International Journal of Health Sciences
Available online at www.sciencescholar.us
E-ISSN: 2550-696X
Int. J. of Health Sci.
DOI: 10.53730

How to Cite:
Iqra, I., Anwar, S., Riaz, F., & Khalid, S. (2025). Effects of Upper Limb Children Action-Observation Training (UP-CAT) with and without visual feedback in children with cerebral palsy. *International Journal of Health Sciences*, *9*(S1), 643–657. https://doi.org/10.53730/ijhs.v9nS1.15824

Effects of Upper Limb Children Action-Observation Training (UP-CAT) with and without visual feedback in children with cerebral palsy

Iqra
Physiotherapist at Nusrat Rashid Medical Complex, Lahore
Email: Iqrafzlsulehri@gmail.com

Samra Anwar
Physical Therapist at Core Rehab Staffing
Email: piewelfareorganization@gmail.com

Faria Riaz
Physical Therapist at Angel Touch Therapy, New York, USA
Email: Fariahassan@hotmail.com

Sarah Khalid
T-DPT, BSPT, First Contact Physiotherapist, Surrey Physio, NHS South West London, United Kingdom
Email: sarah.khalid.gill@gmail.com

***Abstract*---**Cerebral palsy is broad term constituting motor disorders, functional impairments and gait disturbance. CP also causes upper limb impairments in children making them unable to perform daily life activities. Numerous rehabilitation techniques are being used for improving upper limb functions. Upper limb children action observation training is a novel, activity-based rehabilitation technique being used for upper limb impairments in children with cerebral palsy. The objective of this study is to determine the effects of upper limb children action observation training with and without visual feedback in children with cerebral palsy. This was a randomized controlled trial, non-probability sampling technique was utilized to

International Journal of Health Sciences E-ISSN 2550-696X © 2025.
Corresponding author: *Iqra, I.; Email: Iqrafzlsulehri@gmail.com*
Submitted: … , Revised: … , Accepted: 18 April 2025

gather samples. Computer randomization was used to divide patients into two groups; experimental group received upper limb children action observation training with visual feedback while control group received upper limb children action observation training only. Both groups received interventions for four weeks straight; five days a week and one hour per day. Melbourne Unilateral Upper Limb Assessment Tool and ABILHAND-kids were used for assessment. Assessment were conducted at the baseline and after four-week of treatment. The data was analyzed by using statistical software for social sciences (SPSS 25). For within statistics of MUUL assessment of Group A and group B's pre intervention mean± S.D was 51.38±20.48 and 53.84±22.29 respectively while post intervention for group A and Group B's mean± S.D was 104.61±13.07 and 84.89±23.89 respectively with p value of .000. For within statistics of ABILHAND-kids assessment of group A's Z value was -3.11 and p value .002 and group B's Z value was -3.183 and p value was .002. Between group studies of pre intervention MUUL assessment, p value was .772 and after intervention p value was .000. Pre intervention ABILHAND-kids Z value was -1.631 and p value was .103 while post intervention Z value was -4.089 and p value was .000. Both groups showed improvements in upper limb functions but upper limb children action observation training combined with visual feedback resulted in more significant improvements.

***Keywords*---**Activities of daily living, Cerebral palsy, Rehabilitation, Upper extremity.

Introduction

Cerebral palsy (CP) encompasses a wide range of motor disorders resulting from early brain injury, affecting movement, posture, and muscle tone (2). The term was first introduced 170 years ago by British orthopedic surgeon William Little (1). The incidence of CP in industrialized countries is about 1.4–1.8 per 1000 live births, while in middle-income regions it ranges from 2.95–3.4 per 1000 (3). Along with movement abnormalities, CP is often associated with cognitive, behavioral, visual, and speech impairments (4). Risk factors are classified as pre-conceptional, prenatal, perinatal, neonatal, and infant-related (5). Common causes include periventricular leukomalacia, intracranial hemorrhage, infection, hydrocephalus, neonatal stroke, chromosomal defects, and brain malformations (6). Depending on brain injury site, CP is classified as spastic, dyskinetic, or ataxic (9). Based on limb involvement, it is further divided into quadriplegic, diplegic, hemiplegic, and monoplegic types (1). Diplegia is most prevalent, followed by hemiplegia (20–30%) and quadriplegia (10–15%) (7). Children with hemiplegic CP often experience reduced quality of life (11), upper limb dysfunction, and spastic movement patterns that hinder daily tasks and self-care (12). Around 60% of children with CP have impaired hand function (14). Sensory deficits, including impaired tactile and proprioceptive functions, and visual problems further affect motor performance (16). The primary goal of management is to enhance independence, communication, and participation in daily activities (15). CP treatment is multidimensional, emphasizing motor rehabilitation tailored to each child. It is grounded in neuroplasticity, the brain's ability to reorganize and adapt structurally and functionally to stimuli (1). Key objectives include improving posture, movement, coordination, upper limb use, and gait (19). Unilateral spastic CP particularly affects bimanual coordination and sensorimotor integration, limiting performance of activities of daily living (ADLs) (20). The ICF model provides a framework for understanding impairment, activity limitation, and participation restriction (18). Motor and sensory impairments contribute to weak grip, low dexterity, and decreased movement velocity in the affected limb (21). Bimanual therapy involves repetitive use of both hands during functional tasks and is effective for improving coordination in unilateral CP (22). Since most ADLs require bimanual use, poor unimanual performance leads to difficulty in everyday activities (21). As CP has no cure, therapy focuses on symptom control, prevention of secondary complications, and functional enhancement (23). Engagement, motivation, and goal setting with families play a crucial role in improving outcomes (24). Common interventions include neuromuscular stimulation, botulinum toxin injections, occupational therapy, and orthoses, all targeting functional independence (18). Goal-directed therapies such as constraint-induced movement therapy (CIMT), hand-arm bimanual intensive therapy (HABIT), and action observation therapy (AOT) have shown promise in improving upper limb function (25). CIMT involves restricting the unaffected limb to encourage intensive use of the affected side, strengthening motor ability in unilateral spastic CP (8, 27). Bobath or neurodevelopmental therapy (NDT), though widely used, is considered less effective than task-oriented approaches but remains common in "usual care" (28, 29). Assistive technologies like virtual reality (VR) have emerged as engaging, effective tools for enhancing motor skills in children through interactive games (30). Video game–based therapy (VGBT) further increases motivation and allows personalized, immersive rehabilitation (23, 32). Transcranial direct current stimulation (tDCS) is another promising non-invasive technique that uses mild brain stimulation to enhance motor training effects (31). Combinations such as intramuscular BoNT-A injections with orthotics and motor training effectively reduce spasticity and improve upper limb function (33). Additionally, core stability exercises targeting deep trunk muscles support posture and upper limb control, facilitating manual dexterity (34). Robot-assisted interventions are gaining popularity in pediatric rehabilitation. Devices such as the Hybrid Assistive Limb (HAL) support desired upper limb movements and help restore motor control (35). AOT is based on activation of the mirror neuron system, involving regions such as the inferior parietal lobule, inferior frontal gyrus, and superior temporal sulcus, which facilitate motor learning through observation and imitation (36–38). The Upper Limb Children Action Observation Training (UP-CAT) is a recent adaptation designed for pediatric CP rehabilitation (39). Similarly, mirror therapy (MT) uses visual illusion—reflecting the unaffected limb's movement—to stimulate the motor cortex and encourage use of the affected hand (40). MT is simple, cost-effective, and non-invasive, making it ideal for routine home-based rehabilitation (41). In recent years, numerous studies have explored the principles and clinical applications of Action Observation Therapy (AOT) for upper limb rehabilitation in children with cerebral palsy (CP). In June 2023, E. Beani et al. conducted a randomized controlled trial titled "Effectiveness of the Home-Based Training Program Tele-UPCAT", which implemented telemonitored AOT for unilateral CP. Thirty children were assigned to two groups and received individualized, home-based therapy for three weeks, five days per week. Evaluations at baseline, 3, 8, and 24 weeks demonstrated significant improvement in goal-directed upper limb skills (42). In the same year, von Gunten et al. published "Action Observation Training to Improve Upper Limb Function in Infants with Unilateral Brain Lesion". This feasibility study on eight children with spastic CP used home-based AOT combined with motion sensors, revealing its potential to objectively record and enhance upper limb performance (43). In 2022, Errante et al. examined AOT using virtual reality (VR) for motor rehabilitation in pediatric stroke patients. Forty-seven children aged 3–18 months received VR-based AOT, with assessments up to six months post-treatment. The combination enhanced engagement and treatment effectiveness (44). Similarly, Borges et al. conducted a Cochrane systematic review including 16 RCTs (574 participants) and reported significant post-AOT improvements in hand function (45). Sadek et al. explored mirror therapy in 50 children with unilateral CP (aged 6–12 years) over 12 weeks, finding sustained improvement in hand activity after six months (46). A meta-analysis by Allen (2022) compared AOT and constraint-induced movement therapy (CIMT), concluding that CIMT produced superior functional outcomes in CP children (47). Shamili et al. (2021) demonstrated AOT's effectiveness in a 58-year-old stroke patient, highlighting improved upper limb function after therapist-led and self-administered AOT (48). Earlier, Jung et al. (2020) combined AOT with whole-body vibration (WBV) to enhance gross motor function, balance, and gait in children with spastic CP, showing greater improvements than WBV alone (49). Narimani et al. (2019) evaluated mirror therapy combined with occupational therapy in 30 hemiplegic CP children and found positive effects on dexterity and grasp strength (50). G. Sgandurra et al. (2018) introduced the Tele-UPCAT protocol for home-based AOT, reporting encouraging outcomes in promoting goal-directed motor learning and upper limb function in unilateral CP (51). Despite strong evidence supporting UP-CAT and related AOT methods, there remains limited documentation on their combined effects with visual feedback, which may further enhance self-awareness and motor learning. Thus, the present study aims to investigate Upper Limb Children Action Observation Training with and without visual feedback in children with cerebral palsy.

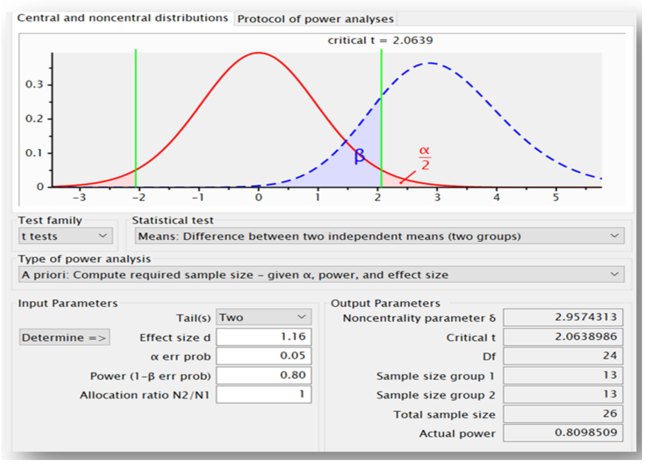
Material and Methods

Study Design

This study was a randomized controlled trial (RCT) registered under trial number NCT06198179.

Sample Size & Sampling Technique

Sample size was calculated using G*Power software, yielding 26 participants. After adding a 10% attrition rate, the total sample size was 28 (13). The calculation used an effect size of 1.16 from a previous study, with a significance level of 0.05 and 80% power. A non-probability purposive sampling technique was used.



Study Setting & Duration
The study was conducted at the Physiotherapy Department of DHQ Hospital, Narowal. The study was completed within six months following approval from the Board of Advanced Studies and Research (BASR).

Sample Selection

Inclusion Criteria
Participants were children with

1. Hemiplegic cerebral palsy (25)
2. Age 5–15 years, both genders included
3. Spasticity graded +1 on the Modified Ashworth Scale
4. House Functional Classification System (HFCS) score of 4–8, indicating moderate upper limb impairment (52)

Exclusion Criteria
Children were excluded if they had

1. Other neurological deficits
2. Visual impairments (15)
3. Upper limb disabilities unrelated to hemiplegic CP
4. Uncontrolled epileptic seizures in the past three years
5. Non-cooperative behavior (15)
6. Recent BoNT-A injection or orthopedic surgery in the last six months (8, 39, 52)

Screening Tools

House Functional Classification System (HFCS):
A reliable tool to assess bimanual upper limb use in children with CP, rated on a 9-point scale from nonuse to independent use. It shows excellent interrater (ICC = 0.94) and intrarater (ICC = 0.92) reliability (51).

Assessment Tools

Melbourne Assessment of Unilateral Upper Limb Function (MUUL):
Used to assess unilateral motor function in children aged 5–15 years. It includes 16 items on a 3–5-point ordinal scale, covering reach, grasp, release, and manipulation. Scores (0–122) are converted to percentages, with excellent reliability (ICC = 0.97) (25).

ABILHAND-Kids Questionnaire:
A parent-reported measure assessing bimanual daily activities in children aged 6–15 years. It contains 21 items scored on a 3-point scale (impossible–difficult–easy). It has strong reliability (R = 0.94) and repeatability (R = 0.91) (25).

Data Collection Procedure

Participants were recruited using purposive sampling and screened using the HFCS for eligibility. After obtaining informed consent from parents or guardians, participants were randomly allocated into two groups using computerized randomization:
Group A: UP-CAT with visual feedback (experimental)
Group B: UP-CAT without visual feedback (control)
Each child received 1-hour sessions, 5 days per week for 4 weeks. Assessments were conducted at baseline and after 4 weeks using MUUL and ABILHAND-Kids tools.

Recruitment & Randomization

Eligible participants were enrolled post-consent and equally assigned to both groups. A computerized randomization process was applied to ensure equal distribution.

Blindness

This was a single-blinded trial where the assessor remained blinded to group allocation.

Intervention

Group A (Experimental Group – UP-CAT with Visual Feedback)
Following baseline evaluation, participants underwent Upper Limb Children Action Observation Training (UP-CAT) with mirror-based visual feedback. Sessions lasted 1 hour, involving 15 functional tasks of increasing complexity — the first 8 unimanual and the next 7 bimanual. Each task consisted of a 2-minute observation phase followed by 2 minutes of execution, totaling 4 minutes per task. Children performed actions while watching themselves in a mirror for feedback. The therapist supervised and assisted when necessary (51). Activities included tasks like tossing coins, manipulating blocks, pouring water, sorting colored cards, folding cloth, making clay shapes, and decorating papers. Tasks were stratified into three levels of difficulty (1–3) according to each child's capability, emphasizing gradual progression in both unimanual and bimanual coordination.

Group B (Control Group – UP-CAT without Visual Feedback)

Participants performed the same 15 structured activities as Group A, following identical timing and supervision, but without mirror feedback. Each child watched pre-recorded action videos for 2 minutes, then replicated the activity for 2 minutes. The therapist monitored the child's performance closely (51). Activities followed the same three difficulty levels and progression pattern as in Group A.

Data Analysis Procedure

Data were analyzed using SPSS version 25. Descriptive statistics (mean, standard deviation, percentages) were used for demographic variables. Normality was assessed through the Shapiro–Wilk test. For normally distributed data (MUUL), parametric tests were applied: Independent t-test for between-group comparisons, Paired t-test for within-group analyses. For non-normally distributed data (ABILHAND-Kids), non-parametric tests were used: Mann–Whitney U test for between-group comparisons, Wilcoxon Signed Rank test for within-group changes. A p-value < 0.05 was considered statistically significant.

Results & Discussion

Results

A total of 26 children with hemiplegic cerebral palsy participated in the study, comprising 11 males and 15 females. Participants were equally divided into two groups: Group A (experimental) receiving upper limb children action-observation training (UP-CAT) with visual feedback, and Group B (control) receiving UP-CAT without visual feedback. The mean age of participants in both groups was 8.30 ± 2.98 years for Group A and 8.30 ± 2.13 years for Group B, with an overall age range of 5–13 years. Gender distribution showed 6 males and 7 females in Group A, while Group B included 5 males and 8 females. The Shapiro–Wilk test of normality indicated that data for the Melbourne Assessment of Unilateral Upper Limb Function (MUUL) were normally distributed (p = 0.793 > 0.05), whereas the ABILHAND-Kids data were not normally distributed (p = 0.000 < 0.05). Therefore, parametric tests were applied for MUUL and non-parametric tests for ABILHAND-Kids. For within-group analysis, the paired sample t-test was used for MUUL outcomes. Group A showed a pre-intervention mean ± SD of 51.38 ± 20.48 and post-intervention mean ± SD of 104.61 ± 13.07, indicating a statistically significant improvement (p = 0.000). Similarly, Group B showed pre-intervention mean ± SD of 53.84 ± 22.29 and post-intervention mean ± SD of 84.89 ± 23.89, also statistically significant (p = 0.000). These findings demonstrate that both interventions improved upper limb function within their respective groups. For ABILHAND-Kids, the Wilcoxon Signed Rank Test was applied due to non-normal data distribution. Group A demonstrated a sum of ranks = 90, Z = –3.111, and p = 0.002, while Group B showed sum of ranks = 91, Z = –3.183, and p = 0.001, confirming a statistically significant difference within both groups after intervention. For between-group comparisons, the independent t-test and Mann–Whitney test were applied to assess post-treatment differences. In MUUL assessment, there was no significant difference between groups before treatment (p = 0.772), indicating comparable baseline scores. However, after four weeks of therapy, the post-intervention mean score of Group A (104.61 ± 13.07) was significantly higher than that of Group B (84.89 ± 23.89), with p = 0.015, confirming that UP-CAT with visual feedback produced superior outcomes. For

ABILHAND-Kids, the Mann–Whitney test revealed that pre-intervention scores were not significantly different (Z = –1.631, p = 0.103), while post-intervention scores showed a highly significant improvement in the experimental group (Z = –4.089, p = 0.000). The mean rank of Group A increased from 15.92 to 19.38, compared to Group B, which decreased from 11.08 to 7.62, indicating that bimanual task performance improved more substantially in the group that received visual feedback.

Table 1 Descriptive statistics of Age

Group name		**N**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Age in years	**Group A**	13	5	13	8.307	2.982
	Group B	13	6	13	8.307	2.136

Table 2 Descriptive statistics of Gender

Groups		**Frequency**	**Percentage**
Group A	**Male**	6	23.07%
	Female	7	26.92%
Group B	**Male**	5	19.23%
	Female	8	30.76%
Total		26	100

Table 3 Shapiro-Wilk test for Normality

Variables	**Statistics**	**df**	**Sig.**
preMUUL	.977	26	.793
preABILHAND-kids	.325	26	.000

Table 4 paired sample T test

Variables	**Groups**	**N**	**Mean**	**Std. deviation**	**p value**
Pre intervention MUUL	**Group A**	13	51.384	20.483	.000
	Group B	13	53.846	22.296	.000
Post intervention MUUL	**Group A**	13	104.615	13.073	.000
	Group B	13	84.461	23.890	.000

Table 5 Wilcoxon signed rank test

Groups	**Variables**	**N**	**Mean ranks**	**Sum of ranks**	**Z value**	**p value**
Experimental group	**preABILHAND-kids-postABILHAND-**	13	7.50	90	-3.111	.002

Groups	Variables	N	Mean ranks	Sum of ranks	Z value	p value
	kids					
Control group	**PreABILHAND-kids-postABILHAND-kids**	13	7	91	-3.183	.001

Table 6 Independent t Test for MUUL assessment

Variables	Groups	N	Mean	Std.Deviation	p value
Pre-intervention MUUL assessment	**Group A**	13	51.384	20.483	.772
	Group B	13	53.846	22.296	
Post-intervention MUUL assessment	**Group A**	13	104.615	13.073	.015
	Group B	13	84.890	23.890	

Table 7 M**ann-Whitney Test for ABILHAND-kids assessment**

Variables	Groups	N	Mean ranks	Sum of ranks	Z value	p value
Pre-intervention ABILHAND-kids	**Group A**	13	15.92	207	-1.631	.103
	Group B	13	11.08	144		
Post intervention ABILHAND-kids	**Group A**	13	19.38	252	-4.089	.000
	Group B	13	7.62	99		

Discussion

Within the context of this randomized controlled trial, individuals were assigned to either the experimental group (Group A) or the control group (Group B) by a random selection process. The interventions were administered to each group for a total of twenty days, with two days of evaluation occurring at the beginning and the conclusion of the treatment programme. One hour of therapy was provided to each of the two groups on a daily basis. During each session, each patient participated in a total of 15 exercises, which included 8 unimanual tasks and 7 bimanual activities. Patients who were part of the experimental or Group A received visual feedback while they were participating in the training session. The purpose of this research was to investigate the effects of engaging in upper limb action observation training (UP-CAT) in children with cerebral palsy, both with and without the provision of visual feedback. Within the context of the rehabilitation of the upper limb in children who have cerebral palsy, the data analysis of this study indicated that upper limb children action observation training (UP-CAT) displayed more promising outcomes when paired with visual feedback. The results of this study suggest that action observation training for children with upper limbs that includes visual feedback may have potential benefits in terms of enhancing upper limb functions, particularly fine motor abilities. Patients were also motivated to attain a certain function through the use of visual feedback, which played a certain role. According to earlier research, children with cerebral palsy benefit from upper limb children action observation training (UP-CAT) in terms of increased upper limb functioning. All studies based on action observation training or treatment carried out between 2010 and 2020 were gathered in this study, which is a notable systematic evaluation of randomized controlled trials of action observation training. 2507 papers were initially included in the evaluation; however, duplicates were removed, leaving 9 randomized controlled trials with 234 individuals. The duration of treatments was the same for both the control and experimental groups in every study. Each training session lasted anywhere from 20 to 60 minutes. The end result of this randomized experiment demonstrated the usefulness of action observation training/therapy, which was found in 7 out of 9 papers, in encouraging activities and involvement in children with unilateral cerebral palsy. This study supported the idea that children with hemiplegic cerebral palsy can benefit from action observation training to improve their motor function (25). Current study showed that upper limb children action observation training combined with visual feedback give potential benefits for upper limb impairments in cerebral palsy children.

Previous studies investigated the effects of action observation training on the stiffness, gross motor function, and balance of children who were diagnosed with cerebral palsy. Studies conducted in the past have consistently demonstrated that children with cerebral palsy (CP) have statistically significant improvements in their balance and gross motor abilities respectively (53). In the context of cerebral palsy treatment, there has been a limited amount of research conducted on upper limb children action observation training (UP-CAT). Both the previous research and the action observation training for children with upper limbs are based on the same idea, but the outcomes of the two sets of investigation are different. Moreover, numerous studies are conducted on the upper limb rehabilitation in cerebral palsy; one of them is by Bingol et al,. (11); in order to find out how the two activity-based rehabilitation approaches affect children with cerebral palsy's upper limb training, they compare them. For a 10-week intervention program, they enrolled thirty children with hemiplegic cerebral palsy, aged seven to eleven. When comparing bimanual intensive movement therapy (BIM) with modified constraint induced movement therapy (mCIMT) for upper limb rehabilitation, they discovered that both treatments were statistically significant. This study added literature for activity based therapy protocol specifically upper limb. Further researchers identified 15 different interventions for cerebral palsy rehabilitation. According to this study constraint induced therapy (CIMT) is statistically significant but NDT is ineffective (54). With advancement in technology, rehabilitation techniques also being advanced in technology and virtual reality based rehabilitation is one example. Goyal et al,. investigated different modes of virtual reality for upper limb rehabilitation (55). In this study, therapy protocol was activity based and it was more engaging due to visual feedback and children did not lost interest and urged to complete treatment. Action observation therapy is adapted for use with children in upper limbs. In order to find out how constraint-induced movement therapy and action observation treatment affected the upper limb kinematics of people with cerebral palsy, Simon-Martinez et al. carried out a randomized controlled experiment. Thirty-six kids were divided into two groups. The experimental group had 15 hours of action observation treatment from mCIMT. They watched films and carried out single-handed chores. They came to the conclusion that the benefits of constraint-induced movement treatment combined with action observation therapy on upper limb kinematics were minimal (52). But in this study unimanual as well as bimanual activities were performed by both groups and outcomes showed potential benefits of upper limb children action observation training on upper limb functions. In previous studies conducted, there is a lot of literature available on action observation therapy but there is limited literature available on upper limb children action observation training (UP-CAT) particularly.

Conclusion

Both groups showed improvements in upper limb functions but upper limb children action observation training combined with visual feedback resulted in more significant improvements.

References

1. Sadowska M, Sarecka-Hujar B, Kopyta I. Cerebral palsy: current opinions on definition, epidemiology, risk factors, classification and treatment options. Neuropsychiatric disease and treatment. 2020:1505-18.
2. Patel DR, Neelakantan M, Pandher K, Merrick J. Cerebral palsy in children: a clinical overview. Translational pediatrics. 2020;9(Suppl 1):S125.
3. Jackman M, Sakzewski L, Morgan C, Boyd RN, Brennan SE, Langdon K, et al. Interventions to improve physical function for children and young people with cerebral palsy: international clinical practice guideline. Developmental Medicine & Child Neurology. 2022;64(5):536-49.
4. Vadivelan K, Sekar P, Sruthi SS, Gopichandran V. Burden of caregivers of children with cerebral palsy: an intersectional analysis of gender, poverty, stigma, and public policy. BMC public health. 2020;20:1-8.
5. Sadowska M, Sarecka-Hujar B, Kopyta I. Analysis of selected risk factors depending on the type of cerebral palsy. Brain Sciences. 2021;11(11):1448.
6. Metz C, Jaster M, Walch E, Sarpong-Bengelsdorf A, Kaindl AM, Schneider J. Clinical phenotype of cerebral palsy depends on the cause: Is it really cerebral palsy? A retrospective study. Journal of Child Neurology. 2022;37(2):112-8.
7. Paul S, Nahar A, Bhagawati M, Kunwar AJ. A Review on Recent Advances of Cerebral Palsy. Oxidative Medicine and Cellular Longevity. 2022;2022:2622310.
8. Simon-Martinez C, Mailleux L, Hoskens J, Ortibus E, Jaspers E, Wenderoth N, et al. Randomized controlled trial combining constraint-induced movement therapy and action-observation training in unilateral cerebral palsy: clinical effects and influencing factors of treatment response. Therapeutic advances in neurological disorders. 2020;13:1756286419898065.

9. Kamate M, Detroja M. Which is the Most Common Physiologic Type of Cerebral Palsy? Neurology India. 2022;70(3):1048-51.
10. Pavone P, Gulizia C, Le Pira A, Greco F, Parisi P, Di Cara G, et al. Cerebral palsy and epilepsy in children: clinical perspectives on a common comorbidity. Children. 2020;8(1):16.
11. Bingol H, Kerem Gunel M, Alkan H. The efficacy of two models of intensive upper limb training on health-related quality of life in children with hemiplegic cerebral palsy mainstreamed in regular schools: a double-blinded, randomized controlled trial. Physiotherapy Theory and Practice. 2023;39(1):10-25.
12. Bingol H, Gunel MK. The effects of hand deformity on upper-limb function and health-related quality of life in children with spastic hemiplegic cerebral palsy. Hand Surgery and Rehabilitation. 2021;40(6):722-8.
13. Dequeker G, Mailleux L. Upper limb rehabilitation in children with unilateral cerebral palsy. Belgian Journal of Paediatrics. 2021;23(1):44-7.
14. Plasschaert VF, Vriezekolk JE, Aarts PB, Geurts AC, Van den Ende CH. Interventions to improve upper limb function for children with bilateral cerebral palsy: a systematic review. Developmental Medicine & Child Neurology. 2019;61(8):899-907.
15. Nuara A, Avanzini P, Rizzolatti G, Fabbri-Destro M. Efficacy of a home-based platform for child-to-child interaction on hand motor function in unilateral cerebral palsy. Developmental Medicine & Child Neurology. 2019;61(11):1314-22.
16. Poitras I, Martinie O, Robert MT, Campeau-Lecours A, Mercier C. Impact of sensory deficits on upper limb motor performance in individuals with cerebral palsy: a systematic review. Brain sciences. 2021;11(6):744.
17. SARI DM, Tuğba K. Upper limb training using visual feedback for children with cerebral palsy. Journal of Exercise Therapy and Rehabilitation. 2022;9(3):179-88.
18. Park H, Choi JY, Yi S-h, Park ES, Shim D, Choi TY, et al. Relationship between the more-affected upper limb function and daily activity performance in children with cerebral palsy: a cross-sectional study. BMC pediatrics. 2021;21(1):1-8.
19. Ökmen BM, Aslan MD, Yüzer GFN, Özgirgin N. Effect of virtual reality therapy on functional development in children with cerebral palsy: A single-blind, prospective, randomized-controlled study. Turkish journal of physical medicine and rehabilitation. 2019;65(4):371.
20. Robert MT, Gutterman J, Ferre CL, Chin K, Brandao MB, Gordon AM, et al. Corpus callosum integrity relates to improvement of upper-extremity function following intensive rehabilitation in children with unilateral spastic cerebral palsy. Neurorehabilitation and neural repair. 2021;35(6):534-44.
21. Ortega-Martínez A, Palomo-Carrión R, Varela-Ferro C, Bagur-Calafat MC. Feasibility of a Home-Based Mirror Therapy Program in Children with Unilateral Spastic Cerebral Palsy. Healthcare (Basel, Switzerland). 2023;11(12).
22. Ouyang R-G, Yang C-N, Qu Y-L, Koduri MP, Chien C-W. Effectiveness of hand-arm bimanual intensive training on upper extremity function in children with cerebral palsy: A systematic review. European Journal of Paediatric Neurology. 2020;25:17-28.

23. Daoud MI, Alhusseini A, Ali MZ, Alazrai R. A game-based rehabilitation system for upper-limb cerebral palsy: a feasibility study. Sensors. 2020;20(8):2416.
24. Metzler MJ, Haspels E, Brunton L, Andersen J, Pritchard L, Herrero M, et al. Goals of children with unilateral cerebral palsy in a brain stimulation arm rehabilitation trial. Developmental Medicine & Child Neurology. 2021;63(5):584-91.
25. Alamer A, Melese H, Adugna B. Effectiveness of action observation training on upper limb motor function in children with hemiplegic cerebral palsy: a systematic review of randomized controlled trials. Pediatric health, medicine and therapeutics. 2020:335-46.
26. Buchignani B, Beani E, Pomeroy V, Iacono O, Sicola E, Perazza S, et al. Action observation training for rehabilitation in brain injuries: a systematic review and meta-analysis. BMC neurology. 2019;19:1-16.
27. Shih T-Y, Wang T-N, Shieh J-Y, Lin S-Y, Ruan S-J, Tang H-H, et al. Comparative effects of kinect-based versus therapist-based constraint-induced movement therapy on motor control and daily motor function in children with unilateral cerebral palsy: a randomized control trial. Journal of NeuroEngineering and Rehabilitation. 2023;20(1):13.
28. Te Velde A, Morgan C, Finch-Edmondson M, McNamara L, McNamara M, Paton MCB, et al. Neurodevelopmental therapy for cerebral palsy: a meta-analysis. Pediatrics. 2022;149(6):e2021055061.
29. Ungureanu A, Rusu L, Rusu MR, Marin MI. Balance rehabilitation approach by bobath and vojta methods in cerebral palsy: a pilot study. Children. 2022;9(10):1481.
30. Chang HJ, Ku KH, Park YS, Park JG, Cho ES, Seo JS, et al., editors. Effects of virtual reality-based rehabilitation on upper extremity function among children with cerebral palsy. Healthcare; 2020: MDPI.
31. Gordon AM, Ferre CL, Robert MT, Chin K, Brandao M, Friel KM. HABIT+ tDCS: a study protocol of a randomised controlled trial (RCT) investigating the synergistic efficacy of hand-arm bimanual intensive therapy (HABIT) plus targeted non-invasive brain stimulation to improve upper extremity function in school-age children with unilateral cerebral palsy. BMJ open. 2022;12(2):e052409.
32. Avcil E, Tarakci D, Arman N, Tarakci E. Upper extremity rehabilitation using video games in cerebral palsy: a randomized clinical trial. Acta Neurologica Belgica. 2021;121(4):1053-60.
33. Andersson G, Renström B, Blaszczyk I, Domellöf E. Upper-extremity Spasticity-reducing Treatment in Adjunct to Movement Training and Orthoses in Children with Cerebral Palsy at Gross Motor Function-and Manual Ability Classification System Levels IV-V: A Descriptive Study. Developmental neurorehabilitation. 2020;23(6):349-58.
34. Abd-Elfattah HM, Aly SM. Effect of core stability exercises on hand functions in children with hemiplegic cerebral palsy. Annals of Rehabilitation Medicine. 2021;45(1):71-8.
35. Kuroda MM, Iwasaki N, Yoshikawa K, Takeuchi R, Mataki Y, Nakayama T, et al. Voluntary-assisted Upper Limb Training for Severe Cerebral Palsy Using Robotics Devices and Neuromuscular Electrical Stimulation: Three Case Reports. Progress in rehabilitation medicine. 2022;7:20220050.

36. Abdelhaleem N, Taher S, Mahmoud M, Hendawy A, Hamed M, Mortada H, et al. Effect of action observation therapy on motor function in children with cerebral palsy: a systematic review of randomized controlled trials with meta-analysis. Clinical rehabilitation. 2021;35(1):51-63.
37. Beani E, Menici V, Ferrari A, Cioni G, Sgandurra G. Feasibility of a home-based action observation training for children with unilateral cerebral palsy: an explorative study. Frontiers in Neurology. 2020;11:16.
38. Errante A, Di Cesare G, Pinardi C, Fasano F, Sghedoni S, Costi S, et al. Mirror neuron system activation in children with unilateral cerebral palsy during observation of actions performed by a pathological model. Neurorehabilitation and neural repair. 2019;33(6):419-31.
39. Sgandurra G, Cecchi F, Beani E, Mannari I, Maselli M, Falotico FP, et al. Tele-UPCAT: study protocol of a randomised controlled trial of a home-based Tele-monitored UPper limb Children Action observation Training for participants with unilateral cerebral palsy. BMJ open. 2021;8(5):e017819.
40. Palomo-Carrión R, Zuil-Escobar JC, Cabrera-Guerra M, Barreda-Martínez P, Martínez-Cepa CB. Mirror Therapy and Action Observation Therapy to Increase the Affected Upper Limb Functionality in Children with Hemiplegia: A Randomized Controlled Trial Protocol. International Journal of Environmental Research and Public Health. 2021;18(3):1051.
41. Mohamed R, Yousef A, Radwan N, Ibrahim M. Efficacy of different approaches on quality of upper extremity function, dexterity and grip strength in hemiplegic children: a randomized controlled study. European Review for Medical & Pharmacological Sciences. 2021;25(17).
42. Beani E, Menici V, Sicola E, Ferrari A, Feys H, Klingels K, et al. Effectiveness of the home-based training program Tele-UPCAT (Tele-monitored UPper Limb Children Action Observation Training) in unilateral cerebral palsy: a randomized controlled trial. European journal of physical and rehabilitation medicine. 2023.
43. von Gunten M, Botros A, Tobler-Ammann B, Nef T, Grunt S. Action Observation Training to Improve Upper Limb Function in Infants with Unilateral Brain Lesion–a Feasibility Study. Developmental neurorehabilitation. 2023;26(4):234-43.
44. Errante A, Saviola D, Cantoni M, Iannuzzelli K, Ziccarelli S, Togni F, et al. Effectiveness of action observation therapy based on virtual reality technology in the motor rehabilitation of paretic stroke patients: a randomized clinical trial. BMC Neurology. 2022;22(1):109.
45. Borges LR, Fernandes AB, Dos Passos JO, Rego IAO, Campos TF. Action observation for upper limb rehabilitation after stroke. Cochrane Database of Systematic Reviews. 2022(8).
46. N Sadek B, A Ali E, Attia Abdalla Abdelfattah Z, Mohamed Khalifa Ewis A, Hafez Afefe Barakat A. Effect of Mirror Intervention Program on Hand Activity, Mastery Motivation and Self-Esteem among Children with Cerebral Palsy. Egyptian Journal of Health Care. 2022;13(1):2188-203.
47. Allen J. Action Observation Therapy Compared to Constraint Induced Movement Therapy in Children with Cerebral Palsy: A Meta-Analysis: California State University, Fresno; 2022.
48. Shamili A, Mehraban AH, Azad A, Raissi GR, Shati M, Farajzadeh A. Effectiveness of Self-Action Observation Therapy as a Novel Method on

Paretic Upper Limb and Cortical Excitability Post-Stroke: A Single-Subject Study. Medical Journal of the Islamic Republic of Iran. 2021;35.
49. Jung Y, Chung E-J, Chun H-L, Lee B-H. Effects of whole-body vibration combined with action observation on gross motor function, balance, and gait in children with spastic cerebral palsy: a preliminary study. Journal of exercise rehabilitation. 2020;16(3):249.
50. Narimani A, Kalantari M, Dalvand H, Tabatabaee SM. Effect of Mirror Therapy on Dexterity and Hand Grasp in Children Aged 9-14 Years with Hemiplegic Cerebral Palsy. Iranian journal of child neurology. 2019;13(4):135-42.
51. Sgandurra G, Cecchi F, Beani E, Mannari I, Maselli M, Falotico FP, et al. Tele-UPCAT: study protocol of a randomised controlled trial of a home-based Tele-monitored UPper limb Children Action observation Training for participants with unilateral cerebral palsy. BMJ Open. 2018;8(5):e017819.
52. Simon-Martinez C, Mailleux L, Jaspers E, Ortibus E, Desloovere K, Klingels K, et al. Effects of combining constraint-induced movement therapy and action-observation training on upper limb kinematics in children with unilateral cerebral palsy: a randomized controlled trial. Scientific Reports. 2020;10(1):10421.
53. Jeong Y-a, Lee B-H. Effect of action observation training on spasticity, gross motor function, and balance in children with diplegia cerebral palsy. Children. 2020;7(6):64.
54. Das SP, Ganesh GS. Evidence-based approach to physical therapy in cerebral palsy. Indian journal of orthopaedics. 2019;53:20-34.
55. Goyal C, Vardhan V, Naqvi W, Naqvi WM. Virtual reality-based intervention for enhancing upper extremity function in children with hemiplegic cerebral palsy: a literature review. Cureus. 2022;14(1).