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Mirror Therapy in Children with Cerebral Palsy: A Narrative Review

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Abstract

Introduction: Cerebral Palsy (CP) can lead to various impairments, activity limitations, and participation restriction. Mirror therapy is considered a useful treatment for improving the movement of lower and upper limbs in individuals with CP. This study examines current evidence on the effects of mirror therapy in children with hemiplegic CP. This study examines current evidence on the effects of mirror therapy in children with hemiplegic Cerebral Palsy (CP). **Material and methods:** We performed this narrative review using the scientific databases (including PubMed, Scopus, Cochrane, springer, ProQuest, web of science, OT seeker, Magiran, SID and IranDoc) and included controlled trials, quasi-experimental, case reports, pilot studies, and case series. We identified 25 studies, from which, 3 were excluded after screening the full text. Totally 22 studies were included for deep reviewing the effect of mirror therapy on functional performance of children with hemiplegic CP. **Result:** Although studies on the effectiveness of mirror therapy in children with hemiplegic CP were limited and the available literatures have shown different results, it appears that mirror therapy as a complementary treatment may improve sensory and upper limb motor function in children with hemiplegic CP. **Conclusion:** This study suggests that mirror therapy may be helpful for sensory and upper extremity motor performance of children with hemiplegic CP. However, more clinical trials are needed to use this intervention to determine the exact effect of this treatment on children with hemiplegic CP.

Keywords: Cerebral Palsy; Mirror Therapy; Motor Skill

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Introduction

Cerebral Palsy (CP) is one of the most common and important causes of disability in children. This condition is characterized by a broad spectrum of developmental impairments that result in different mobility and posture issues (1). This disorder is because of non-progressive brain damage that occurs during pregnancy or infancy. The most frequent type of movement issue linked to a lifelong mobility disability is CP, which is characterized by constant movement and postural abnormalities (2, 3). In the world, 2-3 kids out of every 1000 live births suffer with CP. This condition affects 2.06 births out of every 1000 live births in Iran, indicating a significant incidence of the disease both in Iran and globally (4, 5). In addition to movement limitations, CP can cause cognitive, sensory, communication, seizure, perceptual, and behavioral disorders too (4).

According to the International Classification of Functioning, Disability, and Health (ICF-DH), CP is associated with a negative impact on activities such as walking and body function, such as mental function, as well as a negative effect on body structure like limbs and participation in a sports activity (6, 7). As a result, CP can lead to various impairments, activity limitations, and participation restriction. CP causes movement disorders in children's upper and lower limbs, and nearly 50% of children with CP may experience permanent dysfunction in upper extremity activities such as manipulation, gripping, and grasping, which are among the most important and necessary tasks in daily life (8, 9). According to research, spasticity, which is one of the symptoms of CP, leads to gait disorder in children with CP due to involuntary muscle contraction and muscle weakness (10). 54% of children with CP walk without assistive devices, 16% walk with the help of an assistive device, and approximately 30% of children with CP are unable to walk to the end of their life. As gait pattern requires prerequisites such as proper functioning of the nervous, sensory, and muscular systems, these children can't walk independently and they use different types of assistive devices (11, 12). Sensory and motor

difficulties in children with CP affect their walking characteristics, creating challenges for children to maximize their participation (13). There are approximately 182 therapeutic interventions to help children with CP. Mirror-based therapy is one of the easiest, cheapest, safest, and most effective motor interventions therapy. Other motor interventions therapy include Constraint-Induced Movement Therapy (CIMT), muscle strengthening programs, hippotherapy, and task-oriented (1, 14).

The history of the discovery of mirror neurons back to 1992, when Rizzolatti and his team recorded the mirror activity of brain neurons in mammals using implanted electrodes. They discovered that while conducting and watching an activity, a small number of nerve cells in the ventral premotor cortex were activated (15). However, today several studies have shown that those mirror neurons, although primarily located in the frontal lobe (ventral premotor cortex) and parietal lobe, are found throughout the human cerebral cortex; due to this wide distribution, the network of these neurons is called the "mirror neuron system" (16, 17).

A variety of therapies, such as mirror therapy, action observation, motor imagery, imitation, observation with intent to imitate, are based on the mirror neurons' function (18, 19). Mirror therapy, based on visual stimulation from the movements of unaffected limbs, is considered a useful treatment for improving the movement of lower and upper limbs in individuals with CP (14, 20, 21). However, studies on mirror therapy's mechanism of action have yet to reach a definitive conclusion. Scientists believe that mirror therapy works in three ways: it facilitates motor pathways, prevents learning disuse of affected limbs, and activates mirror neurons (22).

Given that existing studies have not yet reached a general conclusion about the effectiveness of mirror therapy in children with hemiplegic CP, the main purpose of this study was to review the articles related to mirror therapy in children with hemiplegic CP in recent years and, to provide an appropriate and evidence-based summary.

Materials and Methods

To obtain studies related to the effect of mirror therapy in the population of children with CP, databases including PubMed, Scopus, Cochrane, springer, ProQuest, web of science, OT seeker, Magiran, SID and IranDoc were searched simultaneously and the articles which were published between 2010 till 2024 were included.

The inclusion criteria included controlled trials, quasi-experimental, case reports, pilot studies, and case series articles that examined the effect of mirror therapy on children with CP, and the exclusion criteria included studies that were not in English or Persian languages. After finding the relevant articles, they were screened. Based on the criteria and objectives of this study, 29 studies were selected as the most relevant articles, and the full text of 26 were available and met inclusion criteria then the title and full text of the articles were reviewed carefully.

Results

First of all, it should be noted that all studies on the effectiveness of mirror therapy in children with CP belonged to children with hemiplegia CP, and one study is related to diplegia. The results of the articles collected in this research can be generally classified into five areas:

1. The effectiveness of mirror therapy on the upper limbs
2. The effectiveness of mirror therapy on the lower limbs
3. The effectiveness of Mirror Visual Feedback (MVF) on movement impairments
4. The effectiveness of mirror therapy and MVF on sensory impairments
5. Mirror therapy versus other treatments in children with CP

Effectiveness on upper extremities

The majority of studies (16 studies) on the effectiveness of mirror therapy on the upper extremities have reported positive results, as shown in Table 1. The researchers believed that mirror therapy, either alone or in combination with other interventions such as Hand-Arm Bimanual Intensive Therapy (HABIT), strengthening programs, and motor training, could improve upper limb function, including strength, dexterity, and functional activities. Of all the studies, only a limited number showed conflicting results regarding the ineffectiveness of mirror therapy.

Effectiveness on the lower extremities

Few studies have been performed on the effectiveness of mirror therapy on the lower extremities. During the search for a systematic review study, only a summary of one study surfaced. Ryu conducted a study in 2016 to examine the impact of mirror therapy on body perception, balance, and walking ability in children with hemiplegic CP. They found the improvement of gait due to increased balance and body perception as a result of mirror therapy (1, 23). Tahmasebi *et al.* (24) investigated the effect of mirror visual feedback on the static balance of children with CP and their normally developing peers. They selected 15 children with normal development and 15 children with diplegia CP for their study. They also used the force plate to examine the static balance. This study demonstrated that both h groups are equally dependent on visual information, and that visual feedback through the mirror will reduce their static balance ability.

Table 1. A summary of articles on the use of mirror therapy on the upper extremities

Author(s) (year)	Study type	Aim	Sample size	Age (year)	Assessment tools	Duration of intervention	Results
N Sadek B, et al. (2022)	quasi-experimental	Assess the effect of a mirror intervention program on hand activity, mastery motivation, and self-esteem among children with CP.	50	6-12	1. Upper Extremity Functional Index; 2. Activities of Daily Living Checklist; 3. Box and Block Test; 4.Dimensions of Mastery Questionnaire; 5.Coopersmith Self-Esteem Inventory	12 weeks/36 sessions/30 minutes for each session.	The mirror intervention program had significant changes in hand activity and mastery motivation among children with CP ($p<0.05$), while it did not have a significant effect on children"s self-esteem ($p>0.05$) (25).
Mohammed AH, Karim AE, Abouelenein MH, Sheha SM (2022)	RCT	Examine how mirror therapy affects the upper extremities' Selective Motor Control (SMC) in patients with CP that is spastic hemiplegic.	45	6-9	1.Selective control of upper extremity scale (SCUES)	Three sessions/week for three months	There were statistically significant differences between the two groups as evidenced by the results the Selective Control of Upper Extremity Scale (SCUES). ($p<0.05$) (26).
Ortega-Martínez A, et al. (2023)	RCT	To evaluate the feasibility and effectiveness of a five-week homebased Mirror Therapy (MT) program for children with Unilateral Spastic CP	6	8-12	1.Childres Hand-use Experience Questionnaire 2.0 2.somatosensory function assessment 3.Pediatric Inventory of Quality of Life for CP (PedsQL 3.0)	five-week/ five days per week, 30 min per day	For kids with US CP, a home-based program of Mirror Therapy is a viable, affordable, and safe form of treatment when the therapist serves as a coach for the duration of the program (27).
elabasiry Mohamed SM, Din MS, Nour S. (2022)	Clinical trial	detect the degree of deviation of hand grip strength from normal child before and after application of two different techniques of hand rehabilitation therapy in hemiplegic CP children	30	4-9	hydraulic hand held dynamometer	3 times per week for 12 successive weeks each session lasted for 30 minutes.	Both techniques (mirror therapy and constraining therapy) decreased deviation from normal children in hand grip strength, but the mirror therapy has a more significant effect than CIMT in hand grip strength in hemiplegic children (28).
Elanchezhian C, Kumari S (2019)	RCT	Examine the impact of mirror therapy on hand function improvement.	46	3-12	1. MAS 2. FUGEL-MEYER 3. 9 hole peg 4.Upper extremity functional index	Four weeks (60 minutes/session for 5 days a week)	Mirror therapy helps children with spastic hemiplegic CP with their spasticity and hand function. (29).

Kara OK, Yardimci BN, Sahin S, Orhan C, Livanelioglu A, Soylu AR (2019)	RCT	Investigate the impact of mirror therapy combined with a Power and Strength program on children with unilateral CP's upper extremities.	30	7-16	1.QUEST 2.COPM 3.Handheld dynamometer	12 weeks (3 days a week - 30 minutes)	Mirror therapy mixed plus Strength training is a viable intervention strategy for increasing upper limb function and functional activities in children with USCP (30).
Narimani A, Kalantari M, Dalvand H, Tabatabaee SM (2018)	Single-blind clinical trial	The effect of mirror therapy on grip and dexterity in spastic hemiplegic CP children is being investigated.	30	9-14	1. Box and block test 2. Dynamometer	Six weeks (3 days/ week for 30 minutes in addition to the usual treatment program)	Mirror therapy improves dexterity in children with spastic hemiplegic CP (31)
Farzamfar P, Heirani A, Sedighi M (2017)	quasi-experimental	Examine the impact of motor training in mirror treatment on children with hemiplegia's gross motor function.	14	6-12	Box and block	16 30-minute sessions	Mirror therapy improved the dexterity of children with spastic hemiplegic CP (32).
Derakhshanrad SA, (2017)	Single subject	The effect of mirror visual feedback on upper limb movement control.	4	5-15	Box and block	6 weeks	During the treatment period, mirror therapy significantly improved the evaluated items; however, the level of improvement declined after the treatment period ended (33).
Shahanawaz S, Sayali M (2015)	Case study	The impact of mirror therapy on children with hemiplegia CP's hand function.	-	5	1. Box and block 2. QUEST	3 weeks (6 days a week for 30 minutes)	Mirror therapy significantly improves all the variables evaluated and affects the use of the hand in daily activities (34).
Gygax MJ, Schneider P, Newman CJ (2011)	Pilot crossover study	The effectiveness and practicality of mirror therapy in children with spastic hemiparesis were investigated.	10	4-16	1. Mechanical pinch gauge 2. Pneumatic dynam-ometer 3. Shriners Hospital Upper Extremity Evaluation	3 weeks (15 minutes of mirror therapy daily)	Mirror therapy helped improve the dynamic strength and function of the affected arm (35).
Nour AAA, et al. (2016)	Randomized controlled trial	Evaluate the impact of combining HABIT with mirror therapy on hemiparetic children's grip.	30	4-8	1. Hand held dynamometer 2. QUEST 3. MACS	2 months (3 sessions per week/1.5 hours per session)	This study found that combining mirror treatment with HABIT improves hand function significantly (36).

Bruchez R, et al. (2016)	Observer-blinded parallel-group randomized controlled trial	The impact of mirror therapy on children with hemiparesis was studied.	90	7-17	1. Melbourne Assessment 2 2. ABILHAND Kids 3. Pneumatic Dynamometer 4. Mechanical pinch gauge 5. Two point discrimination test 6. Proprioception was assessed too 7.Mirror movements, observed	5 weeks (5 days a week/15 minutes per session)	The use of mirror therapy during treatment had no significant effect on treatment outcomes (37).
Gaillard F, et al. (2018)	Prospective, randomized, single-center, controlled, study	The effectiveness of mirror therapy in children with unilateral CP was investigated.	32	-	Assisting Hand Assessment	5 weeks (5 sessions per week)	Mirror therapy could not have a significant effect on variables (38).

Table 2. A summary of articles on the use of mirror visual feedback in movement disorders

Author(s) (year)	Study type	Aim	Sample size	Age (year)	Assessment tools	Duration of intervention	Results
Smorenburg AR, Ledebt A, Deconinck FJ, Savelsbergh GJ (2011)	Randomized controlled trial	Evaluation of active joint position sense and visual feedback and mirror visual feedback from healthy limbs on joint position sense.	14	10-15	1. Hand held dynamo-meter 2. The Quality of Upper Extremity Skills Test (QUEST) 3. Manual Ability Class-ification System (MACS) 4. proprioceptive measure	-	In children with SHCP, the damaged limb's active joint-position sensation was enhanced by static visual feedback from the less-affected limb. Furthermore, it was shown that matching accuracy was increased by static (mirror) visual input (39).
Smorenburg AR, Ledebt A, Feltham MG, Deconinck FJ, Savelsbergh GJ (2011)	Randomized controlled trial	Examine whether the desired mirror effects are due to the visual illusion that the injured arm has been replaced and moves with less movement while the injured arm.	10	9-16	1.Superficial EMG of the muscles around the arm of both hands 2.Examine the three-dimensional position of the upper limb joints	-	MVF lowers biceps neuromuscular activity, but only if the hemiparesis kid stares at a healthy limb during task (40).
Feltham MG, Ledebt A, Deconinck FJ, Savelsbergh GJ (2010)	Randomized controlled trial	To examine how neuro-muscular activity during bimanual coordination in children with SHCP is affected by mirror feedback information.	20	9-18	1. EMG 2.3D Position	-	During limb pairing, replacing conventional visual input from the afflicted arm with mirror reflection from a healthy arm enhances motor control in children with SHCP (41).
XIAOJIE L, YANG L, LIPING W, YING S	Randomized controlled trial	Investigate the effects of MVF on upper limb function in CP children.	40	-	1. Muscle ultrasound 2. EMG	-	MVF can increase ipsilateral surface electromyographic activity and biceps

(2013)							thickness in persons with CP (42).
Elsepaee MI, Elhadidy EI, Emara HAA-M, Nawar EAEJIJOP (2016)	Randomized controlled trial	Investigate the impact of mirror visual feedback on hand function in children with hemiparesis.	40	5-7	1. Peabody developmental motor scale (PDMS-2) 2.handheld dynamometer	4 weeks	MVF improves hand grip strength, item manipulation and grip, as well as total hand performance. As a result, providing mirror visual feedback to improve hand function in children with hemiparesis can be beneficial (43)

Table 3. A summary of studies on the effectiveness of mirror therapy and mirror visual feedback in sensory disorder

Author(s) (year)	Study type	Aim	Sample size	Age (year)	Assessment tools	Duration of intervention	Results
Auld ML, Johnston LM, Russo RN, Moseley GL (2016)	Replicated randomized controlled crossover case series	Examine tactile perception and registration in children with unilateral CP after mirror-based motor and touch training.	6	6-18	1. Semmes Weinstein Monofilaments 2. Double simultaneous or single-point localization	180 minute	In children with UCP, mirror-based training showed promise in improving tactile perception (44)
Emara HAA-M, El Negamy TE (2017)	Randomized controlled trial	In hemiparesis children, investigate the effects of MVF exercises on upper limb function and alterations in wrist proprioceptive sense.	32	5-7	1. Quality of Upper Extremity Skills Test 2. Electro-goniometer 3. Active Reproduction of Active Positioning test	12 weeks (3 one-hour sessions per week)	In children with hemiparesis, mirror visual feedback can improve upper limb function and wrist proprioceptive sensibility (45).

Table 4. A summary of studies comparing mirror therapy with other treatments

Author(s) (year)	Study type	Aim	Sample size	Age (year)	Assessment tools	Duration of intervention	Results
Korney SS, Zaky NA, Abd-El-Nabie WA. (2023)	Randomized comparative study	Compare the effects of virtual reality and mirror therapy on children with unilateral CP's balance, muscle strength, and overall quality of life.	36	6-10	1.Biodex Balance System 2.Hand-held dynamometer 3. Pediatric Quality of Life Inventory (PedsQL)	3 consecutive months, three days per week, 60 minutes per day.	Both virtual reality and mirror therapy may be recommended to enhance balance, muscle strength and quality of life in children with unilateral CP. Virtual reality is more beneficial in enhancing balance, muscular strength and quality of life among those children(46)
Palomo-Carrión, Rocío Zuil-Escobar, Juan Carlos Cabrera-Guerra, et al. (2021)	RCT	Examine the impact of two mirror therapy therapies and action observation on hemiplegic children's upper extremity use.	20	6-12	1.Assisting Hand Assessment 2.Jebsen Taylor Hand Function Test 3.Surface electromyography 4.Grip dynamometer	Four weeks (one hour a day/5 days a week)	Changes in the spontaneous use and quality of movement of the affected upper limb can be achieved by combining mirror therapy and action observation (47).

Mohamed, RA Yousef, AM Radwan, NL Ibrahim, MM (2021)	RCT	The effect of mirror therapy with taping in comparison with the effect of MCIMT alone and mirror therapy alone on the quality of upper limb function, dexterity, and strength in children with hemiplegic CP.	60	6-8	1.QUEST 2.BBT 3.Dynamometer	1 Hour for five days a week for 12 weeks	All three groups improved following the intervention. However, better results were found in the group that received mirror therapy plus a tapping intervention (48).
Sharan D, et al. (2018)	Prospective clinical trial	After orthopedic selective spasticity surgery (OSSCS), the effects of mirror therapy and MCIMT on upper limb function in children with CP were compared.	80	-	1. Besta scale 2.Melbourne assessment of upper extremity function (MAUULF)	6 weeks (one hour a day)	Both groups increased their performance; However, the MCIMT recipient group obtained a higher score in the evaluations than the MT recipient group (49).
Vaghela V, et al. (2018)	Experimental study	Examine whether restraint of the affected limb, the use of mirrors, and manual interventions can help SHCP children overcome hand function and increase functional activities.	30	10	1.Motor Activity Log Scale 2.Quality of Upper Extremity Skills Test (QUEST)	12 weeks	For young children with spastic hemiplegia, MT is more effective in increasing hand function (50).

The effectiveness of MVF in movement disorders

There have been only 5 studies that addressed this topic. Most studies on the effectiveness of MVF in movement disorders have been performed in the upper extremities, especially in children with hemiplegic CP (Table 2), and very few studies have done in the lower extremities. The benefits of this type of intervention were as follows; increasing the thickness of the biceps, improving grip and manipulation of objects, improving movement control during pairing between limbs, and reducing biceps activity if observed various studies have mentioned unaffected limbs, and researchers generally believe that this type of visual feedback can improve upper limb function in children with CP.

The effectiveness of mirror therapy and MVF in sensory disorder

This issue was addressed by two articles. Mirror therapy, had positive effects on the proprioceptive sense and perception of the sense of touch in children with CP. Researchers have recommended using these techniques to improve the sensory dysfunction of children with CP, especially those with hemiplegic CP (Table 3).

Mirror therapy versus other treatments in children with CP

This topic was only covered by 5 studies. Two studies that reported different results in recent years compared mirror therapy with CIMT. Nevertheless, both interventions improved upper limb function in children with CP (Table 4).

Discussion

The purpose of this study was to review the researches on the MVF and mirror therapy in children with CP especially in children with hemiplegic CP. After reviewing and summarizing the studies, it appears that researchers in the last decade have considered mirror therapy as a complementary therapy for children with CP. In general, studies examining the effect of mirror therapy in children with CP have focused on the impact of this intervention on various aspects of upper limb functions in children with spastic hemiplegic CP. The main reasons to encouraging therapists to use mirror therapy including; being cost benefit, having no side effects, having no need for special equipment, having good effectiveness, ability to perform without the affected limb's involvement, painlessness, and ease of use. Of course (32).

Most studies have found that mirror therapy improves upper limb movement impairments and promotes upper limb recovery, but they have also found conflicting results. Research has suggested various mechanisms for how mirror therapy

works. Mirror therapy's first mechanism of action is a positive effect on increasing motor nerve activity and reducing motor dysfunction, which improves the level of motor function in the upper limb (1, 41). On the other hand, mirror therapy can replace appropriate visual feedback with inappropriate visual feedback in the affected upper limb and help to control upper limb neuromuscular activity (40). Another factor that can affect mirror therapy is the hallucination of vision, which, by simultaneously activating the two hemispheres and activating the primary motor cortex, increases the irritability of the affected limb and increases the neural efferent reaching from the brain to the muscle. According to Garry's research, during mirror therapy, the stimulation in the primary motor cortex of the limb behind the mirror increased sufficiently (51, 52). Finally, the visual illusion of moving the hurt limb on purpose in the mirror activates the compensatory motor area on both sides of the inferior parietal lobe and the primary motor cortex. It improves motor rehabilitation by replacing the functions of the affected parts of the brain with the surrounding areas. Observing the affected hand triggers an action potential in the motor cortex, albeit to a lesser degree than when observing a healthy limb in the mirror (53, 54). According to Altschuler this visual hallucination could also be a substitute for a reduction in the proprioceptive sense. as Kantak points out, It also creates a close connection between the visual input and the premotor areas, activates the premotor area, and enhances the remaining motor function of the upper extremity, which will ultimately help with rehabilitation(54, 55). Mirror therapy utilizes visual feedback to induce changes in the brain's primary motor areas on both the same and opposite sides, aiming to reduce the asymmetrical activation between the hemispheres (56).

Visual feedback of normal movement from the affected limb stimulates the inactive motor nerves in the homunculus motor area connected to the hand area (34). Wann noted that children with CP have difficulty developing the ability to create a self-centered reference framework needed for accurate mapping between sensory modalities, so using two modalities (visual and proprioceptive) is superior to one modality. Of course, in the Wann study, all children with quadriplegia and diplegia CP had bilateral problems (57). According to Tahmasebi et al., VMF could reduce balance in children with CP. We can interpret this outcome in two ways: first, the negative impact of observing balance fluctuations in the mirror may lead to a decrease in balance; second, children with neurological problems may need to use imbalance compensation strategies, which require a greater use of cognitive capacity; and third, distractions or environmental cognitive loads may reduce the ability to maintain balance (24). Conversely, mirror therapy enhances balance in children with unilateral CP by offering visual feedback of normal movement in the affected side, potentially compensating for diminished or lost proprioceptive input (46).

Bruchez *et al.* proposed several hypotheses for the effect of MVF on adult motor retraining: 1. MVF activates the mirror neuron system, often explaining the effect of MVF through the functions of mirror neurons. 2. MVF reactivates unilateral inactive pathways. 3. MVF increases spatial attention and awareness by overcoming the learning disuse phenomenon. Therefore, in mirror therapy, increasing the patient's limb awareness through a mismatch between operation and observation can reduce learning disuse or even stimulate new learning (58, 59). When discussing learning disuse, we should focus more on adults or children who experience mobility problems at an older age, as children with early disabilities often lack the time to learn natural motor patterns or develop a perceptual-motor circuit. In the Bruchez study, some children developed mobility impairment after the age of two; according to statistical studies, they did not affect the results (59). When using MVF, we see an increase in unilateral excitability of the M1 region, which causes an unwanted neural crossing between the brain's hemispheres, that is, the passage from a healthy hemisphere to the affected hemisphere (41). Ramachandran thought that spastic or paralyzed mobility in children with a unilateral acquired motor disability (mostly adults who had a stroke) were partly caused by a problem with how the brain copied motor commands and how it sent signals from the body's senses to the brain. In other words, a mismatch between sensory afferents and distorted movement, as well as a central reference copy of motor commands following a sudden motor defect, can affect motor output and lead to a decline in motor ability. However, the MVF can rectify this flawed process and cycle by adapting this afferent feedback and efferent copying to everyday symmetric two-handed tasks (60, 61). MVF can be an effective treatment even for sensory impairment because seeing motion improves somatosensory cortex representations and discriminating sense (62, 63). Furthermore, the physiological function of the somatosensory organs significantly affects joint sense in children with spastic hemiplegic CP (39). Auld *et al.* found in their study that the older children with hemiplegic CP get to improve tactile dysfunction using mirror-based tactile and motor training because they have a longer attention span. Also, in their study, people with more severe sensory disorders showed the most improvements (44). Smorenborg et al. concluded that if a child looked at their unaffected hand during MVF, it would reduce neuromuscular activity, and Feltham also observed that

MVF could reduce the intensity of neuromuscular activity in the affected hand and also be in unaffected hands (39, 41).

In studies that combine mirror therapy with other interventions, such as Kara et al.'s, which used a combination of mirror therapy and a muscle strengthening program, judging whether the improvement was the result of mirror therapy or accompanying interventions is difficult (30). However, combining mirror therapy with conventional technics is a valid method for improving upper limb mobility of children with hemiplegic CP (45). The outcome of mirror therapy depends on several factors, including the dose of therapy received, the person leading the intervention, the environment, and the age of the children. Kara et al. also recommended that therapists consider the entire kinetic chain. Given the points made about the factors influencing the outcome of mirror therapy, Bruchez's study probably did not see a favorable outcome for this reason. Interestingly, the outcomes varied in adults, which may be due to the time of initial onset because primary or congenital problems in the developing brain are different from acquired brain lesions in adults (30, 37). In the study by Derakhshanrad et al., individuals exhibited a decline in recovery after halting the intervention, likely due to two primary factors. The first factor is the reduction of further development of the sensory cortex and the cessation of this stage of treatment, which has caused new confusion and fluctuations in the sensory system. The second reason is the short duration of mirror therapy (6 weeks), which has not been able to overcome the effects of the disease (33). Most of the studies investigating the effects of MVF on movement disorders did not use a clinical mirror therapy program; however, they reported positive results. Thus, researchers have only compared the effectiveness of mirror therapy with Modified CIMT. In both studies, mirror therapy improved patients, but the MCIMT intervention made significant progress in only one study (49, 50).

In 2013, Weisstanner *et al.* (22) found that mirror therapy modulates cortico motor neuronal pathway excitability in the M1 region of the affected hemisphere. They evaluated the motor evoked potential (MEP) in performing a one-handed or two-handed activity with or without a mirror for the limb-associated hemisphere by TMS from the m1 area and found that the amplitude of the MEP increases regardless of motor or muscle work when there is a mirror. Stanley et al. noted that by the age of three, children begin to recognize visual stimuli in mirrors. By the age of five, their mirror visual system has matured sufficiently, enabling them to concentrate on and respond to mirrored tasks. This finding supports the use of MT in the population of children and adults with hemiparesis (23).

Conclusion

In general, in the field of the effect of mirror therapy on movement, there are few studies from different levels of the evidence-, and to clarify and make evidence-based decisions about the use of this type of intervention, more clinical trials are needed. However, the majority of the current articles suggest that mirror therapy, as a complementary therapy, improve motor and sensory functions of the upper extremities in children with hemiplegic CP.

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Ethical consideration
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Conflict of interest
None.

Authors' contributions
RAK: supervision, data curation, and methodology, writing, original draft. JA: data collection, resources, and writing, original draft. MA: writing, original draft.

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