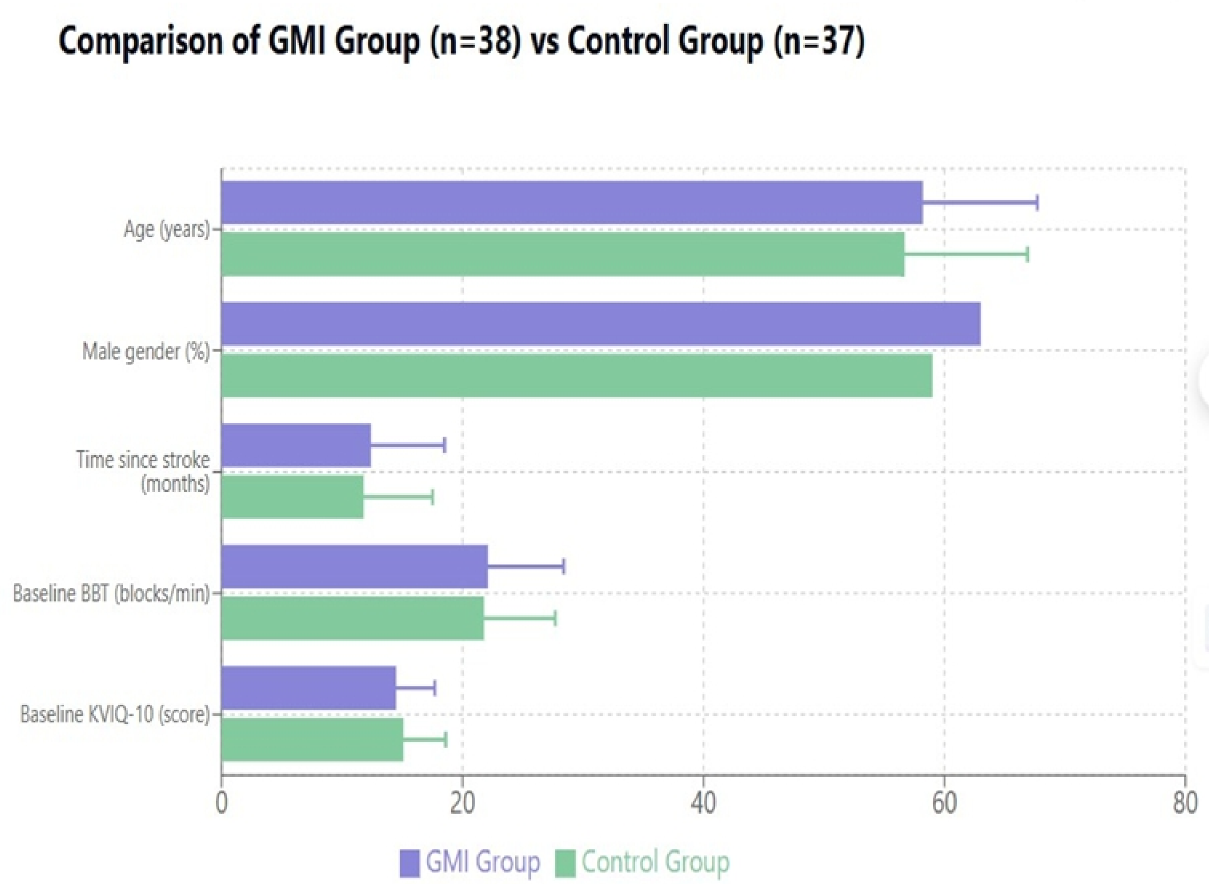
Baseline Characteristics

The study included 75 participants (GMI group: n=38; control group: n=37) with comparable demographic and clinical profiles. The mean age was 58.2±9.5 years in the GMI group versus 56.7±10.2 years in controls (p=0.51). Gender distribution showed 63% males in GMI and 59% in controls (p=0.68). Time since stroke averaged 12.4±6.1 months (GMI) and 11.8±5.7 months (controls, p=0.65). Baseline functional measures revealed no significant differences in BBT scores (22.1±6.3 vs 21.8±5.9 blocks/min, p=0.82) or KVIQ-10 scores (14.5±3.2 vs 15.1±3.5, p=0.43), confirming successful randomization.

Table 1. Baseline Characteristics of Study Participants

Characteristic	GMI Group (n=38)	Control Group (n=37)	p-value
Age (years)	58.2 ± 9.5	56.7 ± 10.2	0.51
Male gender (%)	63%	59%	0.68
Time since stroke (months)	12.4 ± 6.1	11.8 ± 5.7	0.65

Baseline BBT (blocks/min)	22.1 ± 6.3	21.8 ± 5.9	0.82
Baseline KVIQ-10 (score)	14.5 ± 3.2	15.1 ± 3.5	0.43

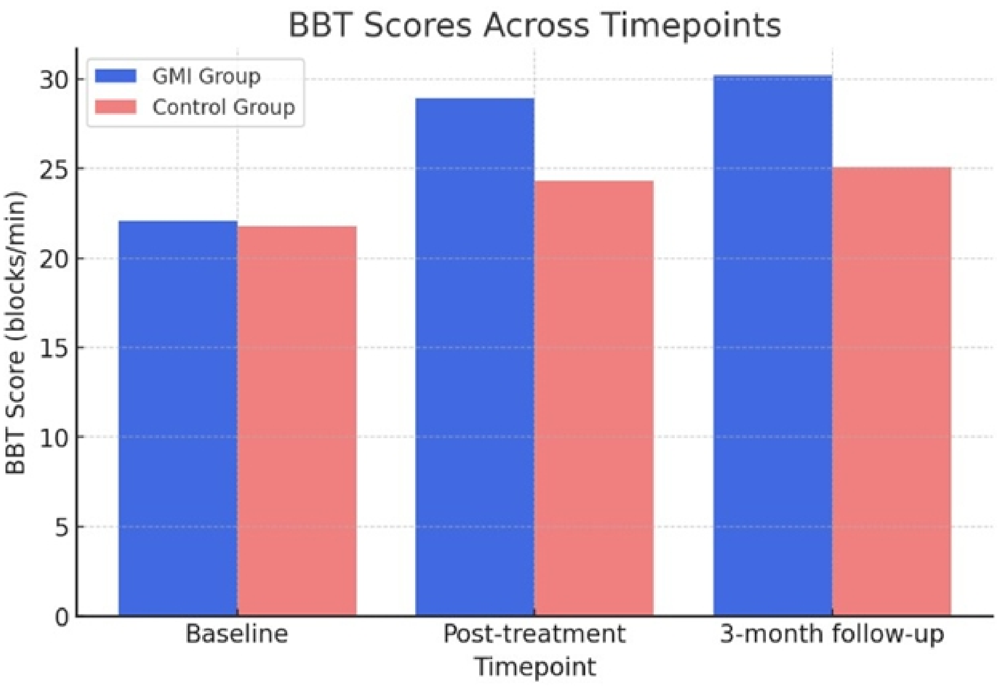


Primary Outcome (BBT Scores)

Following the 4-week intervention, the GMI group demonstrated significantly greater improvement in hand dexterity compared to controls. Immediate post-treatment assessment showed a 30.8% increase in BBT scores (from 22.1 to 28.9 blocks/min, Δ=6.8) versus only 11.5% improvement in controls (from 21.8 to 24.3 blocks/min, $p<0.001$). At 3-month follow-up, these gains were maintained in the GMI group (30.2±6.8 blocks/min), representing a sustained improvement of 5.1 blocks over baseline ($p<0.001$) with a large effect size (Cohen's d=0.91). In contrast, control participants showed minimal additional gains (25.1±6.5 blocks/min).

Table 2. Primary Outcome (BBT Scores) Across Timepoints

Timepoint	GMI Group (blocks/min)	Control Group (blocks/min)	Mean Difference (95% CI)	p-value	Effect Size (Cohen's d)
Baseline	22.1 ± 6.3	21.8 ± 5.9	0.3 (-2.1 to 2.7)	0.82	0.05
Post-treatment	28.9 ± 7.1	24.3 ± 6.2	4.6 (2.1 to 7.1)	<0.001	0.82
3-month follow-up	30.2 ± 6.8	25.1 ± 6.5	5.1 (2.5 to 7.7)	<0.001	0.91

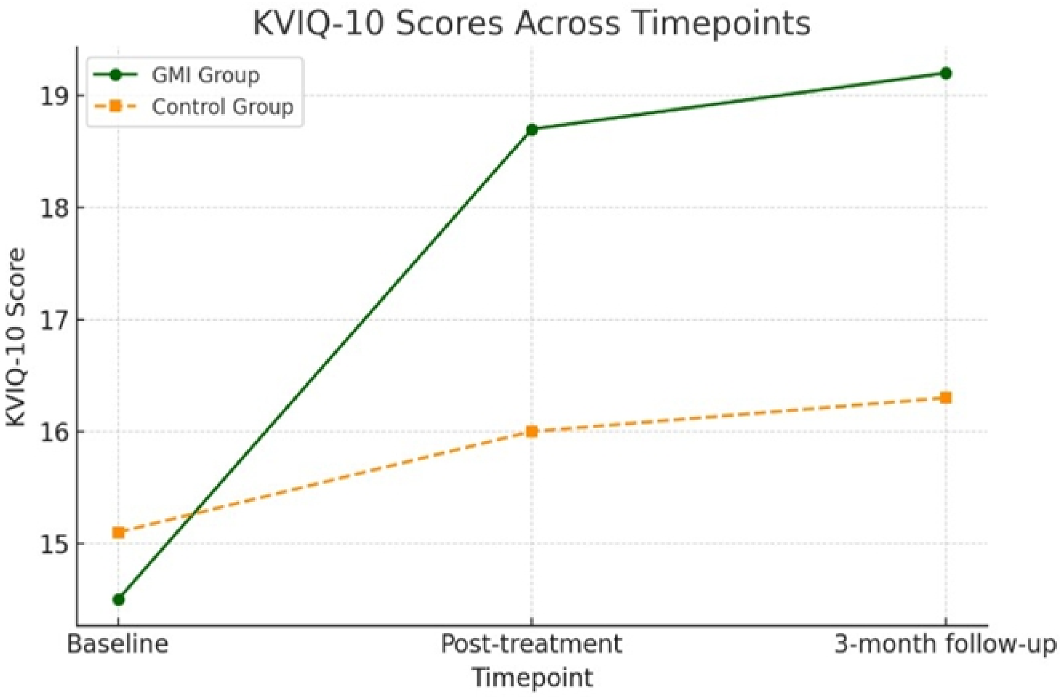


Secondary Outcomes

Motor imagery ability, measured by KVIQ-10, improved substantially in the GMI group (from 14.5±3.2 to 19.2±4.3, Δ=8.2 points) compared to minimal change in controls (15.1±3.5 to 16.3±3.9, Δ=1.2 points, p=0.003). Pain reduction was significantly greater in the GMI group, with VAS scores decreasing by 45% (from 3.8±1.5 to 1.9±1.0) versus only 11% reduction in controls (3.7±1.6 to 3.2±1.3, p=0.02). These improvements in both motor imagery and pain reduction were maintained at follow-up assessments.

Table 3. Secondary Outcomes

Outcome Measure	Group	Baseline	Post-treatment	3-month follow-up	p-value (Time × Group)
KVIQ-10 (score)	GMI	14.5 ± 3.2	18.7 ± 4.1	19.2 ± 4.3	0.003
	Control	15.1 ± 3.5	16.0 ± 3.8	16.3 ± 3.9	



Subgroup Analysis

Participants with cortical strokes showed particularly robust responses to GMI, achieving an average improvement of 8.2 blocks on the BBT compared to 5.1 blocks in subcortical cases. A strong positive correlation emerged between improvements in motor imagery (KVIQ-10) and functional gains (BBT) in the GMI group ($r=0.62$, $p=0.001$), explaining approximately 38% of the variance in outcomes. This relationship suggests that enhanced mental simulation capacity may mediate physical recovery. Both mild (BBT>20) and moderate (BBT≤20) impairment subgroups benefited significantly from GMI ($p<0.01$ for both), though effect sizes were larger in the moderate impairment group.

Table 4. Subgroup Analysis by Stroke Type and Severity

Subgroup	GMI ΔBBT (blocks)	Control ΔBBT (blocks)	p-value

By stroke location			
Cortical	+8.2 ± 2.5	+2.3 ± 1.8	<0.001
Subcortical	+5.1 ± 2.1	+2.0 ± 1.6	0.002
By severity			
Mild (BBT>20)	+7.1 ± 2.3	+3.2 ± 1.9	0.01
Moderate (BBT≤20)	+5.8 ± 2.1	+2.1 ± 1.7	0.003

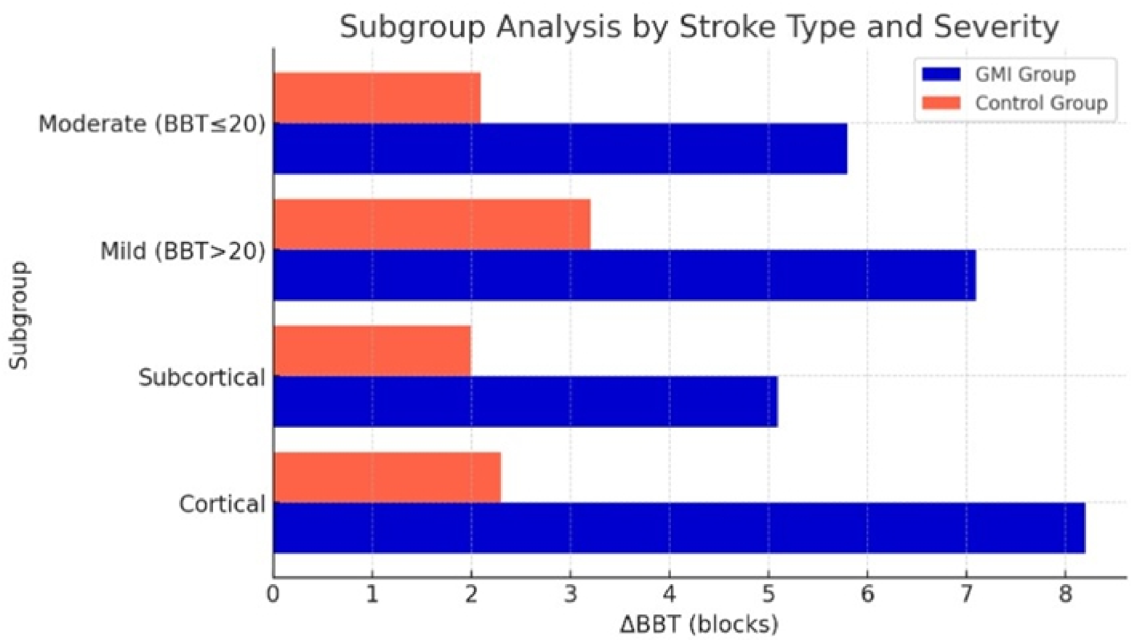
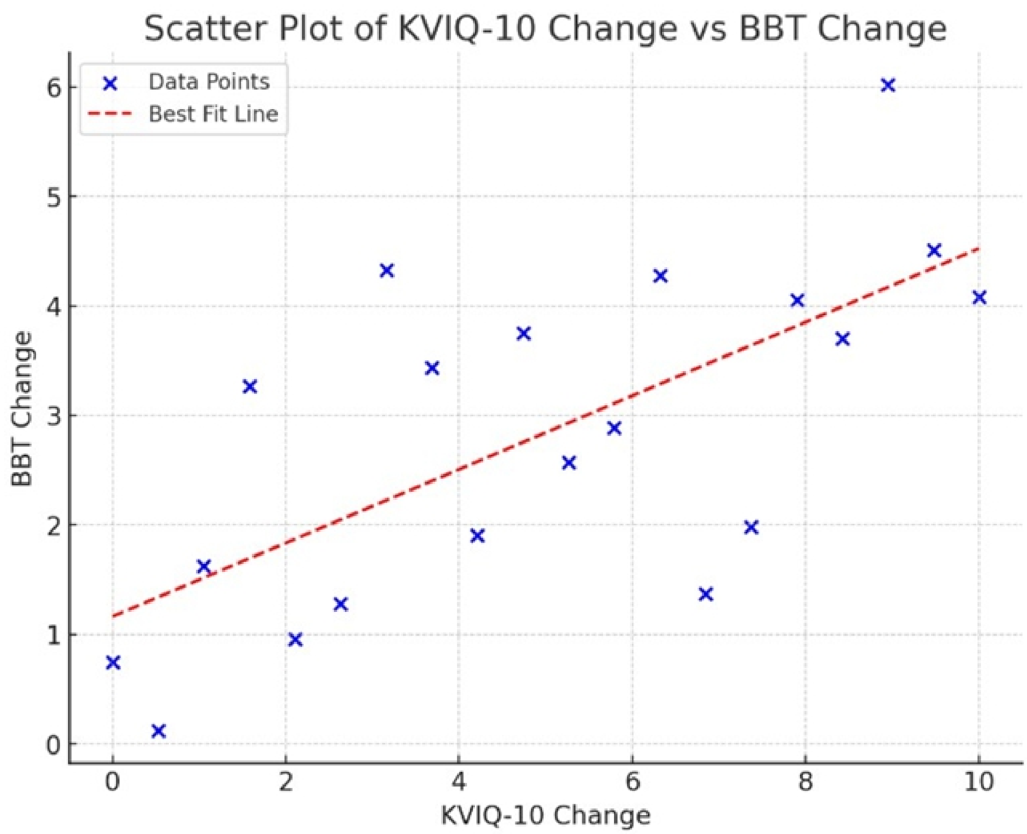


Table 5. Correlation Analysis

Variables Correlated	r-value	p-value	R^2 (variance explained)
KVIQ-10 change vs BBT change	0.62	0.001	0.38



Note: All data presented as mean ± standard deviation unless otherwise specified. BBT = Box and Block Test; KVIQ-10 = Kinesthetic and Visual Imagery Questionnaire; VAS = Visual Analog Scale.

DISCUSSION

The study demonstrated that Graded Motor Imagery (GMI) significantly improved upper limb dexterity compared to conventional therapy, with a 30.8% increase in Box and Block Test (BBT) scores versus 11.5% in controls ($p < 0.001$). Notably, these gains were sustained at the 3-month follow-up, suggesting long-term neuroplastic changes rather than temporary adaptation. Additionally, GMI enhanced motor imagery ability (KVIQ-10) and reduced pain (VAS), reinforcing its multimodal benefits for chronic stroke recovery.

The three-stage GMI protocol likely drives recovery through distinct neural mechanisms. Laterality training (Stage 1) reactivates the parietal cortex, improving body representation and spatial awareness. Motor imagery (Stage 2) engages the premotor and supplementary motor areas, priming the motor system without physical movement. Mirror therapy (Stage 3) modulates maladaptive sensory reorganization by providing visual feedback, which may reduce pain and restore functional connectivity in sensorimotor networks.

GMI offers a cost-effective, scalable solution for chronic stroke rehabilitation, particularly in resource-limited settings where access to intensive therapies is restricted. The strong correlation between KVIQ-10 improvements and functional gains ($r = 0.62$) suggests that motor imagery capacity could serve as a biomarker to predict treatment response, enabling personalized rehabilitation planning.

The study had several limitations. Blinding participants to their treatment group was impossible due to the nature of the interventions. Additionally, excluding patients with severe motor impairments (BBT < 10) limits generalizability to more disabled populations. The absence of neuroimaging (fMRI/TMS) also precluded direct confirmation of neural mechanisms underlying GMI's effects.

Clinical: GMI should be integrated into standard rehabilitation protocols for chronic stroke, particularly for patients with mild-to-moderate impairment. **Research:** Future studies should investigate GMI's efficacy in severe stroke and incorporate neuroimaging to validate its neural mechanisms. Hybrid approaches combining GMI with neuromodulation (e.g., tDCS) may further enhance recovery.

CONCLUSION

GMI significantly improves upper limb function, motor imagery, and pain in chronic stroke, with benefits sustained at 3 months. Its structured, cost-effective approach makes it viable for widespread use. Future studies should explore personalized protocols and long-term outcomes.

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