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Effect of Mirror Therapy on Gait in Hemiplegic Children

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ABSTRACT

Background & Objective: Most children with Cerebral Palsy (CP) experience lower limb-related motor disabilities, such as walking, during their lifetime, leading to a reduced quality of life. Given the great importance of walking and its quality in daily activities, as well as the independence of the individual in their life, the use of various methods to improve walking in children with CP is of great importance. Among the therapeutic approaches explored, mirror therapy stands out for its foundation in the activation of mirror neurons. This study aimed to determine the effect of mirror therapy on gait performance in children with hemiplegic CP.

Materials & Methods: This double-blind randomized controlled trial (RCT) was conducted 20 children with hemiplegic CP. The treatment group (n=10) underwent 20 treatment sessions during 4 weeks. Each session consisted of 30 minutes of routine treatment and 15 minutes of mirror therapy. In the control group (n=10), sham therapy was performed instead of mirror therapy. At the beginning and end of the study, both groups underwent walking assessment via a gait analysis system.

Results: Results revealed that before the treatment, the gait of the two groups did not differ significantly; however, most spatiotemporal gait parameters in the treatment group demonstrated significant improvements post-intervention compared to the control group, except of cadence and stance phase duration, which did not show notable differences ($p<0.05$).

Conclusion: According to the results, mirror therapy as a complementary treatment appears to improve gait in hemiplegic children.

Keywords: Cerebral Palsy, Hemiplegia, Lower Limbs, Mirror Therapy

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1. Introduction

Cerebral Palsy (CP) is a major neurological condition that disrupts movement and posture owing to non-progressive damage sustained during brain development. It affects approximately 2/3 of every 1000 individuals, with the economic burden of care estimated at around 8 billion dollars. Although the brain injury itself does not worsen over time, most children with CP experience progressive musculoskeletal complications. Primary impairments-such as abnormal muscle tone, compromised balance, and diminished strength-stem directly from central nervous system (CNS) dysfunction. As the child grows, these primary deficits often result in secondary issues, including muscle contractures and skeletal deformities, evolving in response to altered biomechanics and impaired motor function (1, 2).

A large number of children with CP experience significant mobility challenges, including difficulty or inability to walk. Thus, enhancing walking ability is a central focus of therapeutic intervention (3). Neuromusculoskeletal impairments associated with CP compromise posture, balance, and locomotion. Hence, these children often exhibit lowered gait efficiency compared to their typically developing peers, which can hinder participation in everyday tasks and recreational activities (4). Children with CP usually present with a variety of neurological impairments that disrupt motor control and restrict their ability to perform daily activities.

Owing to the severity of the pathology, walking speed tends to decline, while the energy required per unit of time and distance grows significantly. Among the various subtypes, children with hemiplegia typically demonstrate the highest level of mobility. Nevertheless, they frequently exhibit dynamic equinus on the affected limb throughout the gait cycle, further complicating efficient movement (5). Children with hemiplegic CP exhibit notable gait deviations compared to their typically developing peers. Their walking pattern is characterized by a prolonged gait cycle, slower speed, and an extended support phase. The stance phase consistently exceeds the swing phase in these children. Marked differences are evident in spatial parameters (such as step and stride length), temporal (including cadence and velocity), and kinematic aspects (joint angles at the hip, knee, and ankle). These discrepancies are especially pronounced along key phases of movement-initial contact, shock absorption, and push-off. Poor motor coordination contributes to shortened strides, higher step frequency to maintain pace, exaggerated limb swing, and lowered postural stability (6, 7).

Hemiplegia accounts for 20K to 30K of all CP cases, with motor impairments in the limbs significantly impacting functional independence and overall quality of life. Common limitations in the lower extremities include restrictions in foot dorsiflexion and eversion (8, 9). These gait abnormalities often result in increased energy demands and diminished walking efficiency (10). Mirror Therapy (MT) has emerged as a promising intervention aimed at enhancing motor recovery. By reflecting the unaffected limb to simulate movement on the affected side, MT provides visual feedback that helps reestablish the link between motor commands and sensory perception, potentially improving functional outcomes (11). Visual input plays a key role in executing and regulating complex motor tasks, such as maintaining posture (12) and coordinating gait (13). Research on neuroplasticity has indicated that, even in the absence of direct sensory input, the brain undergoes adaptive reorganization-underscoring the essential role of sensory feedback in sustaining cortical motor representations and functional movement, particularly after neurological injury such as stroke (14). Studies suggest that MT creates a visual stimulus of the unaffected limb, which the brain interprets as movement of the impaired side. This illusion of motion has been proven to activate key neural regions, including the contralateral primary motor cortex, bilateral somatosensory areas, and the supplementary motor area, thereby promoting motor recovery through enhanced cortical engagement (15). Given the limited scientific evidence available in this field, the purpose of this study was to determine the effectiveness of MT on gait in children with hemiplegic CP.

2. Materials and Methods

This research was designed as a double-blind randomized clinical trial. The study was conducted with approval from the ethics committee of Shahid Beheshti University of Medical Sciences, under ethics code IR.SBMU.RETECH.REC.1399.1382, on the population of children with CP, by visiting the charity center of Tawan Yab, physical movement schools, and welfare centers in Tehran, as well as private rehabilitation centers. The initial sampling was conducted systematically. Next, after providing necessary explanations and obtaining informed consent from the parents, the children who met the inclusion criteria were randomly assigned to two intervention and control groups. Participants were randomly assigned to two groups, with people entering the research project in a gradual manner using a pre-randomized sequence via lottery and without placement. The inclusion criteria were: age between 5-12 years, ability to walk at least 10 meters independently, GMFCS level 1 and 2, Modified Ashworth Score less than three, and ability to follow verbal commands. The exclusion criteria were: uncontrolled seizures, history of orthopedic surgery, Botox injection over the 6 months prior to the intervention, contracture in the lower limb, visual acuity and hearing problems, hemi-anopsia, unilateral amnesia, cognitive impairment and disease, other neurological disorders, unwillingness to cooperate for any reason at any time, and absence in more than two sessions.

Following a pilot study conducted on 8 children, the means and standard deviations of the speed variable were calculated for the two groups. The sample size was determined using PASS 11 and calculated to ensure adequate statistical power to detect a significant difference between the groups. Finally, 20 children entered the study and were randomly split into the treatment (n=10) and control groups (n=10). Both groups received 4 weeks of treatment across 5 weekly sessions. Each treatment session included 30 minutes of conventional occupational therapy intervention (patient-specific) as well as 15 minutes of mirror therapy for the treatment group. In the control group, 30 minutes of occupational therapy intervention (patient-specific) and 15 minutes of sham therapy were performed. A 10-minute break was considered between both types of intervention. An initial assessment was conducted before the intervention, followed by a post-treatment evaluation immediately after therapy the completion using a motion analysis system. Importantly, both evaluations were performed by qualified professionals who were blinded to group allocation, ensuring objectivity and minimizing potential bias during the data collection process.

2.1 Intervention

In this study, the mirror therapy technique was a modified version of the method first introduced by Ji and Kim (16) and later applied by Ji SG in stroke rehabilitation. Participants sat with a vertically oriented mirror (40×70 cm) placed between their legs. This setup allowed the unaffected limb to reflect the impaired limb's movement, creating a visual illusion that could stimulate neural pathways associated with motor recovery (17).

The movements that people were asked to perform included the following: 1) Knee extension with ankle dorsiflexion, 2) Simultaneous flexion of all three hip,

knee, and ankle joints, 3) Bending the knee more than 90 degrees. The subjects were asked to perform the movements bilaterally. In the control group, all conditions were the same as in the mirror therapy intervention, except that the mirror reflected the diseased limb rather than the healthy limb. Conventional occupational therapy interventions for both groups included lower-limb range of motion exercises, neurodevelopmental therapies, PNF exercises, balance training, and lower-limb strengthening exercises, which were planned and implemented according to the condition of the subjects.

2.2 Motion analysis device with 8 cameras (VICON CAMERA VERO V2.2 model), made in England

This device has eight cameras installed on the ceiling of the room and provides the possibility of 3D motion analysis. The dimensions of the constructed corridor are 184 cm (width) * 820 cm (length). The imaging frequency is 120 Hz; to record and measure kinematic data, the markers according to the plug-in-gait marking system are placed on the child's body as displayed in the figure below at the points of the second metatarsal head, the back part of the heel, the medial and lateral malleolus, lateral part of the leg and thigh, the medial and lateral epicondyle of the femur, ASIS and PSIS are located on both sides of the body. In order to employ this marking system, the person's height, weight, right and left wrist and knee width, as well as the radius of the markers and the length of both lower limbs of the person (the distance from the ASIS to the medial malleolus) must be measured. Next, after installing the indicators and calibrating the device, the person is asked to walk the length of the walkway several times as a test in their normal walking style. Then, the next time the system evaluates walking at least 5 times, the child's walking is ascertained; it is assessed on the way (Figure 1).

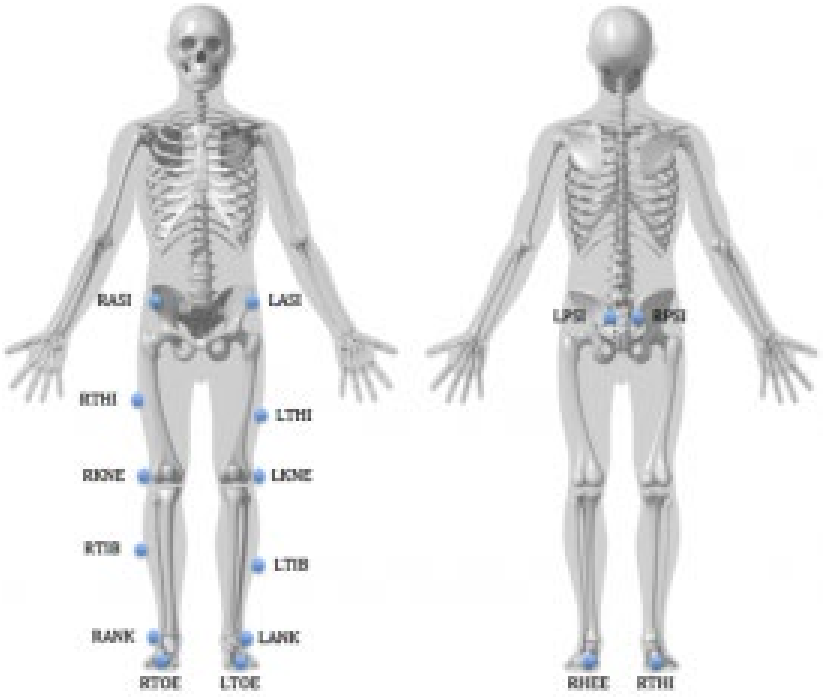

Figure 1. Placement of reflective markers on the body according to the Plug-in Gait model used for 3D motion analysis (**Prepared by Authors, 2025**).

3. Result

The analysis of the variables-speed, cadence, swing phase, stance phase, step length, and stride length-revealed no significant differences between the treatment and control groups prior to the study. Once the study concluded, all variables in the treatment group indicated significant improvements, whereas, only the swing phase time improved in the control group. Further, all variables, except for cadence and stance phase time, were significantly better in the treatment group compared to the control group ($p < 0.05$) (Table1).

Table 1. Statistical analysis of data.

Variable	Maximum	Minimum	Mean (Standard deviation)	p-value		
Stance phase time	106.98	42.28	65.90 (18.35)	0.491	treatment	Before
	90.90	45.23	60.95 (12.62)		control	
	110.23	54	72.64 (16.12)	0.268	treatment	After
	85.94	50.23	65.21 (12.75)		control	
Swing phase time	63.55	45.09	50.79 (5.67)	0.061	treatment	Before
	55.17	25.21	41.08 (9.15)		control	
	75.17	49	56.71 (7.54)	0.007	treatment	After
	61.62	35.29	46.03 (8.00)		control	
Step length	539.73	216.28	393.49 (103.69)	0.109	treatment	Before
	487.10	210.01	323.39 (80.81)		control	
	623.55	265.46	457.24 (105.44)	0.028	treatment	After
	495.65	218.14	354.00 (86.88)		control	
Stride length	1084.62	506.11	800.38 (194.46)	0.261	treatment	Before
	888.17	450.25	708.30 (158.14)		control	
	1109.01	546.82	879.44 (159.66)	0.040	treatment	After
	950.14	500.45	772.59 (157.35)		control	
Cadence	120.84	85.57	106.63 (11.03)	0.900	treatment	Before
	135.45	80.21	106.01 (18.64)		control	
	135.61	99.87	119.68 (10.61)	0.091	treatment	After
	130.12	99.87	109.31 (15.02)		control	
Speed	1.10	0.36	0.72 (0.25)	0.442	treatment	Before
	0.90	0.41	0.64 (0.25)		control	
	120	0.47	0.89 (0.18)	0.028	treatment	After
	0.92	0.45	0.65 (0.17)		control	

4. Discussions

This study aimed to examine the effects of mirror therapy, a complementary treatment, on the gait of children with hemiplegic CP. Prior to treatment, no statistically significant differences were observed between the treatment and control groups in demographic variables, ensuring baseline comparability.

In the present study, all spatiotemporal gait parameters were considered part of lower limb function and were measured using a motion analysis system. Ultimately, in the intra-group comparison, all gait parameters in the treatment group were significantly different post-intervention compared to pre-treatment ($p<0.05$). Also, in the intergroup comparison of data, statistical data analysis of the present study indicated that all parameters except cadence and static phase time in the treatment group had a significant difference from the control group post-intervention ($p<0.05$). Considering the improvement in the cadence and static phase time variables within the group, it was expected that a statistically significant difference would also be observed in the comparison of the results between the groups. However, the lack of significance of these variables may be due to some children's low cognitive capacity in performing the exercises.

Considering the static phase time, it is better to note that the static phase time in this study has been average and the result of the static phase time in both the right and left legs, and it is possible that the results would be different if the

affected and healthy legs were tested separately. In any case, it is better to conduct further research to confirm the findings regarding the cadence and static phase time variables. Since walking is a complex phenomenon, its associated concepts have direct biomechanical effects on one another. For instance, in the present study, we can consider the improvement in walking speed as resulting from increased step length and reduced oscillation phase time (18). Meanwhile, it has been reported that as step length increases, the swing phase time should increase as well; considering this observation in the present study, the rise in oscillation phase time can also be justified from a biomechanical perspective.

Several studies have been undertaken on the impact of mirror therapy on the gait of people with neurological disorders, including stroke, who are the closest group to our study population in terms of the type of injury. The examples include the study by Bhoraniya et al (19) in 2018, the study by Kim et al (20), and the study by Cha and Kim (18), which reached results in accordance with our study (18-20). Given the limited number of studies on the effect of mirror therapy on children with cerebral palsy, we also reviewed studies on interventions with the same or similar mechanisms of action, such as action observation therapy or mental imagery. Studies such as Demirtas Karaoba and Talu (21) indicated that action observation therapy can ameliorate gross motor skills in children with CP (21). Research conducted by Hioka et al (22) and Oostra, Oomen (23) involving stroke patients demonstrated that mirror therapy can significantly boost motor function in the lower limbs. These findings support the therapeutic potential of mirror neuron-based interventions in post-stroke rehabilitation, particularly for improving mobility and muscle coordination (22, 23).

In general, several hypotheses explain how mirror therapy affects movement. For instance, mirror therapy employs mechanisms related to the primary motor cortex and the mirror nerve system; bilateral movements of the limbs during mirror therapy can also improve movement, since bilateral movements can affect the motor pathways of the affected side through the healthy hemisphere and stimulate more of the affected side pathways (24-26). Mirror neurons are a distinct class of neurons located in various regions of the cerebral cortex, including the inferior parietal lobe, inferior frontal gyrus, posterior parietal cortex, superior temporal areas, parietal fissure, and the central portion of the insular cortex. These neurons are known for their role in linking visual perception with motor execution, especially in the context of observed and performed actions. It has been suggested that the primary trigger for this network to get activated is for the individual to perform, see, or imagine a specific action; that is, whether we perform a movement or watch a movement, mirror neurons are likely to be activated in the brain (27). Margrett et al (28) found that mirror neuron networks in the parietal and frontal regions are instrumental in muscle sequencing and coordination. They are generally regarded as a key component in "skills," and these networks are activated in treatments such as mirror therapy. They are naturally utilized in tasks such as walking that require a great deal of coordination (28).

This study faced some limitations, including the lack of previous appropriate and valid studies, the small size of the statistical population, which makes it difficult to generalize the results to the target population, and the use of a larger statistical population which could result in more accurate clinical judgment. The presence of children with low attention spans made it challenging to undertake the intervention for the desired period. The lack of re-evaluation after the secondary assessment also prevents measuring the effect of time on the results. Finally, future studies should use task-based training programs in mirror therapy rather than simple motor tasks.

5. Conclusion

Mirror therapy is a simple, low-cost, accessible, and safe treatment. Overall, based on the present study results, it can be stated that incorporating mirror therapy alongside conventional rehabilitation approaches may enhance gait function in children diagnosed with hemiplegic CP. Nevertheless, due to the small sample size, these results should be interpreted with caution, and further research involving larger, well-controlled clinical trials is recommended to substantiate these outcomes.

6. Declarations

6.1 Acknowledgments

The authors would like to acknowledge all participants who volunteered to participate and helped in conducting this research.

6.2 Ethical Considerations

This study was approved by the Ethical Committee of Shahid Beheshti University of Medical Sciences under the code IR.SBMU.RETECH.REC.1399.1382 and was registered in the clinical trial registry with the code IRCT20211106052977N1.

6.3 Authors' Contributions

Conceptualization and methodology: R. A. K; intervention and data Analysis: J.A; writing-original draft and writing-review, and editing: R. A. K and J.A. All authors participated in reviewing the manuscript and its revision, and they were involved in research, interpretation, and finalizing the manuscript.

6.4 Conflict of Interest

The authors report no conflict of interest.

6.5 Fund or Financial Support

This research received no external funding.

6.6 Using Artificial Intelligence Tools (AI Tools)

The authors were not utilized AI Tools.

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