



EFFECT OF GRADED MOTOR IMAGERY ON PHANTOM LIMB PAIN IN AMPUTEES: A NARRATIVE REVIEW

Dr. Bhumika R. Chaudhari (PT)

MPT, Government Physiotherapy College & Government Spine Institute, Ahmedabad

Corresponding Author: bhumikachaudhari269@gmail.com

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ABSTRACT

Background: Phantom limb pain (PLP) is a common and potentially disabling consequence of limb amputation. Although its pathophysiology is multifactorial and may involve peripheral neural changes, cortical reorganization, and altered sensorimotor processing. Graded motor imagery (GMI) is a non-invasive rehabilitation approach comprising laterality recognition, explicit motor imagery, and mirror therapy.

Objective: To review the available evidence regarding the effectiveness of graded motor imagery in reducing phantom limb pain in individuals with limb amputation.

Methodology: A narrative review was conducted using the full-text studies identified for the review. Studies investigating GMI and related interventions were examined. Data related to study design, sample size, intervention, comparator, outcome measures, and findings were extracted. The methodological quality of applicable RCTs was assessed using PEDro Scale, and the level of evidence was classified according to the Modified Sackett Level of Evidence, Version 4.0. Due to heterogeneity among studies, findings were synthesized narratively.

Result: The strongest direct evidence was provided by Limakatso et al. that a six-week GMI programme produced significantly greater improvements in pain severity than routine physiotherapy. Pain interference was significantly improved in the GMI group, whereas health-related quality of life did not differ between groups. Supporting studies investigating mental imagery, phantom exercises, and mirror therapy generally reported improvements in PLP.

Conclusion: GMI is a promising non-pharmacological intervention for PLP. The available direct evidence supports reductions in pain, but the evidence base remains limited by small samples and methodological heterogeneity.

Keywords: phantom limb pain; amputation; graded motor imagery; mental imagery; mirror therapy

INTRODUCTION

Phantom limb pain (PLP) is defined as painful perception experienced in a body part that has been amputated. It is distinct from residual limb pain and from phantom limb sensation, in which the individual experiences a non-painful perception of the missing limb. PLP can substantially affect functional recovery and quality of life following amputation. Rierola-Fochs et al. reported estimates ranging from approximately 60–80% in earlier literature and 67–87% in more recent reports, while emphasizing that the frequency and intensity of symptoms vary considerably between individuals. (Rierola-Fochs et al., 2022)

The clinical presentation of PLP is heterogeneous. Patients may describe sensations such as burning, shooting, aching, throbbing, stabbing, or other painful perceptions in the absent limb. PLP may interfere with sleep,

mobility, activities of daily living, work, and enjoyment of life. The persistence of PLP may also be associated with psychological difficulties and reduced quality of life.(Limakatso et al., 2020)

The mechanisms underlying PLP are complex and remain incompletely understood. The evidence indicates that both peripheral and central mechanisms may contribute to the condition. Alterations in cortical representation, sensorimotor processing, and mismatch between motor intention and sensory or visual feedback have been proposed as important contributors.

Graded motor imagery (GMI) was developed as a progressive rehabilitation strategy that attempts to address these sensorimotor changes. Rather than immediately requiring physical movement or mirror-based visual feedback, GMI progresses through three stages: (1) Laterality recognition, (2) Explicit motor imagery, and (3) Mirror therapy. (Limakatso et al., 2020)

The purpose of this narrative review is to examine the available evidence concerning the effectiveness of GMI for PLP in amputees. Evidence directly investigating GMI is considered first, followed by supporting evidence from mental imagery, phantom exercise, and mirror therapy.

METHODOLOGY

The literature was identified using combinations of keywords and databases such as CINAHL, Scopus, PubMed, and Google Scholar. Studies involving GMI and related components, including mental imagery, phantom exercises, action observation, and mirror therapy were considered. The full-text studies for the review were examined for study design, sample size, participant characteristics, intervention, comparator, outcome measures, and results. Total 9 studies were included for the final review. (Figure 1)

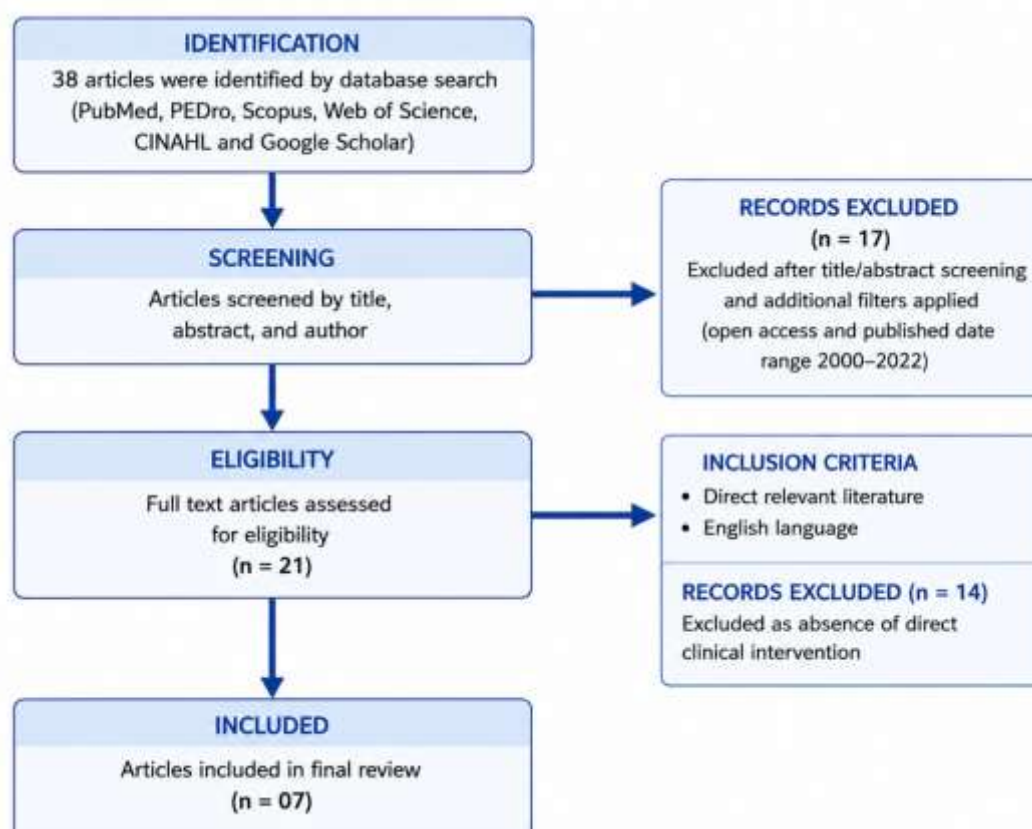


Figure 1: PRISMA Flowchart

The methodological quality of applicable randomized controlled trials was assessed using the PEDro Scale (0–10). Case reports and case series were considered not applicable for PEDro scoring. The Modified Sackett Level of Evidence, Version 4.0, was used to classify the level of evidence according to study design and methodological quality.

Data were synthesized descriptively according to study design, intervention, outcomes, methodological quality, level of evidence, and relevance to GMI. Studies directly evaluating the complete GMI protocol were

distinguished from studies investigating individual components or related interventions. Due to heterogeneity among the included studies, no statistical meta-analysis was performed.

RESULTS

A total of 7 studies of different study designs were reviewed. Findings were synthesized narratively according to intervention type, methodological quality, level of evidence, treatment effects, and clinical relevance.

The included studies comprised randomized controlled trials, a case series, and a case study. The studies investigated graded motor imagery (GMI) directly as well as related approaches, including mental imagery, phantom exercises, action observation, and mirror therapy. The evidence was therefore categorized into direct GMI evidence, GMI-related evidence, and component-level evidence. (Table 1)

Study	Design	Level Of Evidence & PEDro score	Sample	Intervention	Main Outcome	Relevance To GMI
Limakatso et al., 2020	Single-blinded RCT	1b; 7/10	n=21	6-week GMI vs routine physiotherapy	BPI pain severity, pain interference, EuroQol EQ-5D-5L	Direct GMI evidence
Brunelli et al., 2015	RCT	1b; 6/10	n=51	Relaxation + mental imagery + phantom exercise	PEQ, BPI	GMI Related evidence
Mallik et al., 2020	Prospective RCT	2; 5/10	n=92	Mirror therapy vs mental imagery	VAS	Component evidence
Tilak et al., 2016	RCT	1b; 7/10	n=26	Mirror therapy + TENS	PLP	Component evidence
Chan et al., 2007	RCT	2; NA	n=22	Mirror therapy	PLP	Component evidence
Beaumont et al., 2011	Case series	4; NA	n=6	Action observation + imagery	PLP	GMI Related evidence
Kim & Kim, 2012	Case study	5; NA	N=1	Mirror therapy	PLP	Component evidence

NA-Not applicable; RCT-Randomized controlled trial; GMI-Graded motor imagery; BPI-Brief pain inventory; EQ-5D-5L; PEQ-Prosthesis Evaluation Questionnaire; VAS-Visual analog scale; PLP-Phantom limb pain

Table 1: Table of Evidences

Direct GMI Evidence

The only study directly evaluating a complete GMI programme was by Limakatso et al. The RCT study included 21 participants with unilateral upper- or lower-limb amputation and persistent PLP. Participants received either a six-week GMI programme or routine physiotherapy. The study reported greater reductions in pain severity and pain interference in the GMI group compared with the control group, with some benefits maintained at follow-up.(Limakatso et al., 2020)

GMI-Related Evidence

Studies investigating components or approaches related to GMI generally reported favourable effects on PLP. Brunelli et al. conducted a RCT involving 51 individuals with lower-limb amputation. Participants received a programme combining progressive muscle relaxation, mental imagery, and phantom exercises. The intervention resulted in significant improvements in PLP and phantom limb sensation, including reductions in pain intensity, duration, and related discomfort.(Brunelli et al., 2015) Beaumont et al. examined action observation followed by motor imagery in a small case series of individuals with PLP. Several participants demonstrated reductions in pain during the intervention, together with improvements in their ability to move

the phantom limb. However, treatment effects were not consistently maintained at long-term follow-up.(Beaumont et al., 2011)

Component-Level Evidence: Mirror Therapy

Mirror therapy was investigated independently as a component of GMI in several of the included studies. Mallik et al. compared mirror therapy with mental imagery in 92 amputees with PLP. Both interventions resulted in significant reductions in pain, although the mirror therapy group demonstrated a greater reduction in VAS pain scores over follow-up.(Mallik et al., 2020) Chan et al. reported clinical use of mirror therapy for PLP, supporting the potential role of visual feedback in reducing phantom pain.(Chan et al., 2007) Kim and Kim further described the clinical rationale and proposed mechanisms of mirror therapy for PLP.(Kim & Kim, 2012) Tilak et al. investigated mirror therapy and TENS in a randomized controlled trial involving amputees with PLP. The study provided further evidence for the use of non-pharmacological rehabilitation approaches, although it investigated mirror therapy rather than the complete GMI protocol.(Tilak et al., 2016)

Overall Findings

Overall, the reviewed studies demonstrated a generally favourable effect of imagery-based rehabilitation approaches on PLP. The strongest direct evidence indicated that GMI may reduce pain severity and pain interference. Evidence from mental imagery, phantom exercises, action observation, and mirror therapy was also generally supportive.

DISCUSSION

Overall, the available literature suggests that GMI may be beneficial for PLP, but the evidence remains relatively limited. The randomized controlled trial by Limakatso et al. provides the strongest direct evidence. Their six-week GMI programme produced greater improvements in pain severity and pain interference than routine physiotherapy, with some benefits maintained at six months. (Rierola-Fochs et al., 2022)

The findings from related interventions are also generally encouraging. Mental imagery, phantom exercises and mirror therapy have all been associated with improvements in PLP in different studies.(Brunelli et al., 2015; Chan et al., 2007; Kim & Kim, 2012; Mallik et al., 2020; Tilak et al., 2016)

However, the findings should be interpreted with caution because of the small number of studies directly evaluating GMI, variation in study design and intervention protocols, and differences in outcome measures and follow-up periods. Some investigate the complete GMI sequence, whereas others use only one component or combine mental imagery with other treatments. The available evidence supports GMI as a promising rehabilitation approach, but further high-quality randomized controlled trials are required to determine its effectiveness and its relative benefit compared with individual components such as mirror therapy.

An important point is that the evidence does not yet establish that GMI is superior to mirror therapy, mental imagery or other rehabilitation approaches. The available evidence instead suggests that GMI is a promising way of combining several approaches within a structured progression.

The graded sequence may also be clinically important. Limakatso et al. suggested that laterality recognition may provide a less demanding starting point before progressing to imagined movement and mirror therapy. This may be useful because more demanding motor imagery or mirror-based approaches can potentially increase pain in some patients.(Limakatso et al., 2020)

Limitations and Future Recommendations

The main limitation of the current evidence is the small number of trials directly examining complete GMI programmes in amputees with PLP. Future research should include larger multicentre RCTs with standardized GMI protocols.

CONCLUSION

GMI is a promising non-pharmacological intervention for PLP. The available direct evidence supports reductions in pain, but the evidence base remains limited by small samples and methodological heterogeneity.

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