Scientific e-journal
EDUCATION. INNOVATION. DIVERSITY (EID)

VIRTUAL REALITY AS A TRAINING TOOL IMPACT ON UPPER EXTREMITY FUNCTION IN CHILDREN WITH CEREBRAL PALSY: SYSTEMATIC REVIEW

Marta Mezaraupa[1], Linda Jamonte[2], Undine Ceire[3]
[1] Gulbene Hospital, Latvia
[2] National Rehabilitation Center Vaivari, Latvia
[3] Children's Clinical University Hospital, Latvia

Abstract. *Approximately half of children with cerebral palsy (CP) may sustain dysfunctions in upper-extremity activities, such as reaching, grasping, and manipulation. Moreover, several children with CP experience tightness or weakness in their arms and hand muscles, which can lead to difficulty performing daily tasks such as dressing, feeding, performing in school, playing, or academic tasks such as writing. These limitations can lead to reduced health-related quality of life. Growing interest has been developing interventions for children with CP based on assistive technology like virtual reality (VR). VR-based systems in children with CP mostly focus on the lower extremities and ambulation (e.g., walking activity, balance, gait and gross motor skills). However, new treatment approaches are needed to improve upper extremity functions. This systematic review aimed to determine if VR technology as a training tool can increase upper extremity function for children with Cerebral palsy. This review followed the PRISMA guidelines and a literature search in six electronic databases was carried out from November 2021 to May 2024. The quality of the research was assessed by using the PEDRO scale. The findings show that using VR technology as a rehabilitation tool improves upper extremity function. Conventional therapy can be replaced with VR-based therapy, but more randomized and specific studies on the subject are needed in the future.*

Keywords: *Cerebral palsy, children, Virtual reality, upper extremity function, upper limb function*

To cite this article:
Mezaraupa, M., Jamonte, L., & Ceire, U. (2024). Virtual Reality as a Training Tool Impact on Upper Extremity Function in Children with Cerebral Palsy: Systematic Review. *Education. Innovation. Diversity, 1*(8), 154 - 166.
DOI: https://doi.org/10.17770/eid2024.1.7937

Introduction

Cerebral palsy (CP) is a category of non-progressive neurological disorders that permanently affect sensory-motor capabilities in infancy or early childhood (Ravi, Kumar, & Singhi, 2017). CP refers to a group of disorders that affect a person's ability to move and maintain balance and posture. CP is the most common motor disability in childhood (CDC, 2024). The prevalence of CP over the last 40 years is estimated to have increased from 1.5 to 2.5 per 1000 new-borns (Fandim, Saragiotto, Porfírio, & Santana, 2021).

The child with CP's functioning is affected by various neuromuscular and musculoskeletal impairments. Besides motor functioning, cerebral palsy also affects cognitive, affective, and behavioural performances (Ravi et al., 2017).

Approximately half of children with CP may sustain dysfunctions in upper-extremity activities, such as reaching, grasping, and manipulation. Moreover, several children with CP experience tightness or weakness in their arms and hand muscles, which can lead to structural changes resulting in long-term difficulty in performing day-to-day tasks, such as dressing, feeding, performing in school, and playing, as well as reduced health-related quality of life (Chang et al., 2020, Tonmukayakul et al., 2020). Regarding academic performance, handwriting is often challenging in children with CP and upper-limb issues due to poor visuoconstructive skills, impaired finger sensation, and difficulty coordinating both hands.

These difficulties, seen even in milder cases like unilateral CP, can lead to fatigue and frustration (Fluss & Lidzba, 2020).

Research shows that the more motor functions are affected, the greater the difficulties a child has in participating in the learning process at school. Considering the importance of the philosophy of “inclusive education” and its integration into the education system, schools should consider involving professionals from other fields in the educational system, providing mutual consultation and special training, and adapting the environment for working with children with CP (Netto et al., 2020). The inclusion of healthcare specialists has a significant positive effect on children's physical development and academic performance, and improving health outcomes, school health programs can also improve children's education outcomes as well (Hasan, 2020).

Growing interest has been in developing interventions for children with CP based on assistive technology. One such area of interest is the use of virtual reality (VR) in developing functional independence of motor skills.

VR is defined as “the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real-world objects and events” (Chen, Lee, & Howard, 2014). The sessions are provided through a computer-simulated environment where they interact with real-world-like objects and events through sight, sound, smell, and touch. VR technologies vary greatly in terms of immersion, cost, and complexity (Ravi et al., 2017).

VR is a widespread tool in various fields nowadays and rehabilitation, research and assessment are some of them. Use of VR systems can boost motivation due to the variety and novelty of virtual therapy and exercise systems. Additionally, gamification can enhance the fun factor and create new incentives for clients, elevate the self-efficacy, volition, and playfulness. Other benefits of VR systems include the ability to create therapeutic scenarios that are difficult to achieve in the real world, tailor therapy tasks to individual patients, and use the system at home or in different environments, thereby reducing the workload of healthcare professionals (Bateni, Carruthers, Mohan & Pishva, 2024; Reid, 2002). The success of the training process depends on several factors: intensity, repetition, and a goal-oriented and task-specific training program, which are nowadays considered essential in achieving a favourable motor outcome. However, rehabilitation programs tailored to the special needs of an individual child are personnel intensive and, therefore, expensive. Often, limited resources hinder the achievement of optimal therapy conditions and limit the dosages of rehabilitation measures (Chen et al., 2014).

It is also worth noting that the use of the engineer-built system is found to be more effective than using the commercial system. The explanation is that the engineer-built system can meet the children's needs by better-adjusting game difficulty and training goals. On the contrary, commercial systems are restricted to predetermined task difficulties, which are typically too difficult for children with CP. However, the cost of building an engineer-built VR system is generally much higher than that of a commercially available system (Chen et al., 2014).

Numerous studies have explored the use of VR for patient groups like stroke patients, individuals with Parkinson's disease or multiple sclerosis (Bateni, Carruthers, Mohan & Pishva, 2024). Rehabilitation methods using VR based systems in children with CP have mostly focused on gait training, balance and mobility skills, the lower extremity and ambulation, however, new treatment approaches are needed to improve upper extremity functions (Reid, 2002; Fandim, Saragiotto, Porfírio, & Santana, 2021).

The aim of this study was to evaluate the effectiveness of virtual reality as a training tool for improving upper extremity function in children with cerebral palsy, compared to conventional therapy or pre-and post-intervention measurements. The research question formulated using the PICO framework is as follows: In children with cerebral palsy (P), how does using virtual reality as a training tool (I) compared to conventional therapy or pre-and post-intervention measurements (C) affect upper extremity function (O)?

Methods

This systematic review followed the PRISMA guidelines, and results are reported using the PRISMA checklist.

A systematic literature search in electronic databases was conducted. Data sources were 6 electronic databases - Cochrane Library, PubMed, Web of Science, Scopus, ScienceDirect, and BASE. The search strategy involved checking the title and abstracts of articles, using a combination of Mesh term keywords and phrases: "children with Cerebral Palsy," "Virtual Reality," and "upper extremity function", as well as synonyms, such as "upper limb function," "hand function." Selected keywords were joined by bull operators such as "AND" or "OR."

The following studies were selected for the systematic literature review: randomized clinical trials, single-subject experimental design, and non-blinded retrospective full-text articles in English. No time limit regarding the publication date was applied to the search strategy.

The search strategy was executed by three researchers (MM, UČ and LJ), and all publications from each database were extracted using citation management software Endnote and MS Excel. Any duplicates were removed. Titles and abstracts were screened independently by all three researchers based on the keywords, inclusion, and exclusion criteria. For all potentially eligible studies, full texts were retrieved, and eligibility was assessed by the same three researchers. Any conflict was resolved by discussion.

Articles were considered as potentially eligible if they met the following **inclusion criteria:** children with cerebral palsy, female and male, evaluation of virtual reality technology used for upper extremity function, the inclusion of intervention process, and data of health outcome. Only outcome measures related to upper extremity function were used. **Exclusion criteria:** having prior surgery for spasticity within the past six months and having botulinum toxin injection within the past six months.

The quality of the research was assessed by using the PEDRO scale. This process was done by two researchers (MM and LJ), which limited the impact of bias in this process.

Results

Study selection

The database search found 250 publications that were published from 2007 to 2024; after a full-text review, eight studies were included. The process of searching the studies is shown in *Figure 1*. All the included studies are summarized in *Table 1*.

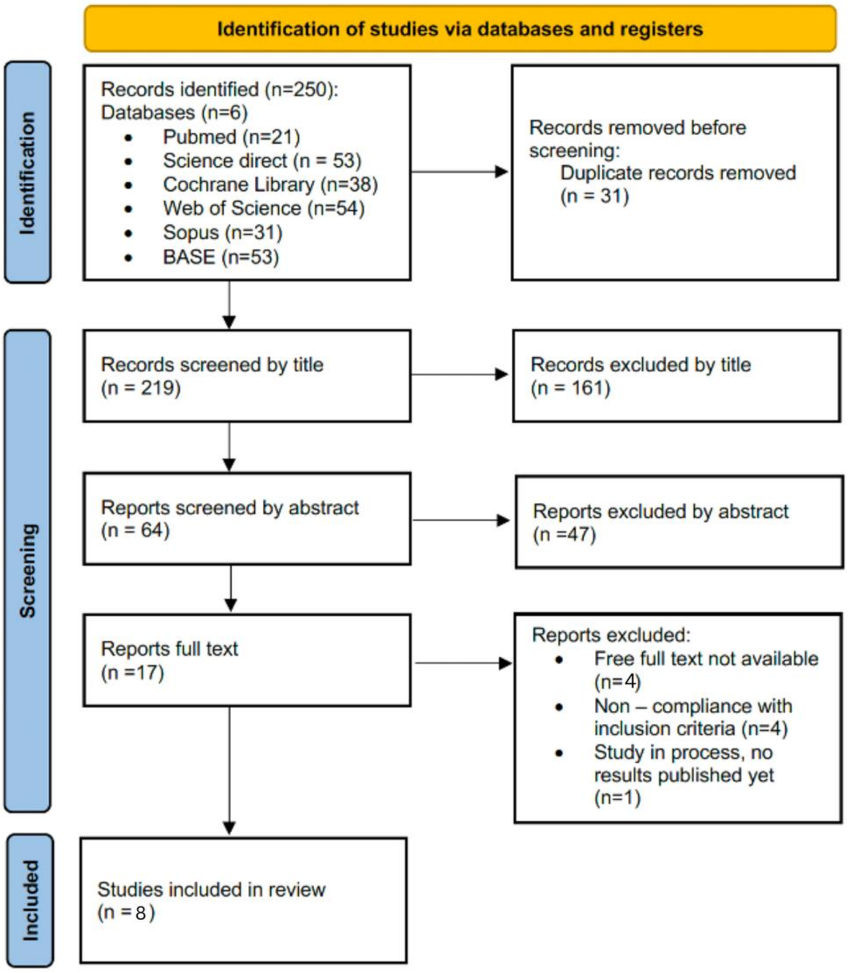

Figure 1 ***PRISMA Flow chart***

In the study by Chang et al. (2020) 17 children with Cerebral Palsy were divided into two groups. The first group of 10 participants did 20 minutes of conventional therapy with 10 minutes of VR therapy, and the second group of seven participants did only 30 minutes of conventional therapy. Both groups performed a total of 16 treatments twice a week for 8 weeks. Clinical outcomes were determined using the Quality of Upper Extremity Skills Test (QUEST) and Pediatric Evaluation of Disability Inventory (PEDI), which was administered before and 8 weeks after the first intervention session. The study showed significant improvement in dissociated arm movement, grasps, weight-bearing, and protective extension in the group that used VR technology as an addition to conventional therapy. The VR group showed significant improvements in all QUEST domains, whereas the second group showed a significant change only in total QUEST scores. Also, the first group demonstrated significantly improved scores in five PEDI domains (i.e., Self-care ($p = 0.017$), Transfer ($p = 0.028$), and Social function ($p = 0.018$) under the functional skills dimension and Self-care ($p = 0.031$) and Transfer ($p = 0.022$) under the caregiver assistance dimension) (Chang et al., 2020).

Chen et al. (2007) in their study evaluated 4 children, ages 8-12, with cerebral palsy – 3 with spastic quadriplegia and a good range of cognitive skills, and a boy with spastic hemiplegia and with mild retardation. A 4-week individualized VR training program (2 hours per week) with two VR systems was applied to all children. The 2-hour intervention time during each intervention week was divided into 45 minutes for the VR-based hand rehabilitation training system and 75 minutes for the commercial VR system. The outcome measures included four kinematic parameters: movement time, path length, peak velocity, and number of movement units for mail-delivery activities in 3 directions - neutral, outward, and inward. Three children who did not have any intellectual disabilities showed improvements in some aspects of reaching kinematics, whereas participants with mild retardation did not show any. The improvements in kinematics were partially maintained during follow-up, which was done twice – 2 weeks and 4 weeks after the last intervention session (Chen et al., 2007).

Bedair, Al-Talawy, Shoukry, & Abdul-Raouf (2016) in their study had 40 spastic hemiplegic children ages 5-10. Children were divided into two equal groups. The study group of 20 children received an upper extremity program for 60 minutes and an additional 30 minutes of VR training using the X-BOX system. In contrast, the second group, the control group of 20 children, received only an upper extremity therapeutic program for 60 min. Intervention time – 3 times a week. VR training can enhance the active participation of children with motor deficits in most upper extremity activities by considering the child's personality and changing environmental factors. Statistical analysis consisted of paired t-tests, and it shows that object manipulation, visual-motor skills, and upper extremity functions were significantly improved in the study group post-treatment compared to the control group. The rationales for the improvement of object manipulation resulting from conventional therapy and VR are related to the improvement of proximal shoulder stability.

In the case of Do, Yoo, Jung & Park (2016) three children, ages 5, 6, and 7, who were diagnosed with hemiplegic cerebral palsy, played Nintendo Wii as bilateral arm training based on VR. The intervention had 20 sessions, and the game was played for 30 minutes in each session. Results showed that after VR-based bilateral arm training, all the children improved in upper extremity motor skills on the affected sides and bilateral coordination ability. After completion of the intervention, measurements revealed that upper extremity motor skills on the affected side and bilateral coordination ability were better than before the intervention.

Qiu et al. (2015) in their study evaluated nine children ages 7-15 with cerebral palsy using the NJIT-RAVR System for 1 hour, 3 times a week for 3 weeks. Pre to post-test changes in peak supination velocity and kinematic measures were collected during daily performance. Results showed statistically significant improvements in sideways and forward reach as well as hand-to-mouth reach and composite of the three timed reaches, but children demonstrated an inability to keep the endpoint of the robot stable during the supination part of the activity.

A randomized controlled trial by Saussez et al. (2023) studied the semi-immersive virtual device REAtouch effectiveness on motor function improvement compared with the conventional, evidence-based two-week program for children with CP. Forty children with unilateral CP were included in this study. Half of them attended the standard HABIT-ILE program, and the other half – almost 50% of program time was spent practicing in REAtouch sessions. Both groups showed significant improvements in most outcome measures, but this study found no significant differences between them. Tasks to practice were made to stimulate object manipulations, repetition of grasps/release, and bimanual coordination.

One more randomized controlled study was conducted by Fidan & Genc (2023), where participants were 52 children with spastic CP. All participants were randomly divided into the VR group (n = 27) and the control group (n = 25). The mean age of the children was 9 years. In the context of this study, measurements were conducted for several body functions and activities. Regarding upper extremity function, the QUEST scale was utilized, which measures four domains: dissociated movement, grasp, protective extension, and weight bearing. The frequency of sessions was 45 minutes per day, two days a week, eight weeks. Like the previous study, this study shows that both treatment approaches are effective for improving upper extremity functions, but neurodevelopmental treatment (NDT) was superior to VR. Researchers explain this as a technology limitation, as Kinect is not designed for the hand movements required for everyday activities.

In the study conducted by Shih et al. (2023), the effectiveness of constraint-induced movement therapy (CIMT) and Kinect-based CIMT program was compared. It should be noted that the Kinect-based program was implemented in natural environments for children (at homes and schools) and supervised by a specialist. Games in the VR group were made to train arm-reaching, manipulation, and arm-hand tasks (reaching, grasping, releasing, holding, aiming, tracking, flapping, and forearm supination/pronation). Twenty-nine children participated in this study (n = 14 in the Kinect-based group and n = 15 in the therapist-based CIMT group). Kinect-based CIMT demonstrated effects comparable to that of therapist-based CIMT on the affected upper extremity motor control and daily function, so authors suggest that Kinect-based CIMT can be considered an alternative to therapist-based CIMT.

Characteristics of participants

The study settings and targeted participants varied as only one study set clear inclusion criteria defining muscle tone of grade 1+ or 2, according to the Modified Ashworth Scale (Bedair et al., 2016). The rest of the studies participated children with spastic quadriplegia, spastic hemiplegia, children with MACS levels 2-4 and GMFCS 1-4. A total number of 202 children, ages 4-18, with cerebral palsy were included in these eight studies, of which 87 children were included in the control groups. The reviewed studies delivered interventions at rehabilitation centres, laboratory settings, schools or homes, and campus rooms. Out of all participants, only 1 was mentioned with mild intellectual disability – 4 out of 5 studies mentioned "being able to corporate and follow instructions" as inclusion criteria for the study.

Characteristics of the Virtual Reality Systems

Virtual environments ranged from a simple display of reaching targets in a 2D plane to a detailed replication of real-life environments, such as a tennis and basketball court or a kitchen activity.

Of the eight studies, eight different VR technology tools were used, and one study used two systems. Custom VR systems were used in two studies – Njit-Ravr System (freedom force-controlled robot combined with a ring gimbal) and a VR-based hand rehabilitation training system (a sensor glove) (Chen et al., 2007; Qiu et al., 2015). Commercial video game platforms and devices, such as Nintendo Wii (used handheld control), Kinect X-Box (camera can capture and track movement) and EyeToy-Play system (players to interact with games using motion), and others were used in six studies (Bedair et al., 2016; Chen et al., 2007; Do et al., 2016, Saussez et al., 2023; Fidan & Genc, 2023; Shih et al., 2023). Commercially available VR systems designed for rehabilitation purposes were used in one study - RAPAEL Smart Kids (wearable smart glove tracing the movements) (Chang et al., 2020).

Functional improvements using Virtual Reality Systems

In all studies, the sessions ranged from 10 to 75 minutes per session, and the frequency ranged from every day to three sessions per week for 2 to 8 weeks.

All eight studies reviewed VR technology as a tool that delivered task-specific training with functionally relevant tasks where all eight studies noted hand coordination, targeted hand movements, and timing as a functional outcome; four studies reviewed reaching and grasping Chang et al., 2020; Chen et al., 2007; Fidan & Genc, 2023; Shih et al., 2023); two studies reviewed arm swing (Bedair et al., 2016; Chen et al., 2007); one study – forearm rotation (Qiu et al., 2015) and in four studies (Do et al., 2016; Saussez et al., 2023) both hands were used simultaneously to improve active range of motion.

Out of eight studies, seven (Chang et al., 2020; Chen et al., 2007; Bedair et al., 2016; Qiu et al., 2015; Saussez et al., 2023; Fidan & Genc, 2023; Shih et al., 2023) noted that difficulty levels progressed by the system created algorithm or based on the judgment of a therapist or interventionist according to task success. One study (Do et al., 2016) did not mention any progression.

Auditory and visual feedback was delivered in all studies.

Table 1 **Included articles**

Author, year	Study design	No. of subjects	Age of participants	Used device/ VR system	Length and frequency of therapy	Results
Chang et al., 2020	non-blinded retrospective study	17	1.group – 6.08 (mean) 2.group – 4.88 (mean)	RAPAEL Smart Kids	1.group - 20min conventional therapy with 10 min VR therapy, 2 times per week, 8 weeks. 2.group - 30 min Conventional therapy, 2 times per week, 8 weeks	The study showed significant improvement in dissociated arm movement, grasps, weight bearing and protective extension in the group who used VR technology as an addition to conventional therapy.
Bedair, Al-Talawy, Shoukry, & Abdul-Raouf, 2016	RCT	40	5-10	X-BOX	Study group - 3 sessions /week, 30 min VR based therapy + 60 min extremity therapeutic program. Control group - therapeutic program for 60 min	Object manipulation, visual-motor skills and upper limb functions were significantly improved in study group post treatment compared to control one.
Chen et al., 2007	Single subject research	4	8-12	EyeToy-Play system on PlayStation 2 and the VR based hand rehabilitation training system	2 hours per week, 4 weeks. 45 minutes for the VR-based hand rehabilitation training system and 75 minutes for the commercial VR system in a week.	Children with no cognitive impairment showed improvements in some aspects of reaching kinematics whereas participants with mild retardation did not show any.

Do, Yoo, Jung & Park, 2016	single subject experimental design	3	5-7	Nintendo Wii	30 min/ 2 times a week, 20 weeks. Therapy divided in 3 periods – evaluation, therapy and follow up.	Virtual Reality based bilateral arm training had positive effects in improving hemiplegic CP children's upper limb motor skills and bilateral hand coordination ability.
Qiu et al., 2011	Quantitative, experimental study	9	7-15	NJIT-RAVR	1 hour, 3 days a week, 3 weeks	Results showed statistically significant improvements in sideways and forward reach as well as hand to mouth reach.
Saussez et al., 2023	RCT	40	REAtouch group – 9.o (mean); HABIT-ILE grou – 9.1 (mean)	semi-immersive virtual device REAtouch	10-12 weekdays in a high – dosage day - camp setting. Total 90 hours for all of participants. 41% of time REAtouch group was in one-to-one REAtouch sessions.	REAtouch group resulted in significant improvements in upper extremity motor function, daily life activity transfer, and goal attainment in children with unilateral CP, demonstrating non-inferiority compared to the usual HABIT-ILE intervention
Fidan & Genc, 2023	RCT	52	VR training group – 9.2 (mean); control group – 9.4 (mean)	XboX one Kinect	45 min/day, 2 days/8weeks	Both treatment approach was effective for improving upper extremity functions, but conventional therapy was superior to VR therapy.
Shih et al., 2023	RCT	27	Kinect-based CIMT – 8.49 (mean); Therapist - based CIMT group – 8.28 (mean)	Windows 8, connected with Kinect 2 sensor.	2.25 h a day, 2 days a week for 8 weeks.	Both treatment approach was effective for improving upper extremity functions, VR based therapy, but kinect-based CIMT may provide extra benefits on improving trunk motor control.

Discussion

This systematic review examines the impact of VR as a training tool on upper extremity function in children with CP. Only a few studies met the inclusion criteria, and the VR interventions varied widely, but despite the different methods employed, research consistently shows that VR enhances upper extremity functionality and coordination in children with CP. Results of randomized controlled trials included in this review show that VR-based interventions can demonstrate effects comparable to conventional therapy on upper extremity motor control and daily function, giving similar therapy results. Such a treatment model could be effective in terms of costs and outcomes. Visual representation of the results on the effect of VR on the functionality of the upper limbs and comparison between interventions can be seen in *Figure 1* and *Figure 2*.

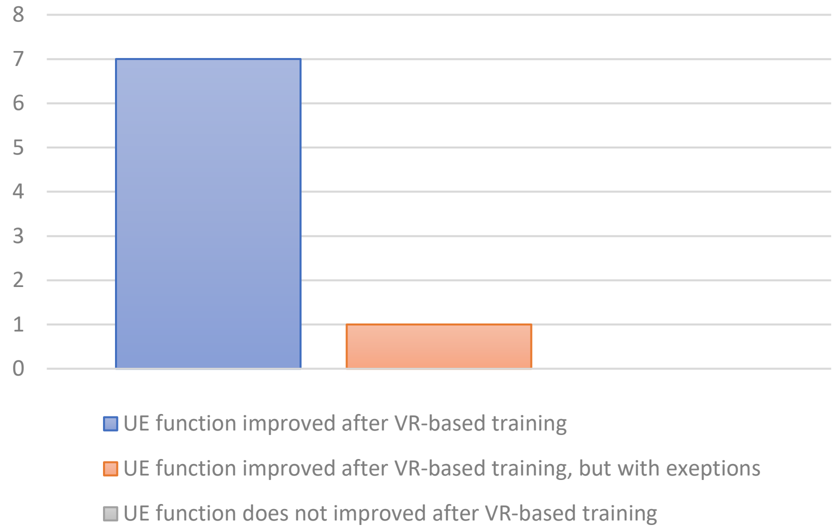

Figure 1 ***Positive results of VR-based training on upper extremity (UE) functions (n=number of studies)***

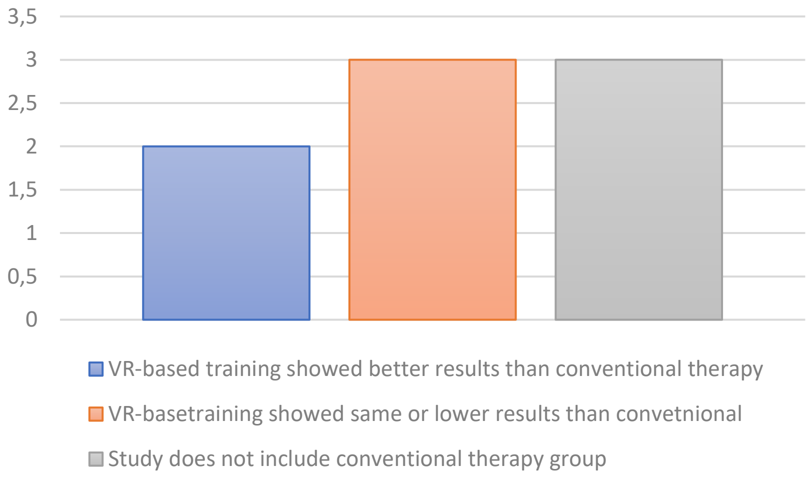

Figure 2 ***Result comparison between VR-based training and conventional training (n=number of studies)***

Some studies (Saussez et al., 2023; Shih et al., 2023) show that therapy sessions can ease the burden on families and therapists by doing sessions at home or in schools, attracting physiotherapists or with specially trained specialists in the use of the specific device. Therefore, educational institutions should also consider additional options for engagingly improving upper extremity function within the school environment - without fear of new technologies and utilizing VR, involving specialists, and caring for the well-being of children. Researchers (Saussez et al., 2023; Shih et al., 2023) believe that further research is needed, especially in a situation nowadays that limits access to various health-related services and ways to ease the burden on professionals and families should be researched.

Rehabilitation therapy is repetitive by nature, and repetition tends to reduce a patient's motivation. The use of VR enables the creation of an exercise environment in which children with CP can practice intensely and simultaneously to receive positive visual and auditory feedback, such as displaying gratifying messages in real-time ("great," "very good," etc.). Most studies comparing VR to conventional therapy cited the advantage of VR in children being still highly motivated, engaged, and playful despite the high number of repetitions of the task. (Weiss et al., 2004; Chang et al., 2020; Saussez et al., 2023; Fidan & Genc, 2023; Shih et al., 2023). VR also can compare the degree of movement performed by children in the real world and the degree of movement they observed in the virtual environment (Weiss et al., 2004; Chang et al., 2020). Moreover, VR allows the trainee to simulate dangerous situations. For instance, training for activities of daily living, such as cutting vegetables with a knife when cooking, may be difficult for children from a safety standpoint. Instead, VR can be a safe and effective alternative for such a dangerous environment (Chang et al., 2020).

The studies used various evaluation methods, but all studies set goals and results. The studies' results indicated that after VR-based bilateral arm training, improvement occurred in upper extremity motor skills on the affected sides and bilateral coordination ability for all the participants. Measurements revealed that upper extremity motor skills on the affected side and bilateral coordination ability were better than before the intervention.

Object manipulation, visual-motor skills, upper extremity functions (dissociated movement, grasp, protective extension, and weight bearing), bimanual manipulation, and gross and fine motor skills were improved in the research group post-treatment. The positive impact in three studied articles was similar to that of the control group. Still, in two of the studies, there was a significant improvement compared with the control group. It's important to note that training children with hand equipment to utilize object manipulation during therapy is unnecessary. VR technology can facilitate and improve the movement (Chen et al., 2007; Bedair et al., 2016; Chang et al., 2020). The training effects were retained in some children after the intervention (Chen et al., 2007; Do et al., 2016).

Each of the studies used a different duration and regimen of treatment, and even though the therapy duration was not similar, the VR intervention allowed for greater and better movement repetition and improved upper extremity function. The improvements showed in different kinematic parameters of reaching performance (Do et al., 2016; Bedair et al., 2016; Chen et al., 2007).

Bedair et al., 2016 and Chang et al., 2020 children were divided into two equal groups, comparing the obtained results - the study showed that VR-based rehabilitation with conventional therapy among children with CP might have better positive effects than conventional therapy alone on upper extremity function, the performance of daily activities and caregiver assistance resulting to reduce the burden on caregivers (Bedair et al., 2016; Chang et al., 2020), however, in studies by Saussez et al., 2023; Fidan & Genc, 2023, and Shih et al., 2023 both groups showed similar results or results were not unambiguous. The study and control groups demonstrated positive effects on the upper extremity motor control and daily function. Comparing two therapy methods, VR-based methods may provide extra benefits in some functions like trunk motor control during forward reaching action, replacing trunk movement with arm forward reaching action. In previous studies, Chen et al. (2007) investigated and showed some improvement in the quality of reaching performance during the VR intervention. The training effects were partially maintained four weeks after the intervention. Compared with Chang's (2020) research results, he showed that VR-based rehabilitation improved upper extremity and functional skills among children with CP. It can be concluded from both studies that using VR will improve and provide significantly reliable results (Chen et al., 2007; Chang et al., 2020).

There are several limitations in this review. Three of the eight studies that were included in this research had a small number of participants and did not have control groups, which limited and reduced the validity of the research. Different tools and measurement methods were used in each study, meaning the results could not be compared statistically according to the same criteria. Scientific article search strategies may not include all research containing the selected keyword. All the studies included in this review did not score high on PEDRO. The main reason is the type of studies included in this research - randomized clinical trial, pilot study, non-blinded retrospective study, and single-subject research.

Conclusion

The aim of this review was to investigate VR technology's impact on upper extremity function for children with CP. The findings suggest that using VR technology as a rehabilitation tool improves upper extremity function. Conventional therapy can be replaced with VR-based therapy, but more randomized and specific studies on the subject are needed in the future. Also, even though previous studies show that custom virtual reality systems are better tailored to the needs of children with CP because of their ability to provide better-adapted experience suited for their individual needs, this review shows that the commercially available and used VR systems can be as successfully used in the rehabilitation process for children with CP targeting specific motor function.

References

Bateni, H., Carruthers, J., Mohan, R., & Pishva, S. (2024). Use of Virtual Reality in Physical Therapy as an Intervention and Diagnostic Tool. *Rehabilitation research and practice*, 1122286. DOI: https://doi.org/10.1155/2024/1122286

Bedair, R., Al-Talawy, H., Shoukry, K., & Abdul-Raouf, E. (2016). Impact of virtual reality games as an adjunct treatment tool on upper extremity function of spastic hemiplegic children. *International Journal of Pharmaceutical and Chemical Sciences, 4*(3), 1-8.

Centers for Disease Control and Prevention (CDC). (2024). Cerebral Palsy (CP). U.S. Department of Health and Human Services. Retrieved from https://www.cdc.gov/ncbddd/cp/facts.html.

Chang, H. J., Ku, K. H., Park, Y. S., Park, J. G., Cho, E. S., Seo, J. S., Kim, C. W., & Se Hwi, O. (2020). Effects of virtual reality-based rehabilitation on upper extremity function among children with cerebral palsy. *Healthcare, 8*(4), DOI: https://doi.org/10.3390/healthcare8040391

Chen, Y. P., Kang, L. J., Chuang, T. Y., Doong, J. L., Lee, S. J., Tsai, M. W., Jeng, S. F. & Sung, W. H. (2007). Use of virtual reality to improve upper-extremity control in children with cerebral palsy: A single-subject design. *Physical Therapy, 87*(11), 1441-1457. DOI: 10.2522/ptj.20060062.

Chen, Y. P., Kang, L. J., Chuang, T. Y., Doong, J. L., Lee, S. J., Tsai, M. W., Jeng, S. F. & Sung, W. H. (2007). Use of virtual reality to improve upper-extremity control in children with cerebral palsy: A single-subject design. *Physical Therapy, 87*(11), 1441-1457. DOI: https://doi.org/10.2522/ptj.20060062

Chen, Y. P., Lee, S. Y., & Howard, A. M. (2014). Effect of virtual reality on upper extremity function in children with cerebral palsy: a meta-analysis. *Pediatric physical therapy : the official publication of the Section on Pediatrics of the American Physical Therapy Association, 26*(3), 289–300. DOI: https://doi.org/10.1097/PEP.0000000000000046

Do, J. H., Yoo, E. Y., Jung, M. Y. & Park, H. Y. (2016). The effects of virtual reality-based bilateral arm training on hemiplegic children's upper extremity motor skills. *NeuroRehabilitation, 38*(2), 115-127. DOI: 10.3233/nre-161302.

Fandim, J. V., Saragiotto, B. T., Porfírio, G. J. M., & Santana, R. F. (2021). Effectiveness of virtual reality in children and young adults with cerebral palsy: a systematic review of randomized controlled trial. *Brazilian journal of physical therapy, 25*(4), 369–386. DOI: https://doi.org/10.1016/j.bjpt.2020.11.003.

Fidan, Ö. & Genç, A. (2023). Effect of Virtual Reality Training on Balance and Functionality in Children with Cerebral Palsy: A Randomized Controlled Trial, *Turkish Journal of Physiotherapy and Rehabilitation, 34*(1), 64-72. DOI: 10.21653/tjpr.1017679.

Fluss, J.,&Lidzba, K. (2020). Cognitive and academic profiles in children with cerebral palsy: A narrative review. *Annals of Physical and Rehabilitation Medicine, 63*(5), 447–456. DOI: https://doi.org/10.1016/j.rehab.2020.01.005

Hasan, Md. (2020). Achieving Functional Independence of Children with Cerebral Palsy at the Mainstream School: An Overview Mainstream School. *Open Access Library Journal, 7*, 1-23. DOI: https://doi.org/10.4236/oalib.1106597

Javaid, M., & Haleem, A. (2020). Virtual reality applications toward medical field. *Clinical Epidemiology and Global Health,* 8(2), 600-605. DOI: https://doi.org/10.1016/j.cegh.2019.12.010

Netto, A., Wiesiolek, C., Brito, P., Rocha, G., Tavares, R., & Lambertz, K. (2020). Functionality, school participation and quality of life of schoolchildren with cerebral palsy. *Fisioterapia em Movimento, 33*. DOI: https://doi.org/10.1590/1980-5918.033.ao29.

Qiu, Q., Adamovich, S., Saleh, S., Lafond, I., Merians, A. S. & Fluet, G. G. (2011). A comparison of motor adaptations to robotically facilitated upper extremity task practice demonstrated by children with cerebral palsy and adults with stroke, *IEEE International Conference on Rehabilitation Robotics*. DOI: 10.1109/ICORR.2011.5975431.

Ravi, D. K., Kumar, N., & Singhi, P. (2017). Effectiveness of virtual reality rehabilitation for children and adolescents with cerebral palsy: an updated evidence-based systematic review. *Physiotherapy,* 103(3), 245–258. DOI: https://doi.org/10.1016/j.physio.2016.08.004

Reid, D. (2002). The use of virtual reality to improve upper ekstremity efficiency skills in children with cerebral palsy: a pilot study. *Technology and Disability, 14*(1), 53-61. DOI: https://doi.org/10.3233/TAD-2002-14202

Saussez, G., Bailly, R., Araneda, R., Paradis, J., Ebner-Karestinos, D., Klöcker, A., Sogbossi, E. S., Riquelme, I., Brochard, S., & Bleyenheuft, Y. (2023). Efficacy of integrating a semi-immersive virtual device in the HABIT-ILE intervention for children with unilateral cerebral palsy: a non-inferiority randomized controlled trial. *Journal of NeuroEngineering and Rehabilitation, 20*(1), 98. DOI: https://doi.org/10.1186/s12984-023-01218-4.

Shih, T. Y., Wang, T. N., Shieh, J. Y., Lin, S. Y., Ruan, S. J., Tang, H. H., & Chen, H. L. (2023). 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*, *20*(1), 13. DOI: https://doi.org/10.1186/s12984-023-01135-6

Tonmukayakul, U., Imms, C., Mihalopoulos, C., Reddihough, D., Carter, R., Mulhern, B., & Chen, G. (2020). Health-related quality of life and upper-limb impairment in children with cerebral palsy: developing a mapping algorithm. *Developmental Medicine and Child Neurology*, *62*(7), 854–860. DOI: https://doi.org/10.1111/dmcn.14488

Weiss, P. L., Rand, D., Katz, N., & Kizony, R. (2004). Video capture virtual reality as a flexible and effective rehabilitation tool. *Journal of neuroengineering and rehabilitation*, *1*(1), 12. DOI: https://doi.org/10.1186/1743-0003-1-12