Review Paper

The Use of Mirror Therapy in Children With Physical Disabilities: A Scoping Review

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ABSTRACT

Objectives: This scoping review allows a better understanding of current evidence regarding mirror therapy (MT) among children to help the future development of MT intervention protocol on children.

Methods: PubMed, Science-Direct, Web of Science and ProQuest databases were searched from January 2005 to January 2023 for interventions within the scope of MT for children. Google Scholar was also scanned for additional resources. The process of the present study was according to guidelines of the preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews. The main inclusion criteria were articles in English and Persian language and peer-reviewed empirical studies of MT for children. This study charted methodological information from articles according to participant characteristics, design, intervention, and outcome measures.

Results: Of 18 studies that were included in this scoping review, 17 studies were conducted in children with hemiplegic cerebral palsy, and only two studies were in other conditions. A total of 16 articles were randomized controlled clinical trials, one case study and one single subject. Meanwhile, 33 outcomes were in the body structures (BS) and functions level, and 10 outcome measures were in the activities and participation levels of the International classification of functioning.

Discussion: The review indicates that in future studies, it is necessary to pay more attention to other disorders beyond hemiplegic cerebral palsy; furthermore, levels of activity and participation as the outcome need to be used more.

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Highlights

- Mirror therapy (MT) can be used alone or in combination with other relevant therapeutic interventions to improve hand function in children.

- Evidence regarding the effect of MT in children is focused predominantly on children with hemiplegic cerebral palsy; thus, more studies are required involving various childhood motor dysfunctions.

- Since in most studies related to the impact of MT on children, the body functions (BF) and structures level of international classification of functioning, disability and health (ICF) have been considered, it is recommended that in subsequent research, levels of activities and participation get more attention.

Plain Language Summary

MT is a therapeutic approach that is relatively affordable and available for the rehabilitation of hand function. The effectiveness of this treatment method has been proven in adults with hemiplegic stroke, but it needs more study in children with hemiplegic cerebral palsy. Although MT can be used in other unilateral disorders of the upper limbs, very limited research has been done in this field. Future research in this field can promise cost-effective services in the rehabilitation of children's unilateral hand disorders.

Introduction

Mirror therapy (MT) harnesses the brain's capacity to generate a visual illusion to trick the brain into perceiving the execution of an action without experiencing distress. Alternatively, it can provide favorable visual feedback regarding the movement of a limb [1].

The idea of using a mirror as a therapeutic intervention was first proposed by Ramachandran et al. (1995) to relieve phantom pain in amputees [2]. Reports of the effectiveness of this method in improving phantom pain, along with the novelty and simplicity of this method, led researchers to expand their studies using this non-invasive approach, thus developing the theoretical foundations supporting mirror visual feedback (MVF) [3]. Most of these studies have focused on identifying and recording the activity of different parts of the nervous system when using MVF [4]. The results of these studies can be considered in three categories. The first is those that study the mirror neuron system and variables that affect the activity of the mirror neurons system while MVF is presented [5-10]. The second category of studies has documented the activity of the cerebral hemispheres and ipsilateral motor pathways and the strengthening of connections between healthy and involved brain hemispheres through MT [11-13]. As a third category, the increased cognitive activity of the brain due to attention to the involved limb [11, 14] and prevention of the learned non-use phenomenon [15, 16] when creating MVF has been investigated in some studies.

In 2009, Shemy conducted the initial clinical trial on MT in children. The study evaluated the impact of two intervention programs that incorporated MT and cross-education alongside occupational therapy and physical therapy. The primary focus was to assess the improvement in hand function among children diagnosed with hemiplegic cerebral palsy (HCP). The findings of this study provided evidence to support the superior effectiveness of mirror exercises for children with HCP [17].

In 2013, Gyax conducted a study to assess the feasibility of MT in children with HCP. This cross-over clinical trial compared the effects of MT and regular exercise on the strength and function of the affected arm. The findings of this study provided evidence supporting the feasibility of MT in children with HCP [18].

In a systematic review conducted by Park in 2016, the study emphasizes that despite the abundance of MT studies, there is still a lack of sufficient research on the effect of MT specifically in children with HCP [19]. Meanwhile, Ezendam et al. (2009) conducted a systematic review and found no studies available specifically focusing on the effect of MT in children [20]. Though a systematic review examined the impacts of MT on children with HCP [19], systematic review studies evaluate and interpret the results of research to clarify the latest evidence on the effectiveness of various interventions in

the field understudy [21]. However, this type of research does not identify knowledge gaps and methodological components in the field under study [22]. While scoping reviews are designed to provide a comprehensive overview of the existing knowledge base and offer insights for future research, practice and policy development [23].

However, the primary objective of this scoping review study is to identify the methodological components of research related to MT in children, using the population-intervention-comparison-outcome-type of question-type of study method [24] and the international classification of functioning, disability and health (ICF) levels of function as the selection criteria. In other words, the present review identifies knowledge gaps in pediatric MT research based on the type of health condition, intervention modifications and outcome measurement that finally led to the design of new questions and appropriate and applied research in this field. Therefore, this review categorizes and synthesizes the scientific literature on the usage of MT interventions in the previous years to potentially inform, guide and inspire future efforts in using MT interventions in the rehabilitation of pediatric conditions.

Key review questions are as follows:

What are the nature and scope of MT in pediatric rehabilitation intervention research? What research designs have been used in MT studies on children? What interventions were used as the independent variables in the field of pediatric MT research? What outcome measurements were examined in MT studies on children (based on ICF levels)? What conditions have been examined in MT? What age range of children participated in MT research? What were the sample sizes of participants in pediatric MT studies?

Materials and Methods

This review was conducted according to five steps of the methodological framework scoping review based on Arksey and O Malley [25], in addition to the complementary recommendations of Levac et al. [26]. The report of the method and results was arranged by preferred reporting items for systematic reviews and meta-analyses–scoping review [27].

Identifying the research question and operationalize definitions

This study investigates the following questions:

How much research is on rehabilitation in children using MT? What research designs were used in these studies? What groups of participants were involved in reported studies? What types of interventions report conducting these studies? What kind of outcome measures are used for evaluating the effectiveness of MT interventions?

In this study, MT defines the method that the affected limb in a person with a complication is covered, and the reflection of the movement of a healthy limb in the mirror causes a visual illusion (perceptual misinterpretation of a real external visual stimulus) of the affected limb in the child."

Identifying relevant studies

This study used PubMed, Science-Direct, ProQuest, and the Web of Science databases to collect data using systematic search strategies. Meanwhile, Google Scholar was scanned for additional resources. An example of a search strategy is provided in Table 1.

Our search keywords in the field of MT included the following items: "Mirror," "mirror therapy," "mirror visual feedback," and "mirror training" in combination with "children." The date limit was set from inception to January 2023. After identifying studies related to the field, the authors reviewed references of articles to ensure that the search was complete.

Inclusion-exclusion criteria

The inclusion criteria for articles in the study included the following items:

Original articles published in peer-reviewed journals and written in Persian and English languages; clinical trial and single-case designs; childhood age range of 0 to 18 years for the research participants; articles published between January 2005 to September 2021; studies involving MT intervention.

Meanwhile, grey literature articles and studies that involved children and adults simultaneously were excluded.

After completing the search process, the titles and the abstracts of articles were checked out and irrelevant studies were excluded. In the next step, the full text of

Table 1. The sample of search strategy in PubMed

	Search String	Results
1	“Mirror therapy””[title/abstract]”	385
2	“Mirror visual feedback””[title/abstract]”	102
3	“Mirror training””[title/abstract]”	26
4	Children [MeSH terms]	1950
5	(“”Mirror therapy””[title/abstract]) OR (“”mirror visual feedback””[title/abstract]) OR (“”mirror training””[title/abstract])””	485
6	“(Children [MeSH terms]) AND (((“”mirror therapy””[title/abstract]) OR (“”mirror visual feedback””[title/abstract])) OR (“”mirror training””[title/abstract]))”	19
7	(Children [MeSH terms]) AND (((“mirror therapy”[title/abstract]) OR (“mirror visual feedback”[title/abstract])) OR (“mirror training”[title/abstract])) AND ((humans [filter]) AND (2005:2020 [pdat]) AND (English [filter] OR Persian [filter]) AND (allchild [filter]))	18

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the articles were scrutinized and relevant articles were selected. Finally, the remaining articles were included in the study.

All steps of the selection procedure were conducted separately by two authors (FM and HS) based on inclusion and exclusion criteria.

Charting the data

After studying the full text of articles, the information classification was extracted based on the components of the research design, namely study participants, design, intervention, and outcome measure.

Data charting was accomplished based on the components related to design, participants, intervention, and outcome measures based on the population, intervention, comparison, outcome – type of study design, and type of clinical questions method.

According to the study design, the articles were classified into three categories, including, randomized control clinical trials (RCT), case series and single-case designs.

The sample size and characteristics of the participants (age and condition) were extracted and charted.

According to the independent variables for the MT program in the intervention group and comparison group (if any), we classified the studies into five categories:

a) MT: The MT group program includes only MT; b) MT versus modified mirror therapy (mMT): The intervention group underwent modified MT and the comparison group received conventional MT; c) MT versus other interventions: The intervention group performed MT exercises and the control group performed different exercises. Studies in this group of interventions, according to the exercises of the control group divided into two subgroups:

1) MT versus other interventions: Children in the control group performed a different intervention program than the MT group. 2) MT versus the same movement without a mirror: The exercise of the control groups performed the same as the MT group without using the mirror.

d) MT plus other interventions versus other interventions: The protocol of the intervention group included a combination of mirror exercises with other programs or training (integrated MT program) while the control group received other interventions (conventional occupational therapy). e) MT versus MT plus other interventions versus other interventions: The independent variable contains three levels including MT, MT in addition to other intervention programs and another treatment program (without MT).

The classification of outcome measures based on ICF levels can provide a clear picture of the studies related to MT in children. Therefore, we classified the outcome measure of the studies based on the level of functions based on ICF. Levels of functioning based on ICF include body functions (BF) and body structures (BS), activities, and participation, each with different components. One of the important questions in related research is what effect the interventions have on each level of the ICF [28, 29].

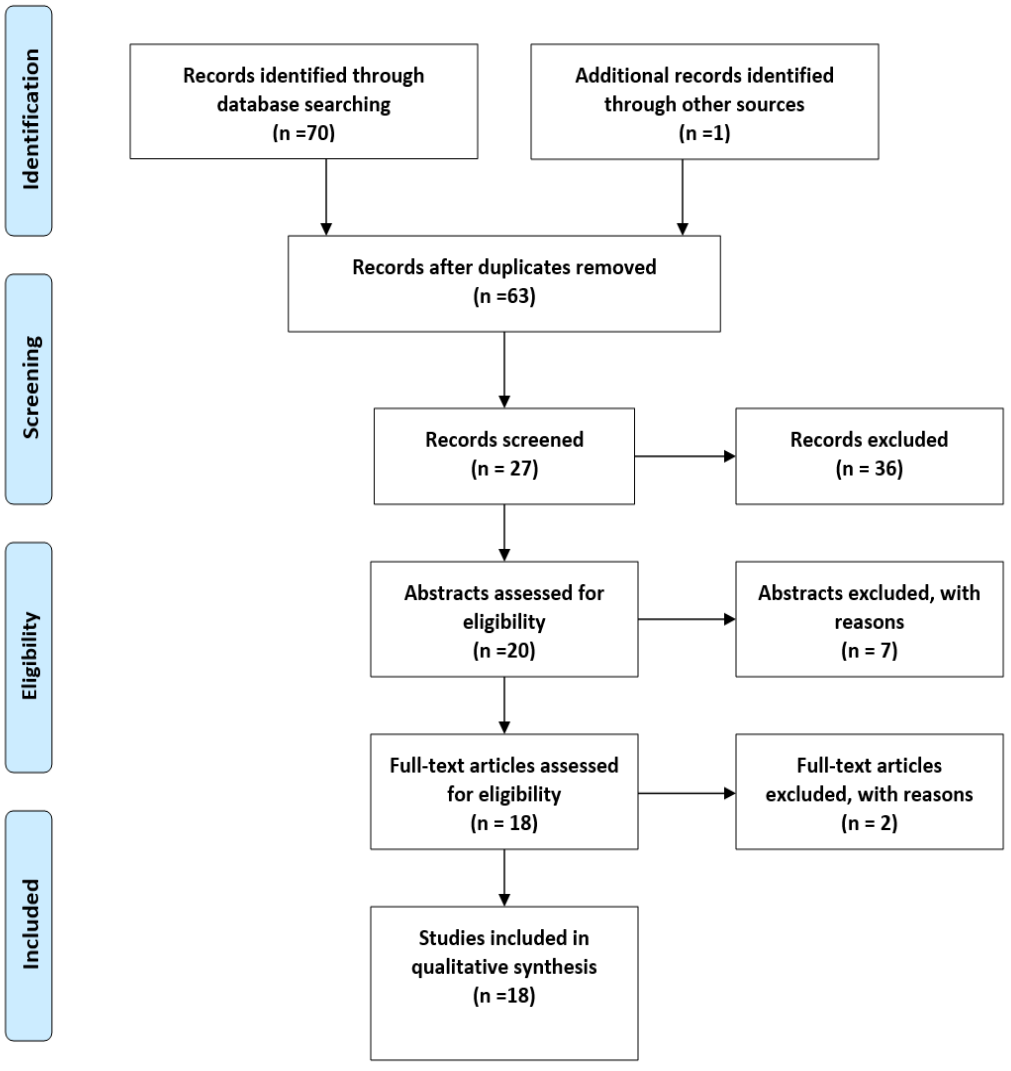

Figure 1. Preferred reporting items for systematic reviews and meta-analyses flow of articles through the study

Collating, summarizing, and reporting results

All team members discussed the data extracted to analyze the data (involving a descriptive numeric overview and a thematic analysis), reporting results, and applying intentions to the results. The studies were summarized descriptively and assessed for similarities and dissimilarities.

Results

In the initial search, by using the keywords, 73 articles were identified from the databases. By excluding duplicates (n=8) and scanning titles, 29 papers and after screening the abstracts, 22 papers were selected. By reading the full texts, 20 eligible articles that satisfied the inclusion criteria were selected for the qualitative analysis (Figure 1).

According to the method categorized in the charting data section, the information obtained from the studies is as follows.

Design

Among the articles that matched the inclusion criteria, the types of study design were as follows. In 18 studies, RCT design were used. Among these group projects, 16 studies were parallel-group, and two were crossover studies. In one study, the single-subject design was used, and in another study, the case series design was applied. Among these designs, three studies [30-32] had measurements in the follow-up stage (Table 2).

Table 2. Continued.

Author	Design	Study Participants	Intervention Arms	Outcomes	Duration and Frequency	Main Findings
Shahanawaz et al. (2015) [35]	Case study	HCP Age: 5 (y) n=1	MT	Quality of upper extremity skills Unilateral gross manual dexterity	30 min per day for 6 days a week for 3 weeks	Significant improvements were observed in hand skills and dexterity for both the right and left upper extremities following the intervention.
Nour et al. (2016) [51]	RCT	HCP Age: 4 to 8 (y) n=30	Intervention group: Hand-arm intensive bimanual training with modified mirror apparatus. Comparison group: The same hand-arm intensive bimanual training as in the intervention group but without the modified mirror apparatus.	Palmar grasp strength Pinch grasp strength	1.5 h for 5 days a week, for 2 months	Both groups demonstrated a significant improvement when comparing the pre-test and post-test. However, there was no statistically significant difference observed between groups in the post-test.
Elsepaee et al. (2016) [50]	RCT	HCP Age: 5 to 7 (y) n=40	Intervention group: Physical therapy program for 1 h followed by MT for half an hour; Comparison group: Same daily physical therapy program without an MT	Gross and fine motor skills Handgrip strength	Intervention group: 1.5 h (physical therapy program followed by half 1 h MVF in 7 days a week, for 4 weeks Comparison group: 1 h physical therapy program in 7 days a week, for 4 weeks	The results showed a significant enhancement in hand skills and grasp strength among both groups in the post-test. Furthermore, the intervention group exhibited a greater degree of improvement compared to the control group.
Bruchez et al. (2016) [30]	RCT with fallow-up	HCP Age: 7 to 17 (y) n=76	Intervention group: Home base task-oriented MT Comparison group: Home base task-oriented therapy	Primary outcome measures: Pinch and palmar strengths of the hand Grasp strength: The function of the affected upper extremity Secondary outcome measures: ADL Sensory function	15 min for 5 days a week, for 5 weeks	A significant difference was observed in the outcomes and their progression over time between the MT group and the comparison group.
Farzamfar et al. (2017) [53]	RCT	HCP Age: 6 to12 (y) n=40	Intervention group: Task-oriented MT Comparison group: Task-oriented therapy	Gross motor skill	16 sessions of 30 min	Both groups showed a notable improvement in gross manual dexterity from pre- to post-treatment. However, participants in the MT group demonstrated superior performance in the gross motor skills of their affected hand compared to the control group.
Auld et al. (2017) [52]	Replicated randomized controlled crossover case series	HCP Age: 6 to 18 (y) n=6	Two sessions-one of mirror-based training and one of standard practice, bimanual therapy-in alternate order	Tactile registration Perception (double simultaneous or single-point localization)	Two 90-minute sessions in alternate order	Tactile perception improved in four participants, with MT, but was unchanged with bimanual training. Neither intervention affected tactile registration.

Author	Design	Participant	Intervention Arms	Outcomes	Duration and Frequency	Main Findings
Derakhshanrad et al. (2017) [33]	Single-subject design	HCP Age: 5 to 15 (y) n=4	Home-based MT	Hand function stacking rings, and threading beads	The study comprises three phases: Baseline (2 weeks), treatment (6 weeks), and withdrawal (2 weeks)	During the baseline phase, participants' hand function ability remained stable. However, a notable improvement was observed during the intervention phase, which then decreased during the withdrawal phase.
Elanchezhian et al. (2019) [55]	RCT	HCP Age: 3 to 12 (y) n=46	Intervention group: Task-oriented MT Comparison group: Conventional treatment for the affected hand	Spasticity, finger dexterity upper limb motor, improvement function of upper limb	60 min for 5 days a week, for 4 weeks	Mean post-test values of all MT in spasticity, dexterity, motor improvement and self-evaluating questionnaire were better than those of the conventional group.
Narimani et al. (2019) [54]	RCT (single-blind)	HCP Age: 9 to 14 (y) n=30	Intervention group: MT in addition to the convenient occupational therapy Comparison group: Convenient occupational therapy	Dexterity grasp	30 min for 3 days a week, for 6 weeks	After the MT, a significant difference in dexterity was observed between the two groups. However, there was no significant difference between the two groups in terms of hand grasp.
Kara et al. (2019) [58]	RCT	HCP Age:7 to 16 (y) n=30	Intervention group: MT combined with exercise program Comparison group: Occupational therapy program	Primary outcome measures: Quality of upper extremity skill Secondary outcomes measures: Occupational Performance	Intervention group: 1 h a day (30 min MT and 30 min exercise program) for 3 days in 12 weeks Comparison group: 1 h a day for 3 days in 12 weeks	The intervention group demonstrated more improvements in dissociated movements, grasp, weight-bearing, quality of upper limb function, satisfaction, total scores of Canadian occupational performance measure and isometric muscle strength in the affected upper extremities compared to the control group.
Abo-Zaid et al. (2020) [57]	RCT	HCP Age: 8 to 12 (y) n=60	Intervention group: The convenient physical therapy program in addition to MT Comparison group: The same traditional physical therapy without MT	Overall stability index Antro-posterior stability Medio-lateral stability	3 days a week, for 3 successful months	Significant improvements were observed in the overall stability index, anteroposterior stability index, and mediolateral stability index only in the post-test within the study group.
Farag et al. (2020) [56]	RCT	CRPS Age: 10 to16 (y) n=30	Intervention group: Conventional hand progressive exercise program in addition to MT Comparison group: Conventional hand progressive exercise program	Degree of pain, hand grip and pinch	Intervention group: 30 min (15 min conventional hand progressive exercise program in addition, the same exercises were done by the sound hand in front of mirror for 15 min). Comparison group: 30 min (conventional hand progressive exercise program); both groups participated in 12 sessions	Significant differences in decrease degree of pain and increase in hand grip and pinch strength, in mirror group than control group.

Author	Study Design	Study Participants	Intervention Arms	Outcomes	Duration and Frequency	Main finding
Yeves-Lite Et al. (2020) [61]	RCT	OBP Age: 6 to 12 years n=12	Intervention group: Virtual Reality exercise program in addition to MT Comparison group: Conventional MT	QoL Hand-use Experience Grasp	20 min for 3 days a week, for 4 weeks	In the virtual reality mirror MT group, there was a statistically significant improvement in spontaneous use of the affected upper extremity for independent tasks and overall usage. However, the routine MT group did not show significant improvements in spontaneous use of the affected hand. Furthermore, the Virtual Reality MT group exhibited significant improvements in the Physical and Health activity categories of the parents' questionnaire, as well as in the total score of the children's questionnaire. Conversely, there were no significant improvements in the QoL for the routine MT group.
Mohamed Et al. (2021) [60]	RCT (3 group)	HCP Age: 6 to 8 years n=60	Intervention group: Group A: the program with MT and taping Comparison group: Group B: Program with mCIMT alone Group C: Program with MT alone	Quality of upper extremity function Dexterity Grip strength	2 h (physical therapy for 1 h in addition 1 h MT program) for 5 days a week, for 12 successive weeks	Significant improvements were observed in the quality of upper extremity function, dexterity, and grasp strength across all groups. However, the combined MT and taping group showed the most pronounced effects in these areas.
Azizi et al. (2021) [59]	RCT	HCP Age:4 to 12 years n=16	Intervention group: Bilateral motor training in front of a mirror, combined with the routine rehabilitation program; Comparison group: Bilateral motor training without a mirror combined with the routine rehabilitation	Upper limb joints range Gross manipulative skills	30 min (involving 5 min warm up, 20 min main exercises and five minutes cool down) for 3 days a week, for 6 week	Exercise group in the mirror was superior to the other group in both Upper limb joints range and gross manipulative skills.
Madbouly Et al. (2021) [62]	RCT	HCP Age: 5 to 8 years n=40	Intervention group: MT Comparison group: mCIMT	Quality of upper extremity function	Intervention group: 30 min for 5 days a week, for 4 weeks; Comparison group: 3 h for 5 days a week, for 4 weeks	The targeted functional training was found to be effective for children with HCP. Both MT and mCIMT were identified as effective approaches for motor recovery in these children.
Palomo-Carrión et al. (2022) [32]	RCT with follow-up	HCP Age: 6 to 12 years n=12	Intervention group: Home-based MT and action observation Comparison group: Home-based action observation therapy	Feasibility of interventions and procedures Spontaneous use of the upper extremity Functionality of the upper extremity	60 minute for 5 days a week, for 4 weeks	Action observation therapy and MT combined with action observation therapy is considered feasible to be practicable at home for children with HCP.

Author	Study Design	Study Participants	Intervention Arms	Outcomes	Duration and Frequency	Main finding
Madbouly Et al. (2021) [62]	RCT	HCP Age: 5 to 8 (y) n=40	Intervention group: MT Comparison group: mCIMT	Quality of upper extremity function	Intervention group: 30 min for 5 days a week, for 4 weeks; Comparison group: 3 h for 5 days a week, for 4 weeks	The targeted functional training was found to be effective for children with HCP. Both MT and mCIMT were identified as effective approaches for motor recovery in these children.
Palomo-Carrión Et al. (2022) [32]	RCT with follow-up	HCP Age: 6 to 12 (y) n=12	Intervention group: Home-based MT and action observation Comparison group: Home-based action observation therapy	Feasibility of interventions and procedures Spontaneous use of the upper extremity Functionality of the upper extremity	60 minute for 5 days a week, for 4 weeks	Action observation therapy and MT combined with action observation therapy is considered feasible to be practicable at home for children with HCP.

Abbreviations: MT: Mirror therapy; HCP: Hemiplegic cerebral palsy; RCT: Randomized controlled trial; ADL: Activities of daily living; CRPS: Complex regional pain syndrome; OBP: Obstetric brachial palsy.

Table 3. The classification of studies according to the study arms and interventions

Arms of Intervention	Authors
MT	Shahanawaz et al. (2015) [35]; Derakhshanrad et al. (2017 [33])
MT vs mMT	Yeves-Lite et al. (2020) [57]
MT vs others interventions	Gygax et al. (2011) [18]; Smorenburg et al. (2013) [31]; Farzamfar et al. (2017) [53]; Azizidarabkhani et al. (2021) [60]; Auld et al. (2017) [52]; Elanchezhian et al. (2019) [52]; Narimani et al. (2019) [54]; Bruchez et al. (2016) [61]; Modbouly (2021) [59]
MT plus other interventions vs other interventions	Shemy et al. (2009) [62]; Elsepaee et al. (2016) [50]; Nour et al. (2016) [51]; Kara et al. (2019) [58]; Palomo-carrion et al. (2022) [32]
MT versus MT plus other interventions vs other interventions	Mohamed et al. (2021) [60]

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Abbreviations: MT: Mirror therapy intervention program (individual projects); MT vs mMT: Mirror therapy vs modified mirror therapy; MT vs other interventions: Mirror therapy vs other interventions; MT plus other interventions vs other interventions: mirror therapy in addition to other intervention program versus other interventions; MT vs MT plus other interventions vs other interventions: Mirror therapy vs mirror therapy in addition to others program vs other interventions.

Participants' characteristic

A total of 17 studies investigated the impact of MT on children with HCP. In one study, children with complex regional pain syndrome participated. All documented studies evaluated the effectiveness of mirror exercises on upper limbs.

Overall, in all studies on pediatric MT, 461 children with HCP, 30 children with complex regional pain syndrome, and 12 children with obstetric brachial palsy participated, and the age range of participants was from 2.5 to 18 years. The lowest number of participants in the study was related to a single-subject study with one child [30] and, the highest number of participants in an RCT study was 76 people [31] (Table 2).

Study intervention

According to Table 3, this review demonstrated that two articles were included in the MT group. One study was in the MT versus mMT category. MT versus other interventions design was used in nine studies. Of these, in four studies, the participants of the control group performed a different program than the mirror exercises group (MT versus other interventions), and in five studies the exercise of the comparison group was the same as the MT group without using the mirror (MT versus the same movement without the mirror). In the intervention program of the five studies, the study group received an integrated intervention program that combined MT with other rehabilitation methods. A comparative analysis was conducted between this group and a control group (MT plus other interventions versus other interventions). In one study with a three-group design, intervention groups include the MT group, MT with other intervention, and, another intervention (modified constraint-induced movement therapy).

These intervention programs accomplished in duration ranging from 42 sessions, in a single subject study [33] to one intervention session with unimanual and bimanual training [34]. Three research were performed as the home base and 16 studies were performed in clinical and laboratory settings (Table 3).

Outcome measure

In this scoping study, 45 outcome measures were extracted from the articles. According to this, 35 outcome measures were in the BF and BS level and 10 outcome measures were in the activities and participation level.

At the level of BF and BS, dexterity has been used in more studies as an outcome (n=5). At the levels of activities and participation, the variable of upper limb function (n=2) has the highest frequency (Table 4).

Discussion

The objective of this scoping review was to present a comprehensive overview of studies about MT in children and the classification of studies with an emphasis on methodological components of research design, characteristics of participants, types and patterns of interventions, and outcomes.

Our review indicated that most authors have used RCT design in the MT studies in children. The designs of the two remaining studies were the case series [35] and

Table 4. Outcomes and instruments in terms of international classification of functioning, disability and health levels

International Classification of Functioning, Disability and Health Levels	Outcome	Instrument
BF and structures	Pinch strength (n=4)	Mechanical pinch gauge [18, 30]
		Hand-held dynamometer [51, 56]
	Palmar stretch (n=2)	Mechanical pinch gauge [30]
		Hand – held dynamometer [51]
	Grasp strength (n=4)	Hand mechanical pinch gauge [30]
		30 Ps pneumatic Dy namometer [18]
		Hand–held dynamometer [51, 54]
	Quality of upper extremity function [n=4]	Quality of upper extremity skills test [17, 58, 60, 62]
	Unimanual matching accuracy	End point in cm [34]
	Bimanual matching accuracy	End point in cm [34]
	Dexterity (n=5)	Box and block test [33, 35, 54, 60]
		9-hole page boards test [55]
	Gross motor skills (n=3)	Box and block test [53, 59]
		Grasping and object manipulation subtests of Peabody
		Developmental motor scale [50]
	Fine motor skills	Grasping and object manipulation subtests of PDMS-2 [50]
	Handgrip (n=2)	Dynamometer [17, 50]
	Stability of lower limb	Biodex balance system [57]
	Tactile registration	Semmes Weinstein monofilaments [52]
	Tactile perception	Double simultaneous or single-point localization [52]
	Spasticity	Modified Ashwearth [55]
	Degree of pain	Visual analog scale [56]
	Range of motion (n=2)	Electronical goniometer [17]
		MSD Marker goniometer [59]
	Upper limb motor impairment	Fegl Meyer assessment [55]
	Tactile sensibility	Two point discrimination [30]
Activity and participation	Daily living and sensory function	ABILHAND – KILD questionnaire [30]
	Upper limb function (n=2)	Melborn assessment 2 [30]
	Occupational performance	Canadian occupational performance measure [58]
	Functional analysis score	Shriner's hospital for children upper extremity evaluation [18]
	Function of upper limb	Melborn [30]
	QoL	Pediatric QoL inventory generic core scales (peds QLTM 4.0) [61]
	Grasp	Children's hand-use experience questionnaire [61]
	Functional upper extremity	Upper extremity functional index questionnaire [55]
	Functional hand use	Jebsen hand function test [32]
	Spontaneous use of hand	Assisting hand assessment [32]

single-subject [33]. RCT is a valid design for measuring the effectiveness of clinical and therapeutic research. Although this design was applied in most studies in the field of MT in children, the number of research is yet insufficient for evaluation of efficacy.

The persistence of changes resulting from therapeutic intervention over time is clinically valuable [36]; therefore, one of the essential goals of interventional research in this field can be to examine the persistence of changes that are achieved by following up the study. Considering that in this review, only in three studies, the long-term effectiveness of interventions has been followed up, it is suggested that a follow-up phase be considered in the design of future research in the field of MT in children.

Despite the importance of the lower limbs in children's overall participation in life [37, 38], only one study investigated the impact of MT specifically on the lower limbs. Therefore, the impact of MT on the BF and BS, and activities related to the lower extremities of children can be researched. In this regard, due to the concurrent involvement of upper and lower extremities in most functional performance [39], it is suggested that in future research, upper and lower extremities be considered concurrently in MT intervention protocol.

Looking at the scope of the MT studies in the children, we recognized that in early research, the MT programs were compared with similar programs without mirror feedback (or other interventions) that had two levels of independent variables, while in more recent studies, research designs had two or three levels of independent variables, which includes different intervention programs of MT and modified MT interventions that have been compared with each other and other interventions.

Through classifying outcome measures based on ICF levels of function, we found that in about %78 of the studies of MT on children, the outcome measurements predominantly focused on the BF and BS levels and levels of activities and participation had less attention. Regarding the importance of levels of activity and participation in health and quality of life (QoL), in MT studies, focusing on these levels of ICF as an outcome measure should be given more consideration by researchers.

According to the results, no study has examined the impact of MT on kinetic and kinematic parameters of movement. According to the overview of motor control, movement with any level of quality is related to the interaction and cooperation between the control and executive levels of the motor system [40]. This means that in addition to measuring performance variables, focusing on movement mechanisms and motor system strategies to overcome motor dysfunctions in children with motor impairments can provide more knowledge about the control process and the impact of MT and exercise program [41, 42]. Thus, based on theories, such as motor variability, it is possible to study the underlying mechanisms of movement, including biomechanical connections between the joints to produce coordinated movements following MT interventions [40, 43]. Additionally, the study of visual receptive strategies (such as eye-tracking) in MT can have useful results in investigating the neural bases of MT.

According to the findings of this review, in terms of conditions of participants, in most studies, individuals with HCP participated, while less attention was paid to other unilateral lesions such as phantom limbs. Therefore, it is suggested that the variety of unilateral lesions of extremities be further addressed as conditions of the participants in future research. In addition, theoretically, MT has the potential to limit the complications of casting following orthopedic injuries, such as atrophy and movement dysfunctions. The study of this issue can also be the target of future research in the field of MT in children.

Finally, since methods of direct study of brain activity using tools such as transcranial magnetic stimulation [44-46], functional magnetic resonance imaging [11, 47], positron emission tomography [45, 48] and brain mapping [49] were interesting for researchers to study the effects of MT on adults with unilateral extremity dysfunction, similarly in MT research on children, applying these advanced types of equipment to assess children's brain activities as an outcome measure during and after MT can answer fundamental questions.

Conclusion

In summary, the main finding of our study was that MT studies in children are insufficient and limited to children with HCP, and in most of the studies, the functions of BF and BS levels of ICF are considered as research outcomes.

The findings of this scoping review showed that more studies are needed on the efficacy of MT in children. Based on the literature, it is suggested that the impacts of MT beyond HCP on other unilateral conditions of children be examined. Also, variables related to levels of activities and participation of ICF as an outcome measure should be given more deliberation by researchers.

Finally, it is recommended to use modern instruments to measure kinetic and kinematic motion as well as advanced measurements of brain activity in MT studies in children.

Study limitations

The first limitation of this review was that only studies written in English and Persian were included. This can lead to missing studies that have been reported in other languages. Another limitation was that only a partial range of grey literature was searched. For instance, we did not search academic conferences or seminars for potential materials.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Conceptualization: Fatemeh Mohamadian; Supervision: Alireza Farsi and Behrouz Abdoli; Methodology, data collection and analysis: All authors.

Conflict of interest

The authors declared no conflict of interest.

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