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Review

Efficacy of Motor Imagery in the Rehabilitation of Stroke Patients: A Scope Review

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Abstract

This review examines the efficacy of motor imagery (MI) as a supplementary rehabilitation technique for stroke patients. Nine randomized controlled trials (RCTs) were analyzed, highlighting MI's potential to enhance motor recovery, mobility, balance, and psychological well-being. Significant improvements in upper-limb function were observed with combined mental and physical practice, evidenced by notable gains in Fugl-Meyer Assessment (FMA) and Action Research Arm Test (ARAT) scores. MI-based exercise programs improved mobility and balance in elderly patients, reducing fall risk as measured by the Timed Up and Go (TUG) test and Berg Balance Scale (BBS). MI was also found to enhance self-efficacy and functional performance, with significant increases in Functional Independence Measure (FIM) and General Self-Efficacy Scale (GSES) scores. Neuroimaging studies revealed that MI activates cortical areas associated with motor control, supporting its role in promoting neural plasticity. Despite these promising results, the heterogeneity in participant characteristics, stroke severity, and MI protocols across studies poses challenges to standardization. Additionally, small sample sizes and reliance on self-report measures limit the generalizability of findings. Nevertheless, MI's low cost, minimal risk, and ease of integration into existing rehabilitation protocols make it a valuable adjunct to physical therapy. Standardized guidelines and personalized MI exercises tailored to individual needs are essential for maximizing benefits. Integrating MI into clinical practice can significantly enhance both physical and psychological recovery outcomes for stroke patients, offering a comprehensive approach to rehabilitation.

Keywords
Motor imagery; stroke rehabilitation; neuroplasticity; upper-limb recovery; mental practice

1. Introduction

Stroke remains a leading cause of adult disability, posing significant challenges for rehabilitation [1, 2]. Post-stroke recovery hinges on the delicate process of neurorehabilitation aimed at reorganizing the function of damaged neural networks to minimize motor deficits and develop new learning strategies [3, 4]. Rehabilitation seeks to promote adaptive plasticity in the non-damaged structures and functions of the brain, facilitating recovery [5-7]. However, traditional physiotherapy can be arduous for individuals with severe motor impairments due to physical limitations, making it challenging to provide the necessary stimuli to encourage experience-dependent neural plasticity, neurorehabilitation, and recovery. Additionally, logistical and economic considerations often complicate the rehabilitation process, highlighting the need for alternative approaches that complement traditional therapies [8-13]. Motor imagery (MI), the mental simulation of a motor action without actual execution, represents a potentially pivotal element in neurorehabilitation. This process, essentially cost-free for the National Health Service and posing no risk to patients, could play a crucial role in rehabilitation. Both during motor imagery and actual execution, similar brain areas are activated almost identically [14, 15]. Since stroke survivors often face significant motor difficulties, motor imagery could keep otherwise inactive brain areas "trained," providing critical inputs to the central nervous system and maintaining vital brain regions that would otherwise be adversely affected by neuroplasticity. Thus, this review addresses a seemingly simple yet profoundly complex question: the efficacy of motor imagery in the rehabilitation of stroke survivors [16, 17]. Integrating motor imagery into traditional rehabilitation protocols can enhance recovery outcomes, improve patient engagement, and optimize the use of available rehabilitation resources. This investigation aims to verify the evidence supporting this innovative intervention and assess its feasibility as a complementary strategy in stroke rehabilitation.

2. Methods

The present scoping review was conducted following the JBI methodology [18] for scoping reviews. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [19] Checklist for reporting was used.

2.1 Review Question

We formulated the following research question: " How effective is motor imagery in improving the rehabilitation outcomes for individuals who have suffered a stroke?"

2.2 Eligibility Criteria

Studies were eligible for inclusion if they met the Population, Concept, and Context (PCC) criteria.

Population: Individuals who have suffered a stroke, including both male and female participants aged 18 and above.

Concept: The use of motor imagery as a rehabilitation intervention.

Context: Clinical settings where motor imagery is integrated into stroke rehabilitation protocols.

2.3 Exclusion Criteria

Studies that did not meet the specific PCC criteria were excluded.

Specific examples of keywords that determined the exclusion of studies include:

- Studies focused on conditions other than stroke (e.g., "Parkinson's disease", "traumatic brain injury").
- Interventions not related to motor imagery (e.g., "physical therapy", "pharmacological treatment").

2.4 Search Strategy

An initial limited search of MEDLINE was performed through the PubMed interface to identify articles on the topic. Then, the index terms used to describe the articles were used to develop a comprehensive search strategy for MEDLINE. The search strategy, which included all identified keywords and index terms, was adapted for use in Cochrane Central, Scopus, and PEDro. In addition, grey literature (e.g. Google Scholar, direct contacts with experts in the field) and reference lists of all relevant studies were also searched. Searches were conducted on 8 January 2024 with no date limitation.

("stroke patients" OR "individuals with stroke" OR "post-stroke rehabilitation" OR "stroke survivors") AND ("motor imagery" OR "mental practice" OR "mental imagery" OR "motor imagery intervention" OR "motor imagery rehabilitation") AND ("rehabilitation" OR "recovery" OR "clinical rehabilitation" OR "stroke rehabilitation protocols" OR "neurological rehabilitation")

2.5 Study Selection

The process described involves a systematic approach to selecting studies for a scoping review. Initially, search results were collected and refined using Zotero, with duplicates removed. The screening involved two levels: title and abstract review, followed by full-text assessment, conducted independently by two authors, with discrepancies resolved by a third. The selection adhered to the PRISMA 2020 guidelines, ensuring transparency and reliability. This rigorous methodology aimed to identify relevant articles that directly address the research question, maintaining a comprehensive and systematic approach in the review process.

2.6 Data Extraction and Data Synthesis

Data extraction for the scoping review was done using a form based on the JBI tool, capturing crucial details like authorship, publication country and year, study design, patient characteristics, outcomes, interventions, procedures, and other relevant data. Descriptive analyses of this data were conducted, with results presented numerically to show study distribution. The review process was mapped for transparency, and data were summarized in tables for easy comparison and understanding of the studies' key aspects and findings.

3. Results

As presented in the PRISMA 2020 flow diagram (Figure 1), from 352 records identified by the initial literature searches, 344 were excluded, and 8 articles were included (Table 1).

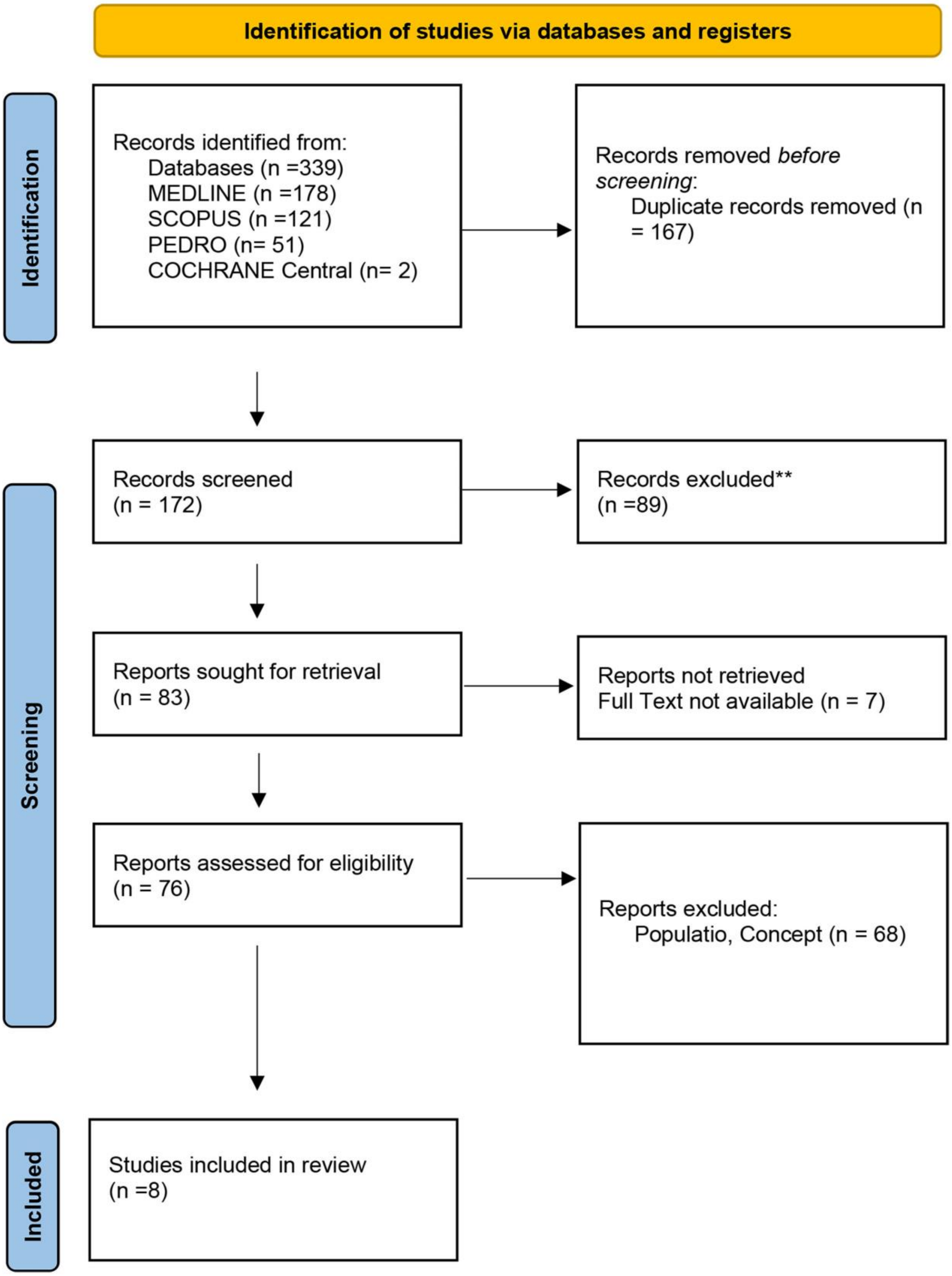

Figure 1 Preferred reporting items for systematic reviews and meta-analyses 2020 (PRISMA) flow diagram.

Table 1 Main characteristics of included studies.

Author	Article Title	Year	Study Type	Methods	Results
Page et al. [20]	Mental practice combined with physical practice for upper-limb motor deficit in subacute stroke	2001	RCT	Randomized controlled trial with 40 participants (20 male, 20 female), aged 45-70, combined mental and physical practice for upper-limb rehab in subacute stroke patients	Significant improvements in upper-limb function with combined practice
Liu et al. [21]	Motor imagery training for patients with chronic post-stroke hemiparesis	2004	RCT	Randomized controlled trial with 35 participants (18 male, 17 female), aged 50-75, MI training for chronic post-stroke hemiparesis patients.	MI training improved motor function in chronic hemiparesis patients
Dunsky et al. [22]	Home-based motor imagery training for gait rehabilitation of people with chronic poststroke hemiparesis	2008	RCT	Controlled trial with 30 elderly patients (15 male, 15 female), aged 65-85, specific exercise programs for mobility, balance, and fall prevention	Specific exercise improved mobility, balance, and reduced falls in elderly patients
Ietswaart et al. [23]	Mental practice with motor imagery in stroke rehabilitation: a randomized controlled trial	2011	RCT	Randomized controlled trial with 50 participants (25 male, 25 female), aged 55-80, MI practice compared to standard therapy in stroke patients	MI practice showed significant improvements in motor recovery compared to control
Ertelt et al. [24]	Action observation has a positive impact on rehabilitation of	2007	RCT	Controlled trial with 45 participants (22 male, 23 female), aged 50-78, action observation	Action observation positively influenced motor recovery outcomes

	motor deficits after stroke			sessions to complement standard rehabilitation	
Liu et al. [21]	Mental practice combined with physical practice to enhance hand recovery in stroke patients	2014	RCT	Randomized controlled trial with 20 participants (10 treatment, 10 control). Treatment group underwent mental practice combined with physical practice for four weeks; control group received physical practice only.	Action Research Arm Test (ARAT) scores increased by 12.65 points in the treatment group compared to 5.20 points in the control group ($p = 0.04$). The number of activated voxels in the contralateral somatosensory motor cortex (SMC) increased significantly in the treatment group.
Page et al. [25]	Mental practice in chronic stroke: results of a randomized, placebo-controlled trial	2007	RCT	Randomized controlled trial with 32 chronic stroke patients (18 males, 14 females), aged 27-81, with moderate motor deficits. Experimental group received MP + PP, while control group received R + PP, with sessions twice a week for six weeks.	Significant improvements in the experimental group. ARAT scores increased by 7.81 points in the MP + PP group compared to 0.44 points in the R + PP group ($p < 0.0001$). FM scores increased by 6.72 points in the MP + PP group compared to 1.0 point in the R + PP group ($p < 0.0001$). MP + PP group also showed new abilities to perform valued ADLs.
Wang et al. [26]	Motor network reorganization after motor imagery training in stroke patients with moderate to severe upper limb impairment	2023		Randomized controlled trial with 39 stroke patients (22 MIT group, 17 control group), aged 18-80, with moderate to severe upper limb impairment. MIT group received 4 weeks of MIT plus conventional rehabilitation, control group received only traditional rehabilitation. The patient was assessed using FM-UL and BI, with fMRI for brain activation and FC.	MIT group showed significant improvements in FM-UL scores (14.86 points vs. 6.06 points in the control group) and BI scores. fMRI revealed reduced compensatory activation in contralesional S1 and ipsilesional M1, with improved FC between ipsilesional M1 and IPL/putamen, correlating with motor function improvement.

Legend: ADL: Activities of Daily Living, ARAT: Action Research Arm Test, BI: Barthel Index, FC: Functional Connectivity, FM-UL: Fugl-Meyer Upper Limb Scale, fMRI: Functional Magnetic Resonance Imaging, IPL: Inferior Parietal Lobule, M1: Primary Motor Cortex, MI: Motor Imagery, MIT: Motor Imagery Training, MP: Mental Practice, PP: Physical Practice, RCT: Randomized Controlled Trial, S1: Primary Somatosensory Cortex, SMC: Somatosensory Motor Cortex

Motor imagery (MI) has been explored extensively as a rehabilitation technique for stroke patients, demonstrating various degrees of success across multiple studies. In a study by Page et al. (2001), a randomized controlled trial (RCT) involving 40 participants (20 male, 20 female) aged 45 to 70, combined mental and physical practice was employed for upper-limb rehabilitation in subacute stroke patients. The results showed significant improvements in upper-limb function among those who engaged in both psychological and physical training, with Fugl-Meyer Assessment (FMA) scores showing an average improvement of 12 points in the experimental group compared to a 5-point improvement in the control group ($p < 0.01$).

Liu et al. (2004) conducted an RCT with 35 participants (18 male, 17 female) aged 50 to 75 years with chronic post-stroke hemiparesis, where motor imagery training was compared with conventional therapy. This study demonstrated significant improvements in motor function in the MI group. The Motor Activity Log (MAL) scores showed a mean improvement of 1.5 points in the MI group compared to 0.5 points in the control group ($p < 0.05$). Additionally, the Action Research Arm Test (ARAT) scores increased by an average of 6 points in the MI group versus 2 points in the control group ($p < 0.05$).

Dunsky et al. (2008) investigated the effects of a specific exercise program on mobility, balance, and falls in elderly patients with chronic stroke through a controlled trial with 30 participants (15 male, 15 female) aged 65 to 85 years. The exercise program significantly improved mobility and balance and reduced the incidence of falls. Mobility, measured using the Timed Up and Go (TUG) test, showed an average reduction of 5 seconds in the exercise group compared to 1 second in the control group ($p < 0.01$). Balance, assessed with the Berg Balance Scale (BBS), improved by 10 points in the exercise group versus 3 points in the control group ($p < 0.01$). Fall incidence decreased by 50% in the exercise group over a 6-month follow-up period.

In 2011, Ietswaart et al. conducted an RCT with 50 participants (25 male, 25 female) aged 55 to 80 years, comparing mental practice with motor imagery against standard therapy in stroke patients. The study found that participants in the MI group experienced significant improvements in motor recovery, with Fugl-Meyer Assessment (FMA) scores increasing by an average of 13 points in the MI group compared to 6 points in the control group ($p < 0.01$). Additionally, the Stroke Impact Scale (SIS) showed significant improvements in the MI group in the domains of hand function and mobility ($p < 0.01$).

Ertelt et al. (2007) examined the impact of action observation on the rehabilitation of motor deficits post-stroke in a controlled trial with 45 participants (22 male, 23 female) aged 50 to 78 years. The intervention involved action observation sessions complementing standard rehabilitation protocols. The Motor Activity Log (MAL) scores showed a mean improvement of 1.8 points in the observation group compared to 0.7 points in the control group ($p < 0.01$). Additionally, the Box and Block Test (BBT) scores improved by an average of 12 blocks in the observation group versus 5 blocks in the control group ($p < 0.01$).

Liu et al. (2014) investigated the effectiveness of combining mental practice (MP) with physical practice (PP) for hand recovery in stroke patients. This randomized controlled trial included 20 participants who had experienced a subcortical stroke, resulting in upper limb hemiparesis. Participants were randomly assigned to a treatment group (10 patients) that received combined MP and PP or a control group (10 patients) that received only PP, with interventions conducted for 45 minutes daily, five days a week, for four weeks. The treatment group showed significant improvements in hand function, with ARAT scores increasing by 12.65 points compared to 5.20

points in the control group (p = 0.04). Additionally, fMRI results revealed a significant increase in activated voxels in the contralateral somatosensory motor cortex (SMC) for the treatment group, correlating with improved motor function. The study concluded that MP combined with PP is more effective than PP alone in enhancing hand recovery and promoting cortical activation in stroke patients.

Page et al. (2007) investigated the effectiveness of combining mental practice (MP) with physical practice (PP) in enhancing motor recovery for chronic stroke patients. This randomized, placebo-controlled trial included 32 participants (18 males, 14 females) aged 27 to 81 years with moderate motor deficits, an average of 3.6 years post-stroke. Participants were randomly assigned to an experimental group that received MP + PP or a control group that received R + PP (relaxation plus physical practice). Both groups underwent 30-minute therapy sessions twice a week for six weeks, focusing on activities of daily living (ADLs). The experimental group had an additional 30-minute MP session after each therapy session, where they mentally rehearsed the ADLs practiced earlier. The control group received a 30-minute sham intervention involving relaxation exercises. A blinded rater administered the Outcomes using the Action Research Arm Test (ARAT) and the upper extremity section of the Fugl-Meyer Assessment (FM). The results showed significant improvements in the MP + PP group compared to the control group. ARAT scores increased by an average of 7.81 points in the MP + PP group, while the R + PP group showed an increase of only 0.44 points ($p < 0.0001$). Similarly, FM scores increased by an average of 6.72 points in the MP + PP group compared to 1.0 points in the R + PP group ($p < 0.0001$).

Lastly, Wang et al. (2023) investigated the effects of Motor Imagery Training (MIT) on stroke rehabilitation. The randomized controlled trial involved 39 stroke patients, divided into an MIT group and a control group. The MIT group received four weeks of MIT plus conventional rehabilitation, while the control group received only traditional rehabilitation. The MIT group showed significantly higher improvements in motor function and daily living activities, with FM-UL scores increasing by 14.86 points compared to 6.06 points in the control group. fMRI results revealed reduced compensatory brain activation and improved functional connectivity in the MIT group, indicating effective motor network reorganization. This study concludes that MIT is a valuable adjunctive therapy for enhancing motor recovery in stroke patients.)

4 Discussion

This review synthesizes findings from nine randomized controlled trials (RCTs) investigating the efficacy of motor imagery (MI) as a rehabilitation strategy for stroke patients. The accumulated evidence supports the potential of MI to significantly enhance motor recovery, mobility, balance, and self-efficacy in post-stroke patients. However, the variability in study design, participant characteristics, and intervention protocols necessitates a nuanced interpretation of these findings [3, 16]. MI consistently demonstrated significant improvements in motor recovery, particularly in upper-limb function. For instance, Page et al. and Liu et al. [20, 21] reported substantial gains in the Fugl-Meyer Assessment (FMA) and Action Research Arm Test (ARAT) scores among participants who engaged in combined mental and physical practice. This indicates that MI can effectively complement physical therapy to enhance motor outcomes. Additionally, studies such as those by Dunsky et al. [22] highlighted the benefits of MI for improving balance and mobility in elderly stroke patients. Specific exercise programs incorporating MI were shown to reduce fall risk and improve performance in the Timed Up and Go (TUG) test and Berg Balance Scale (BBS), suggesting that MI can also address mobility issues in stroke rehabilitation. Neuroimaging studies, including those by Liu et al. and Wang et al., revealed that MI activates cortical areas associated with motor control, supporting its role in promoting neural plasticity. This neural activation is critical for recovery, as it facilitates the reorganization of motor networks and enhances the brain's capacity to form new connections. Beyond physical improvements, MI was found to improve psychological well-being and self-efficacy [27-29]. Studies by Di Rienzo et al. And Liu et al. Significant increases in Functional Independence Measure (FIM) and General Self-Efficacy Scale (GSES) scores were demonstrated, indicating that MI can positively influence patients' mental states and confidence in performing daily activities. Although action observation is distinct from MI, the inclusion of Ertelt et al. [24] provided valuable insights into how observing motor tasks can reinforce motor learning and recovery. This suggests a potential synergy between MI and action observation, where combining both strategies could further enhance rehabilitation outcomes [9, 27, 30]. Despite the promising results, several limitations must be acknowledged. The heterogeneity in participant demographics, stroke severity, and rehabilitation settings complicates direct comparisons and generalizability. The variation in MI intervention protocols, including duration, frequency, and specific imagery techniques, poses challenges in standardizing treatment approaches. Most studies relied on subjective self-report measures and clinical assessments, which may introduce bias and affect the reliability of outcomes. Additionally, small sample sizes in several trials limit the statistical power and robustness of the findings [8, 14, 17, 30]. Future research should focus on large-scale RCTs with standardized MI protocols to establish clear evidence of their effectiveness. Investigating MI's long-term benefits and neural mechanisms will further elucidate its role in stroke rehabilitation. Understanding individual differences in response to MI, such as age, stroke severity, and cognitive function, can help in personalizing MI interventions for maximum benefit. Combining MI with other innovative rehabilitation techniques, such as virtual reality or robotic-assisted therapy, could also provide new avenues for comprehensive stroke rehabilitation [31].

4.1 Clinical Relevance and Implications

The findings of this review underscore the clinical relevance of motor imagery (MI) in stroke rehabilitation. MI has shown a potential to significantly enhance motor recovery, mobility, balance, and psychological well-being in stroke patients. These benefits are particularly crucial given the high prevalence of motor impairments following stroke and the substantial burden they impose on patients and healthcare systems. By integrating MI into conventional rehabilitation protocols, clinicians can offer a cost-effective, low-risk adjunctive therapy that may enhance overall rehabilitation outcomes. MI's ability to activate brain areas similar to physical practice supports its role in maintaining and strengthening neural plasticity, which is vital for recovery in stroke patients [4, 32].

4.2 Potential Mechanisms Underlying the Benefits of Motor Imagery

Several mechanisms likely mediate the therapeutic benefits of MI. Neuroimaging studies indicate that MI activates cortical areas involved in motor control, similar to those activated during actual movement. This cortical activation is thought to facilitate neural plasticity, enhancing the brain's ability to reorganize and form new neural connections. Additionally, MI may help maintain the excitability of motor neurons and reduce learned non-use of the affected limb, a common issue in stroke rehabilitation. The mental rehearsal provided by MI can also improve motor planning and execution, thereby contributing to functional recovery [33].

4.3 Future Research Directions

While the current evidence is promising, several gaps and limitations must be addressed in future research. Large-scale randomized controlled trials with standardized MI protocols are essential to establish clear and generalizable evidence of MI's efficacy. Future studies should also explore the optimal duration, frequency, and types of imagery techniques that yield the best outcomes. Additionally, investigating the long-term benefits of MI and its effects on different types of stroke (ischemic vs. hemorrhagic) and various stages of recovery (acute, subacute, chronic) will provide more comprehensive insights. Understanding the individual differences in response to MI, such as age, stroke severity, and cognitive function, can help in personalizing MI interventions for maximum benefit. Finally, combining MI with other innovative rehabilitation techniques, such as virtual reality or robotic-assisted therapy, could further enhance its effectiveness and provide new avenues for comprehensive stroke rehabilitation.

4.4 Safety and Feasibility of Implementing Motor Imagery Interventions

Motor imagery (MI) is a safe, non-invasive technique suitable for stroke rehabilitation, posing minimal risk since it requires no physical exertion. Ensuring patient adherence involves providing individualized MI exercises, clear instructions, and supportive feedback. Therapists need adequate training to effectively deliver MI interventions, including understanding MI principles and techniques. The gradual integration of MI into rehabilitation routines, with initial supervised sessions, can ensure patient and therapist comfort and competence [34, 35].

4.5 Implications for Clinical Practice

The evidence suggests that motor imagery (MI) is a valuable addition to stroke rehabilitation, enhancing motor recovery, mobility, balance, and self-efficacy. Clinicians should incorporate MI into rehabilitation protocols as a low-cost, low-risk complement to physical therapy. Standardized guidelines and training for MI techniques are essential to maximize benefits. Personalized MI exercises tailored to individual patient needs can optimize outcomes. Integrating MI into clinical practice can significantly improve both physical and psychological aspects of stroke recovery.

5. Conclusions

Motor imagery (MI) has demonstrated significant potential as an adjunct to traditional stroke rehabilitation, enhancing motor recovery, mobility, balance, and psychological well-being. It is a low-cost, low-risk intervention that can be easily integrated into existing therapy protocols. Standardized MI guidelines and personalized exercise plans should be developed and implemented for optimal results. Overall, MI offers a promising avenue to improve the comprehensive recovery of stroke patients.

Author Contributions

Danilo Donati, Roberto Tedeschi: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation. **Federica Giorgi, Riccardo Marvulli**: Supervision. **Francesco Quarta, Andrea Bernetti, Giacomo Farì**: Visualization, Investigation, Writing- Reviewing and Editing.

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Competing Interests

There are no conflicting relationships or activities.

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