Review

Exploring Methodological Issues in Mental Practice for Post-stroke Paralytic Lateral Upper Limb Function: A Scoping Review

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Article

Exploring Methodological Issues in Mental Practice for Post-Stroke Paralytic Lateral Upper Limb Function: A Scoping Review

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Abstract: The purpose of this scoping review was to comprehensively clarify the methodology of Mental practice (MP) to date by systematically mapping studies that have performed MP on post-stroke paralytic upper extremity function. Specifically, (1) When is the most common timing of MP intervention after stroke onset? (2) What is the MP load (intervention time, number of intervention days, and intervention period)? (3) What are the most common methods of Motor Imagery (MI) recall and MI tasks during MP? (4) Is MP often used in conjunction with individual rehabilitative therapies? (5) What is the paralyzed side's upper limb and cognitive function level at the start of MP intervention? Our scoping review was performed ac-cording to PRISMA-ScR to identify research questions. Then, the PubMed, Scopus, Medline, and Cochrane Library databases were used to screen articles published by July 19, 2022. Eligible articles were selected all study designs were included, including studies involving the use of MP for post-stroke paralytic upper extremity function. Selection of eligible papers was done by two or more independent persons. Data were extracted from the eligible papers for items necessary to identify the research questions. English-language articles identified for this study were 694, of which 62 were accepted. The most common intervention time was 30 minutes or less and the duration of the intervention was 5 times a week in MP. The most common method of recalling MI during MP was using an audio guide. In the future, it will be important to conduct accumulation of research to unify the varied widely MP methodologies identified in this study.

Keywords: mental practice; stroke; upper limb function; methodology

1. Introduction

Stroke is a typical target disease in rehabilitation. The factors that cause stroke patients to require some support in their daily lives include the appearance of symptoms such as motor paralysis, sensory disturbance, and higher brain dysfunction. Among these, motor paralysis significantly impacts daily life and quality of life, and improvement through rehabilitation is strongly required.

In this context, Mental Practice (MP) is one intervention to rehabilitate gait, balance, and upper limb function after a stroke. MP is the continuous repetition of Motor Imagery (MI) to improve performance on motor tasks, and its usefulness has been reported in systematic reviews of stroke patients [1,2]. Based on the results of many such studies, MP is also classified as Grade A in guidelines published by the American Heart Association [3].

However, it has been pointed out that there is no standardized intervention method in the implementation of MP for gait, balance, and upper limb function after stroke because of the wide variety of intervention methods, such as MP intervention time, intervention frequency, and intervention duration [4,5]. In other words, the clinical use of MP to improve gait, balance, and upper limb function after stroke is left to the subjective judgment of the practitioner, and the development of intervention methods is required for future development.

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This scoping review focuses on MP for paralytic upper limb function. It aims to understand the current status and identify problems for more effective MP for paralytic upper limb function and its further application in clinical practice. The scoping review systematically maps studies of MP for post-stroke paralytic upper limb function and comprehensively clarifies the methodology of MP that has been used to date.

2. Materials and Methods

Our scoping review methodology was originally conceived by Arksey and O'Malley [6], developed in detail by Levac et al. [7], and was implemented based on "Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Review (PRISMA-ScR)" as compiled by Triccol et al. [8]. We structured our protocol by applying a four-step process: identifying the research question, identifying the studies, selecting the studies, and extracting and analyzing the data.

Step 1: Identifying the research question

The purpose of this scoping review was to comprehensively clarify the methodology of MP to date by systematically mapping studies that have performed MP on post-stroke paralytic upper extremity function. Specifically, (1) When is the most common timing of MP intervention after stroke onset? (2) What is the MP load (intervention time, number of intervention days, and intervention period)? (3) What are the most common methods of MI recall and MI tasks during MP? (4) Is MP often used in conjunction with individual rehabilitative therapies? (5) What is the paralyzed side's upper limb and cognitive function level at the start of MP intervention?

Step 2: Identifying relevant studies

We searched for articles that included "stroke" and "mental practice (motor imagery training)." The databases used were PubMed, Scopus, Medline, and the Cochrane Library; the last search date was July 19, 2022. The PubMed search prompts are shown below as an example.

"cerebrovascular disorder" OR stroke OR "Brain infarction" OR "Brain Stem Infarctions" OR "Cerebral Infarction" OR Lacunar OR "Brain injury"

AND

"mental practice" OR "motor imagery training" OR "motor image"

Duplicate papers were removed after extracting papers from each database.

Step 3: Study selection

Papers meeting our criteria were selected from among English language publications, and all study designs were included, including studies that performed MP on the paralyzed upper limb function after stroke. Five authors selected eligible articles using the Rayyan literature screening software (https://www.rayyan.ai/). For each article, the first author (Akira Nakashima) and two other authors (from among Takefumi Moriuchi, Kengo Fujiwara, Ryohei Okamura, or Toshio Higashi) checked whether it met the eligibility criteria. In case of disagreement, the five authors reviewed the manuscript until 100% agreement was reached.

Step 4: Data Extraction and Analysis

The following information was extracted from the articles for the eligible articles. Author, year of publication, study design, country of study, age of participants with MP, type of stroke, timing of MP intervention, cognitive function at the start of MP, paralytic upper limb function at the start of MP, duration of MP intervention, daily MP intervention time, MP intervention days per week, how MI was performed during MP, and whether MP was combined with individual rehabilitation therapy. Akira Nakashima and Takefumi Moriuchi subsequently identified the level of evidence and study design of 62 articles using the American Journal of Occupational Therapy's systematic review guidelines [9].

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Table 1. Levels of evidence and forms of intervention for the articles included in this scoping review.

No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
1	Park et al./2022	The effects of task-oriented mental practice on upper limb function and coordination in chronic stroke patients—Randomized controlled trial design	British Journal of Occupational Therapy	2B/RCT	Time per intervention：5 min Intervention frequency per week：5/W Total intervention period：3 week
2	Xiong et al./2021	Motor imagery training reduces contralesional compensation in stroke patients with moderate to severe upper limb impairment	International IEEE/EMBS Conference on Neural Engineering, NER	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：4 week
3	Qian Hu et al./2021	Motor imagery-based brain-computer interface combined with multimodal feedback to promote upper limb motor function after stroke: A preliminary stud	Evidence-based Complementary and Alternative Medicine	2B/RCT	Time per intervention：30 min Intervention frequency per week：None Total intervention period：Performed only once
4	Liepert et al./2020	Effects of a single mental chronometry training session in subacute stroke patients – a randomized controlled trial	BMC Sports Science, Medicine and Rehabilitation	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week：None Total intervention period：Performed only once
5	Fang et al./2018	Motor imagery training induces changes in brain neural networks in stroke patient	Neural Regeneration Research	2B/RCT	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：4 week
6	Azad et al./2018	Effect of motor imagery training with sensory feedback on sensory-motor function of the upper extremity in patients with chronic stroke	Journal of Babol University of Medical Sciences	2B/Tow group, nonrandomized	Time per intervention：None Intervention frequency per week：None Total intervention period：None
7	Park et al./2017	Effects of mental practice combined with electromyogram-triggered electrical stimulation for upper extremity function in stroke patients	Journal of Physical Therapy Science	2B/Tow group, nonrandomized	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：4 week
8	Iso at al/2016	Effect of mental practice using inverse video of the unaffected upper limb in a subject with chronic hemiparesis after stroke	Journal of Physical Therapy Science	4/Case study	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：6 week
9	Park et al./2016	Influence of mental practice on upper limb muscle activity and activities of daily living in chronic stroke patients	Journal of Physical Therapy Science	4/Case series	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：2 week
10	Park et al./2016	The effects of game-based virtual reality movement therapy plus mental practice on upper extremity function in chronic stroke patients with hemiparesis: A randomized controlled trial	Journal of Physical Therapy Science	2B/RCT	Time per intervention：5 min Intervention frequency per week：5/W Total intervention period：2 week

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No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
11	Seung et al./2016	Effects of Adjuvant Mental Practice on Affected Upper Limb Function Following a Stroke: Results of Three-Dimensional Motion Analysis, Fugl-Meyer Assessment of the Upper Extremity and Motor Activity Log	Annals of Rehabilitation Medicine	2B/Tow group, nonrandomized	Time per intervention：20 min Intervention frequency per week：3/W Total intervention period：3 week
12	Kim et al./2015	The effects of modified constraint-induced therapy combined with mental practice on patients with chronic stroke	Journal of Physical Therapy Science	2B/RCT	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：6 week
13	Bajaj et al./2015	Functional organization and restoration of the brain motor-execution network after stroke and rehabilitation	Frontiers in Human Neuroscience	2B/Tow group, nonrandomized	Time per intervention：240 min Intervention frequency per week：Not specified Total intervention period：3 week (3600 min)
14	Kim et al./2015	Motor imagery training improves upper extremity performance in stroke patients	Journal of Physical Therapy Science	2B/RCT	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：4 week
15	Park et al./2015	Effects of mental practice on stroke patients' upper extremity function and daily activity performance	Journal of Physical Therapy Science	2B/RCT	Time per intervention：10 min Intervention frequency per week：5/W Total intervention period：2 week
16	Hua et al./2014	Changes in brain activation in stroke patients after mental practice and physical exercise a functional MRI study	Neural Regeneration Research	2B/Tow group, nonrandomized	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：4 week
17	Ji et al./2014	Effects of Mental Practice in Conjunction with Repetitive Transcranial Magnetic Stimulation on the Upper Limbs of Sub-acute Stroke Patients	Journal of Magnetics	2B/RCT	Time per intervention：15 min Intervention frequency per week：5/W Total intervention period：6 week
18	Gaggioli et al./2011	Combined use of music and virtual reality to support mental practice in stroke rehabilitation	Journal of Cyber Therapy and Rehabilitation	4/Case series	Time per intervention：None Intervention frequency per week：7/W Total intervention period：4 week
19	Prasad et al./2009	Using Motor Imagery Based Brain-Computer Interface for Post-stroke Rehabilitation	2009 4th International IEEE/EMBS Conference on Neural Engineering, NER '09	4/Case series	Time per intervention：None Intervention frequency per week：2/W Total intervention period：6 week
20	Page et al./2021	Multimodal Mental Practice Versus Repetitive Task Practice Only to Treat Chronic Stroke: A Randomized Controlled Pilot Study	The American Journal of Occupational Therapy	2B/RCT	Time per intervention：45 min Intervention frequency per week：3/W Total intervention period：10 week

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No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
21	Kang et al./2021	The effects of additional electrical stimulation combined with repetitive transcranial magnetic stimulation and motor imagery on upper extremity motor recovery in the subacute period after stroke	Medicine	2B/Tow group, nonrandomized	Time per intervention：20 min Intervention frequency per week：5/W Total intervention period：2 week
22	Ji et al./2021	Graded motor imagery training as a home exercise program for upper limb motor function in patients with chronic stroke A randomized controlled trial	Medicine	2B/RCT	Time per intervention：30 min Intervention frequency per week：7/W Total intervention period：8 week
23	Wang et al./2020	Motor Imagery Training After Stroke Increases Slow-5 Oscillations and Functional Connectivity in the Ipsilesional Inferior Parietal Lobule.	Neurorehabilitation and Neural Repair	2B/RCT	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：4 week
24	Nam et al./2019	Effects of adjuvant mental practice using inverse video of the unaffected upper limb in subacute stroke: a pilot randomized controlled study.	International Journal of Rehabilitation Research	2B/RCT	Time per intervention：20 min Intervention frequency per week：5/W Total intervention period：4 week
25	Kim et al./2018	The effects of mental practice combined with modified constraint-induced therapy on corticospinal excitability, movement quality, function, and activities of daily living in persons with stroke.	Disability and Rehabilitation	2B/RCT	Time per intervention：10 min Intervention frequency per week：5/W Total intervention period：2 week
26	Page et al./2016	Retention of the spacing effect with mental practice in hemiparetic stroke.	Experimental Brain Research	2B/RCT	Time per intervention：60 min Intervention frequency per week：3/W Total intervention period：10 week
27	Cha et al./2015	Effects of mental practice with action observation training on occupational performance after stroke.	Journal of Stroke and Cerebrovascular Diseases	4/Case series	Time per intervention：4 min Intervention frequency per week：None Total intervention period：20 times
28	Page et al./2015	Mental Practice–Triggered Electrical Stimulation in Chronic, Moderate, Upper-Extremity Hemiparesis After Stroke	The American Journal of Occupational Therapy	4/Case series	Time per intervention：60 min Intervention frequency per week：7/W Total intervention period：8 week
29	Oliveira et al./2014	Mental practice and mirror therapy associated with conventional physical therapy training on the hemiparetic upper limb in poststroke rehabilitation: a preliminary study.	Topics in Stroke Rehabilitation	3B/One group, nonrandomized	Time per intervention：25 min Intervention frequency per week：2/W Total intervention period：8 week

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No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
30	Liu et al./2014	Mental practice combined with physical practice to enhance hand recovery in stroke patients.	Behavioural neurology	2B/Tow group, nonrandomized	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：4 week
31	Sun et al./2013	Cortical reorganization after motor imagery training in chronic stroke patients with severe motor impairment: a longitudinal fMRI study.	Functional Neuroradiology	2B/RCT	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：4 week
32	Page et al./2011	Retention of motor changes in chronic stroke survivors who were administered mental practice.	Archives of physical medicine and rehabilitation	2B/RCT	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：10 week
33	Page et al./2011	Longer versus shorter mental practice sessions for affected upper extremity movement after stroke: a randomized controlled trial.	Clinical rehabilitation	2B/RCT	Time per intervention：20 or 40 or 60min Intervention frequency per week：3/W Total intervention period：10 week
34	Ietswaart et al./2011	Mental practice with motor imagery in stroke recovery: randomized controlled trial of efficacy	Brain	1B/RCT	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：4 week
35	Wu et al./2011	Improved function after combined physical and mental practice after stroke: a case of hemiparesis and apraxia.	American Journal of Occupational Therapy	4/Case study	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：6 week
36	Céline et al./2010	Determining specificity of motor imagery training for upper limb improvement in chronic stroke patients: a training protocol and pilot results.	International Journal of Rehabilitation Research's cover	3B/One group, nonrandomized	Time per intervention：15 min Intervention frequency per week：4/W Total intervention period：3 week
37	Page et al./2009	Cortical plasticity following motor skill learning during mental practice in stroke.	Neurorehabil Neural Repair	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：10 week
38	Page et al./2009	Modified constraint-induced therapy combined with mental practice: thinking through better motor outcomes.	Stroke	2B/RCT	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：10 week
39	Page et al./2007	Mental practice in chronic stroke: results of a randomized, placebo-controlled trial.	Stroke	1B/RCT	Time per intervention：30 min Intervention frequency per week：2/W Total intervention period：6 week
40	Müller et l/2007	Mental practice improves hand function after hemiparetic stroke.	Restorative Neurology and Neuroscience	2B/RCT	Time per intervention：30 min Intervention frequency per week：5/W Total intervention period：4 week
41	Butler et al./2006	Mental practice with motor imagery: evidence for motor recovery and cortical reorganization after stroke.	Archives of Physical Medicine and Rehabilitation	4/Case study	Time per intervention：180 min Intervention frequency per week：7/W Total intervention period：2 week

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No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
42	Gaggioli et al./2005	A strategy for computer-assisted mental practice in stroke rehabilitation.	Neurorehabil Neural Repair	4/Case series	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：12 week
43	Page et al./2005	Effects of mental practice on affected limb use and function in chronic stroke.	Arch Phys Med Rehabil	2B/RCT	Time per intervention：30 min Intervention frequency per week：2/W Total intervention period：6 week
44	Dijkerman et al./2004	Does motor imagery training improve hand function in chronic stroke patients? A pilot study.	Clinical Rehabilitation	2B/RCT	Time per intervention：None Intervention frequency per week：7/W Total intervention period：4 week
45	Crosbie et al./2003	The adjunctive role of mental practice in the rehabilitation of the upper limb after hemiplegic stroke: a pilot study.	Clinical Rehabilitation	4/Case series	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：2 week
46	Page et al./2001	Mental practice combined with physical practice for upper-limb motor deficit in subacute stroke.	Physical Therapy	4/Case study	Time per intervention：10 min Intervention frequency per week：2/W Total intervention period：6 week
47	Chowdhury et al./2018	Active Physical Practice Followed by Mental Practice Using BCI-Driven Hand Exoskeleton: A Pilot Trial for Clinical Effectiveness and Usability.	IEEE journal of biomedical and health informatics	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week：2-3/W Total intervention period：6 week
48	Kawakami et al./2018	Change in Reciprocal Inhibition of the Forearm with Motor Imagery among Patients with Chronic Stroke.	Neural Plasticity	3B/One group, nonrandomized	Time per intervention：45 min Intervention frequency per week：5/W Total intervention period：10 days
49	Assis et al./2014	An augmented reality system for upper-limb post-stroke motor rehabilitation: a feasibility study.	Disability and Rehabilitation	3B/One group, nonrandomized	Time per intervention：60 min Intervention frequency per week：1~2/W Total intervention period：4 week
50	Morone et al./2015	Proof of principle of a brain-computer interface approach to support poststroke arm rehabilitation in hospitalized patients: design, acceptability, and usability.	Archives of Physical Medicine and Rehabilitation	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：4 week
51	Clarissa et al./2013	The addition of functional task-oriented mental practice to conventional physical therapy improves motor skills in daily functions after stroke.	Brazilian journal of physical therapy	4/Case series	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：4 week
52	Mihara et al./2013	Near-infrared spectroscopy-mediated neurofeedback enhances efficacy of motor imagery-based training in poststroke victims: a pilot study.	Stroke	2B/RCT	Time per intervention：30 min Intervention frequency per week：3/W Total intervention period：2 week

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No.	Author/Year	Paper title	Journal of publication	Evidence level/Study Design	MP Intervention
53	Timmermans et al./2013	Effect of mental practice on the improvement of function and daily activity performance of the upper extremity in patients with subacute stroke: a randomized clinical trial.	Journal of the American Medical Directors Association	2B/RCT	Time per intervention：30 min Intervention frequency per week：7/W Total intervention period：6 week
54	Nilsen et al./2012	Effect of imagery perspective on occupational performance after stroke: a randomized controlled trial.	The American journal of occupational therapy	2B/RCT	Time per intervention：18 min Intervention frequency per week：2/W Total intervention period：6 week
55	Braun et al./2012	A multicenter randomized controlled trial to compare subacute 'treatment as usual' with and without mental practice among persons with stroke in Dutch nursing homes.	Journal of the American Medical Directors Association	2B/RCT	Time per intervention：None Intervention frequency per week：None Total intervention period：6 week
56	Riccio et al./2010	Mental practice is effective in upper limb recovery after stroke: a randomized single-blind cross-over study.	European Journal of Physical and Rehabilitation Medicine	2B/RCT	Time per intervention：60 min Intervention frequency per week：5/W Total intervention period：3 week
57	Gaggioli et al./2009	Computer-guided mental practice in neurorehabilitation.	Studies in Health Technology and Informatics	3B/One group, nonrandomized	Time per intervention：30 min Intervention frequency per week： minimum 2/W Total intervention period：8 week
58	Simmons et al./2008	Motor imagery to enhance recovery after subcortical stroke: who might benefit, daily dose, and potential effects.	Neurorehabilitation and Neural Repair	3B/One group, nonrandomized	Time per intervention：60 min Intervention frequency per week：5/W Total intervention period：2 week
59	Hewett et al./2007	Reaching kinematics to measure motor changes after mental practice in stroke.	Topics in Stroke Rehabilitation	4/Case series	Time per intervention：30 min Intervention frequency per week：2/W Total intervention period：6 week
60	Page et al./2007	Mental practice as a gateway to modified constraint-induced movement therapy: a promising combination to improve function.	The American Journal of Occupational Therapy	4/Case series	Time per intervention：None Intervention frequency per week：2/W Total intervention period：6 week
61	Stevens et al./2003	Using motor imagery in the rehabilitation of hemiparesis	Archives of Physical Medicine and Rehabilitation	4/Case series	Time per intervention：60 min Intervention frequency per week：3/W Total intervention period：4 week
62	Page et al/2001	Mental practice combined with physical practice for upper-limb motor deficit in subacute stroke.	Physical Therapy	4/Case study	Time per intervention：10min Intervention frequency per week：2/W Total intervention period：6week

MP, mental practice; RCT, randomized controlled trial

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3. Results

English-language articles identified were 694 for this study, of which 62 were selected for inclusion (Figure 1). The 62 articles selected are listed in Table 1. The study designs included 26 randomized controlled trials, 16 pre/post comparisons, 11 case series, 4 quasi-randomized controlled trials, 4 single case studies, and 1 crossover comparison study. The majority of the randomized controlled trials had several methodological problems, and the quality of the studies was poor. The largest number of participants in each study was between 11 and 20 (18 studies), and 12 included more than 30 participants, of which the largest number was 121 [10]. The participants in each study were between 51 and 70 years old in the majority of 48 studies. Only a single study included participants aged 70 years or older [11]. The most common stroke type in each study was not described in 29 papers, and among those that did, 20 papers included both cerebral hemorrhage and cerebral infarction.

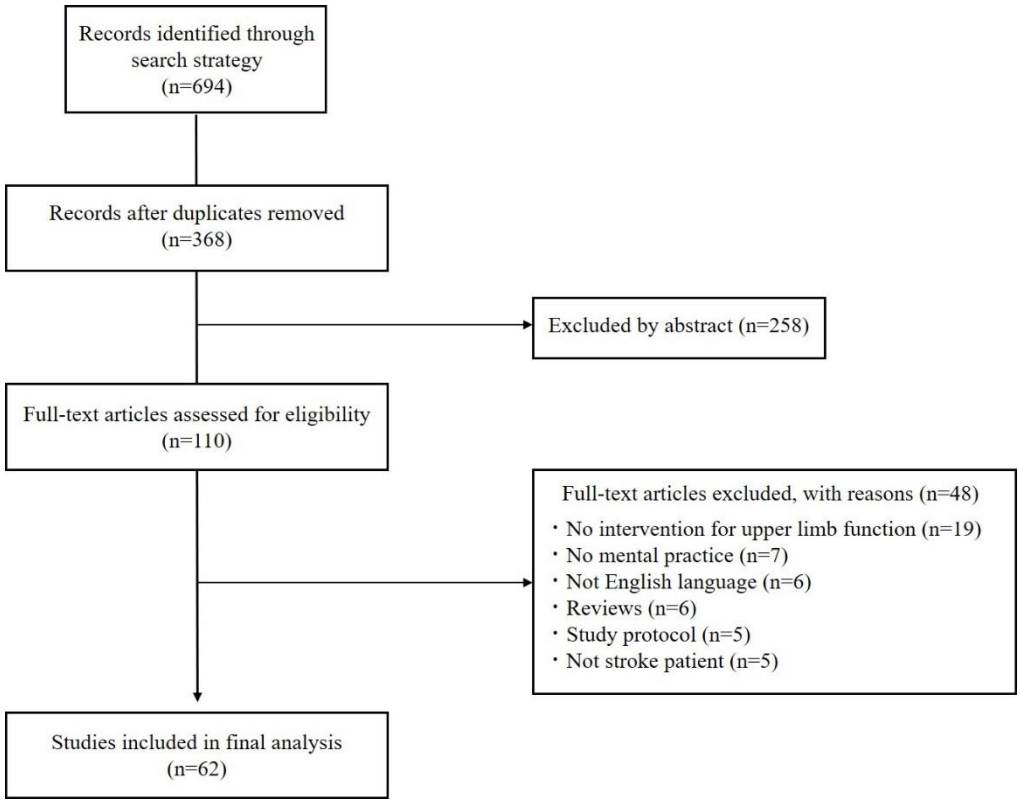

Figure 1. Flow diagram for inclusion and exclusion of studies. Figure format from "Preferred Reporting Items for Systematic Reviews and Meta-Analysis: The PRISMA Statement," by D. Moher, A. Liberati, J. Tetzlaff, and D. G. Altman; PRISMA Group, 2009, PLoS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097.

(1) When is the most common time to start MP intervention for post-stroke paralytic side upper limb function after stroke?

The timing of MP intervention was within 6 months after stroke onset in 20 studies, after 6 months in 37 studies, and 5 studies did not provide information confirming the start of MP intervention. The study that started MP the earliest was 27.8 ± 19.2 days after stroke onset [12], and the study that started MP the latest was 72.2 ± 20.3 months [13]. The timing of the intervention in all studies is described in Figure 2.

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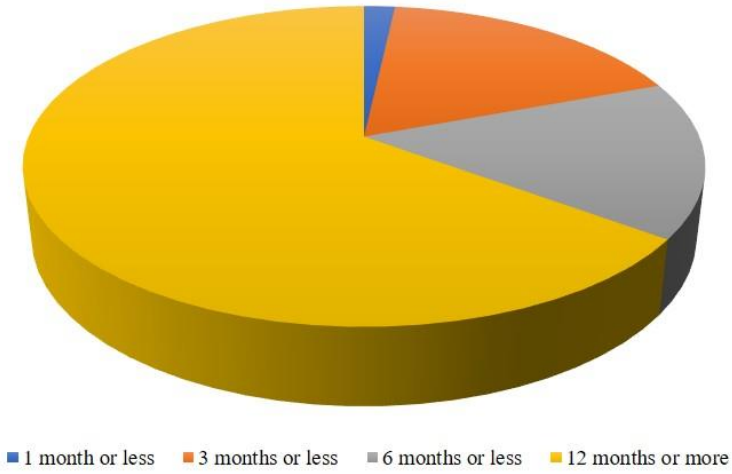

Figure 2. Time to start Mental Practice after stroke onset.

(2) What is the MP load (intervention time, number of intervention days, and intervention period)?

The intervention times for MP varied across the studies: 13 studies had MP intervention times of 20 minutes or less, 26 studies had MP intervention times of 30 minutes or less, 14 studies had MP intervention times of 60 minutes or less, 1 study had MP intervention times of 60 minutes or longer, and 8 studies lacked information concerning MP intervention time. The study with the longest MP intervention time was by Butler et al. [14], at 180 minutes. Regarding the intervention frequency, 23 studies reported 5 weekly interventions, followed by 15 with 3 weekly interventions, 11 with 2 weekly interventions, and 7 with 7 weekly interventions. There were no studies in which MP was performed once per week or 6 times a week. Five studies did not mention any MP. Next, regarding the duration of the MP intervention in each study, 4 weeks was the most common (18 studies), followed by 6 weeks (14 studies), 2 weeks and 10 weeks (7 studies). The most common combination of intervention time per intervention, intervention frequency per week, and overall intervention period were 30 minutes per intervention, 5 times per week for 4 weeks (5 studies [15–19], followed by 4 papers with 45 minutes per intervention, 5 times per week, and four weeks [10,20–22].

(3) What are the most common methods of MI recall and MI tasks during MP?

The most common method of recalling MI during MP was using an audio guide to prompt MI while giving verbal instructions (23 studies), MI alone (18 studies), and combined with motor observation (7 studies).

Other methods included using BCI in 5 papers using BCI [23–27] and VR in 3 papers [28–30].

The most common MI tasks used in MP were daily activities such as "drinking water from a glass" and "buttoning a shirt" (28 papers). Twenty-two studies used joint movements such as hand flexion and wrist dorsiflexion. Seven studies used both daily activities and joint exercises.

(4) Is MP often used in conjunction with individual rehabilitative therapies?

Forty-nine studies examined the effects of MP in combination with individual rehabilitative therapies, and 10 studies used MP alone.

(5) What is the upper limb and cognitive function level on the paralyzed side at the start of MP intervention?

In this scoping review, FMA, ARAT, MAL, and BBT data were extracted from each article to confirm the status of paralyzed side upper limb function at the start of MP. As a result, FMA, ARAT, MAL, and BBT were implemented in 38, 21, 9, and 6 studies.

Twelve studies measured cognitive function at the start of MP using the MMSE. Nineteen studies used MMSE>24 or 25 or 27 as the inclusion criterion. 11 studies used the Modified Mini-Mental State Examination>69 or 70 as the inclusion criterion. Nineteen studies did not test cognitive

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function. Among the 12 studies that measured cognitive function using the MMSE at the beginning of the MP intervention, the minimum MMSE score was 25±2 points [12].

4. Discussion

This scoping review aimed to systematically map studies in which MP was performed for post-stroke paralytic lateral upper extremity function to provide a comprehensive picture of the MP methodologies used to date. Among these, our investigation considered (1) When is the most common timing of MP intervention after stroke onset? (2) What is the MP load (intervention time, number of intervention days, and intervention period)? (3) What are the most common methods of MI recall and MI tasks during MP? (4) Is MP often used in conjunction with individual rehabilitative therapies? (5) What is the upper limb and cognitive function level on the paralyzed side at the start of MP intervention?

(1) When is the most common timing of MP intervention after stroke onset?

Most studies were conducted in the chronic phase after stroke onset, and this scoping review suggests that MP is an effective intervention strategy for upper limb function on the paralyzed side 3 months after stroke onset. However, very few studies have examined the effect of intervention in the acute phase of a stroke. The need for such intervention can be inferred from how cognitive aspects have a significant impact on how MP is conducted and that the participant is unable to perform adequate MI during MP in the acute phase of stroke onset because of impaired consciousness. Further, from the viewpoint of research design, it is difficult to derive the effects of specific approaches for participants in the acute and subacute phases of stroke because there are many factors (cerebral edema, diaschisis, improvement of penumbra) [31] that may improve physical function, and researchers are reluctant to publish negative data. However, studies in the acute and subacute phases of stroke onset are essential to determine the appropriate time to start MP intervention, and future research should focus on the effectiveness of MP in the acute and subacute phases.

(2) What is the MP load (intervention time, number of intervention days, and intervention period)?

In all studies, there were no clear criteria for the amount of MP loading, and the intervention time, days of intervention, and duration of intervention varied in a wide variety of situations. The only study that has investigated MP loading was Page et al.'s study of the MP intervention period [32]. In addition, in recent years, when considering MP load, it has become clear that MI can cause muscle and mental fatigue with sustained repetition, which can also affect performance improvement [33–37]. Against this backdrop, systematic reviews on MP have pointed out the importance of formulating interventions that account for fatigue associated with sustained repetition of MI [38]. In the future, it will be important to cooperate with basic researchers to establish standardized intervention criteria for MP and to investigate what level of load is most effective from a neurophysiological perspective.

(3) What are the most common methods of MI recall and MI tasks during MP?

The most common method of conducting MP was using an audio guide to facilitate MI while giving verbal instructions, and it is important to know how MI can be performed to maximize the effectiveness of MP [39]. Several recent studies have begun to use VR and BCI to enhance MI clarity [23–30], and we believe that it will be important to apply MI clarifying techniques to optimize MP efficacy in the future.

The most common tasks used during MP were tasks for daily activities, such as "drinking water from a glass" and "buttoning a shirt." This may be because of the combination of task-oriented training, the ease of generalization to daily activities, and the use of familiar activities to ensure MI clarity.

(4) Is MP often used in conjunction with individual rehabilitative therapies?

The majority of the studies used MP in conjunction with individual rehabilitative therapies. MP is ultimately a complementary intervention to physical training, which is believed to be more

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effective than MP as a stand-alone training method. In this context, Page et al. reported that combining exercise observation, physical exercise [40], and MP improved paralyzed upper limb function after more than 45 minutes of physical exercise and 15 minutes each of motor observation, physical exercise, and MP. These findings suggests that it may be necessary not only to combine these exercises in the future, but also to consider the order of the exercises and the allocation of time for each exercise within the overall practice time.

(5) What is the upper limb and cognitive function level on the paralyzed side at the start of MP intervention?

Depending on the FMA score, MP tends to be performed on participants with mild-to-moderate paralysis, and according to MMSE, MP tends to be performed on participants with relatively preserved cognitive function. There is no indication criteria for MP concerning paralytic upper limb function or cognitive status. For example, in CI therapy, the criteria for indication include the ability to perform a 10° extension of the MP and IP joints and a 20° dorsiflexion of the wrist in the paralyzed upper extremity, and an MMSE score of 24 or higher in cognitive function [41]. In the case of MP, it is important to perform clear MI tasks to realize their effects fully, and the participant must understand the practitioner's explanations. From this point of view, participants with relatively preserved cognitive functions are likely to benefit from MP. However, it is important to combine AO and VR to ensure motor imagery ability and to prepare the environment so that even participants with diminished cognitive function can benefit from MP. Future accumulation of research data is needed to accumulate studies on people with severe paralytic upper limb dysfunction and cognitive decline to investigate the extent to which people with paralytic upper limb function and cognitive function can benefit from MP.

One limitation of this study was that this was a scoping review, so we did not evaluate the advantages and disadvantages given by MP in each study. For this reason, it is not possible to describe the effectiveness of MP in rehabilitation interventions in this study. In addition, although five experienced occupational therapists reviewed each study in this study, we cannot deny the possibility that another occupational therapist or a different team of occupational therapists would have had a different opinion.

5. Conclusions

In this study, we comprehensively reviewed the MP methodologies used to date for the rehabilitation of paralyzed upper extremity function. We found that the duration of MP interventions varied widely and that many studies differed in their methods of MI recall. In the future, conducting accumulation of research in cooperation with basic and clinical researchers will be important to unify the varied widely MP methodologies identified in this study.

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