JBI EVIDENCE SUMMARY

Cerebral Palsy (Children and Adolescents): Virtual Reality Rehabilitation

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Question

What is the best available evidence regarding the effectiveness of virtual reality rehabilitation for cerebral palsy in children and adolescents?

Clinical Bottom Line

Cerebral palsy (CP) is a non-progressive neurological disorder characterized by deficits in motor, sensory, cognitive or perceptual functions that result in significant childhood disability.[1,2] The overall prevalence of CP is estimated to be 2.11 per 1,000 live births globally.[2]Rehabilitation improves mobility and self-care independence, improving quality of life and social engagement. Virtual reality (VR) rehabilitation is characterized by the use of computer-generated interactive simulations, which give the user opportunities to interact with virtual environments that appear similar to real-world events and objects.[2] Three key features of VR are immersion, imagination and interaction and can include a wide range of technologies and software that are commercially available or specifically designed for rehabilitation.[2]

- A systematic review investigated the effectiveness of VR to improve upper extremity function and motor performance in children with cerebral palsy (CP). Interventions in the included studies were predominantly non-immersive VR including the Nintendo Wii sports and Wii Fit (6 studies), Xbox Kinect (5 studies), Move to improve (Mitii) a web-based home program (2 studies), a computer assisted VR rehabilitation (1 study) and a home-based VR rehabilitation system (1 study). Other types of semi-immersive VR interventions included augmented virtuality (PlayStation Eyetoy), robot-assisted therapy, RAPAEL Smart Kids and individualized upper extremity VR training. There was significant variation between studies in the frequency and duration of intervention sessions ranging from 30 to 60 minutes session daily to twice a week, with the overall total intervention time ranging from 6 hours to 60 hours. Comparator interventions included conventional therapy, or constraint-induced movement therapy (1 study). A wide variety of measures were used to assess upper limb and hand function including Melbourne Assessment of Unilateral Upper Limb Function Test (MAUULF), Quality of Upper Extremity Skills Test (QUEST), ABILHAND-Kids, Box and Block Test (BBT), Bimanual Fine Motor Function, Modified Functional Reach Test, active range of motion (AROM), Melbourne Assessment 2 (MA-2), The Manual Ability Classification System (MACS) and the Upper Limb Physician's Rating Scale (ULPRS). Overall, the review reported moderate strength evidence of statistically significant improvements in upper limb and hand function (12 studies), gross motor function (10 studies), functional mobility (4 studies) and independence in daily life and occupational performance (8 studies) compared to control intervention.

Authors concluded that VR, including robot- and computer-assisted games, has the potential to improve or maintain functional status and upper limb performance in children with CP, although further research is required to confirm the results of this review.[1](Level 1)

- A systematic review and meta-analysis assessed the feasibility and effects of VR-enhanced home rehabilitation in children and adolescents with CP. Interventions included a variety of customized and commercially available VR systems including Mitii, a customized system with data glove and a PlayStation (3) game, the Timocco (system developed by occupational therapists), EyeToy Play (rehabilitation specific VR system), a computer-assisted arm rehabilitation gaming system, a home-based virtual cycling training program, Dashy Square video game with customized hardware and software for rehabilitation and off-the-shelf VR gaming systems including the Nintendo Wii and Kinect. Home-based rehabilitation sessions varied in duration from 4 to 12 weeks (except one program that was conducted for 6 to 10 months in 3 participants). The meta-analysis found that home-based VR improved hand function, gross motor function and grip strength from base-line to post-intervention; however, most studies reported no difference between home-based VR and usual care, conventional constraint-induced therapy or a home-based physical activity program for upper extremity function and gross motor function. Included randomized controlled trials (RCTs) were moderate to high quality (Physiotherapy Evidence Database assessment tool) and observational studies were fair to good quality based on the National Institutes of Health Quality Assessment Tools. Authors concluded that overall VR appears to be feasible and effective for home-based rehabilitation for children and adolescents with CP and may be used as an adjunct to conventional facility-based therapy. Further research is required using valid and reliable outcomes, with adequate power to confirm the results of this review.[2](Level 1)
- A systematic review and meta-analysis investigated the effects of VR on balance, motor function and activities of daily living for children with CP. The included interventions used different types of VR including non-immersive (8 studies), semi-immersive (10 studies) and fully immersive (1 study). Interventions in the included studies were the Nintendo Wii/ Wii-fit, RAPAEL smart kids, The Eloton SimCycle Virtual Cycling System, E-link Evaluation and Exercise System, X-box Kinect, LeapMotion controller based training, Scratch software with computer and joystick. The meta-analysis reported that VR significantly improved balance, gross motor function, upper limb function and activities of daily living (The Functional Independence Measure for Children [Wee-Fim]) compared to control (control interventions not reported). Overall, most of the included studies were found to be low risk of bias. Authors concluded that VR has significant potential as an effective therapeutic modality for children with CP; however, further research investigating optimal VR applications including immersive versus non-immersive VR and long-term effects is required.[3](Level 1)
- A systematic review investigated the potential effects of immersive VR on motor and cognitive outcomes in children with CP. Immersive VR interventions included the (Gait Real-Time Analysis Interactive Lab) GRAIL system, CAREN system, Oculus Rift system, a VR horse riding simulator and VR with double tapis-roulant (treadmill). The majority of studies reported similar effectiveness between immersive VR and conventional therapies. One study reported that immersive VR combined with a wearable haptic device combined with conventional therapy improved kinesiological indices of linear path tracking and reach-and-grasp tasks. Authors highlight that the immersive and engaging virtual environments combined with the audio-visual feedback may enhance motor learning and functional recovery. Authors concluded that immersive VR may be an effective adjunct therapy with conventional rehabilitation for children with CP, although further research is required to determine the optimal VR type (semi-immersive, fully-immersive) and devices.[4](Level 2)
- A systematic review evaluated the effect of VR training on upper limb motor function compared to conventional physiotherapy programs in children with CP. All interventions were delivered in clinical

settings and used VR and video games compared to conventional rehabilitation exercises. The review found variable results within the included studies with some suggesting a positive effect of VR on the QUEST or grip strength while others reported no difference when compared to conventional physiotherapy interventions (very low-certainty evidence). Authors concluded that the effect of VR on upper limb rehabilitation in children with CP is unclear compared to conventional physiotherapy and further research is required before conclusions about the clinical utility of VR in CP physiotherapy can be drawn.[5](Level 1)

- A systematic review determined the effectiveness of different types of VR systems targeted at improving upper limb impairments in children with CP. Interventions included commercially available video games including the Nintendo Wii, Kinect for Xbox or computer and the PlayStation, systems designed for rehabilitation including Fizyosoft games, Mitii, Mandala Gesture Xtreme IREX VR system, E-Link – Evaluation and Exercise System, the Leap Motion Controller and the Q4 system. One study did not report the names of the system but developed a system in collaboration with researchers and computer engineers. The duration of programs ranged from 3 to 20 weeks and the frequency of sessions varied from 1 to 6 per week, lasting 30 to 90 minutes. Interventions that combined VR with conventional therapy (15 studies) reported length of sessions between 30 and 145 minutes. The meta-analysis found low-certainty evidence that showed improvement in upper limb functioning favoring VR combined with conventional therapy compared to conventional therapy alone. Authors concluded that VR appears to be an effective tool for upper limb rehabilitation for children with CP when combined with conventional therapy.[6](Level 1)
- A systematic review and meta-analysis examined the effects of VR on motor functions and daily life activities in children with CP in the short-term (immediately after the intervention), medium-term (≥ 1 week to < 12 weeks from the end of the intervention) and long-term (≥ 12 weeks from the end of the intervention). Interventions used varying VR devices including the Nintendo Wii (including the Wii Balance Board), OpenFeasyo software platform (rehabilitation-specific faming software), TYROMOTION force plate, the RAPAEL Smart Kids software, E-Link Evaluation and Exercise System and a computer with a joystick. Overall, two thirds of the included studies used devices that were specifically developed for therapy. Session duration ranged from 15 to 90 minutes 2 to 7 times per week. In almost all studies VR was combined with conventional therapy and compared to a control group (conventional therapy only). For upper limb function, results were mixed with 3 studies reporting significant improvement in both groups, with greater improvement in the VR group, 3 studies reported no effect of the intervention and 1 study with a small sample size (n=3) did not conduct statistical analysis. The meta-analysis for upper-limb function (4 studies) reported a small statistically significant effect favoring VR + conventional therapy compared to conventional therapy alone, although heterogeneity was high. The meta-analysis also reported no statistically significant difference between intervention and control groups for gross motor function and activities of daily living. All included studies were found to be fair- to excellent-quality (modified Downs and Black checklist). Authors concluded that the addition of VR to conventional rehabilitation for children with CP may provide additional benefits and that VR devices designed specifically for therapy allow for greater customization and control. Additional research is required to determine the effects of VR on gross motor control and activities of daily living in children with CP.[7](Level 1)
- A systematic review and meta-analysis investigated the effects of VR exergaming on motor function and participation outcomes in children with CP. VR exergaming interventions included the Nintendo Wii, Super Scape VRT 3-D construction packages, PAPAEL Smart kids, virtual cycling, virtual golf trainer, Mitii, X-box Kinect, Leap Motion (controller-based) and exergaming (unspecified), some interventions combined exergaming with neurodevelopmental therapy or conventional occupational therapy. Sessions ranged from 25 to 90 minutes, 1 to 7 times per week over 4 to 20 weeks. The meta-analysis reported

statistically significant effects in favor of exergaming for Gross Motor Function Measurement (GMFM)-88 score (low-certainty evidence), the GMFM walking dimension (moderate-certainty evidence), mobility and social cognitive subscales of the Pediatric Evaluation of Disability Inventory (PEDI) scale (low-certainty evidence), Canadian Occupational Performance Measure (COPM) score (very-low certainty evidence), WeeFunctional Independence Measure (WeeFIM) score (low-certainty evidence), MA-2 score (low-certainty evidence), compared to control. There was no difference between exergaming and control reported for the GMFM-66 (a sub-scale of the GMFM-88) score (low-certainty evidence), Pediatric Balance Scale (PBS) score (low-certainty evidence), QUEST score (very-low certainty evidence) and ABILHAND-Kids score (very-low certainty evidence). For the studies not included in the meta-analysis most reported that VR exergaming was equally as effective or slightly more effective than conventional therapy when compared to control. No adverse events were reported (n=11 studies), suggesting that VR-assisted exergaming interventions in the studies that reported on adverse events were safe. Authors concluded that VR-assisted exergaming may have some advantages for improving function and activities of daily living compared to conventional rehabilitation for children with CP and may be considered as a complementary approach.[8](Level 1)

- A systematic review assessed the effectiveness and applications of VR-based physical exercise interventions in the rehabilitation of children and adolescents aged 4 to 18 years with CP. The review aimed to evaluate how VR can enhance motor skills, balance, coordination, and participation in physical activities. The included studies included participants diagnosed with CP, primarily classified as GMFCS levels I–III, with some studies reporting MACS and Modified Ashworth Scale (MAS) scores. The total sample across studies was 616 participants, with the most frequent age range being 6 to 12 years, and a roughly equal gender distribution. The review examined physical exercise programs using virtual reality tools, such as Nintendo Wii Fit, Xbox Kinect, REAtouch®, IREX system, and VR-augmented biofeedback systems. Duration of training varied across studies from as short as 1 week up to 12 weeks or more. Frequency ranged from 2 to 5 sessions per week, with session durations from 20 to 90 minutes. Interventions focused on balance training, strength development, motor control, hand function, and functional independence. Most studies reported significant improvements in gross motor function, balance, muscle strength, reaction time, hand-eye coordination, and participation in daily activities in children who underwent VR-based training. VR interventions were well-accepted and motivating, often outperforming or complementing conventional therapy in engagement and adherence. Wii Fit and Kinect-based programs improved balance and gross motor function, while biofeedback-VR and REAtouch® systems enhanced manual dexterity and neuromuscular control. The overall methodological quality of the included studies was rated as moderate (n=3) to high (n=21). However, the risk of bias was observed, particularly in performance and detection domains, due to the inherent challenges of blinding in VR interventions. Thus, the evidence quality is generally high, but results should be interpreted with some caution due to methodological and reporting variability across studies. The authors concluded that VR-based physical exercise programs are effective and beneficial for improving motor function, balance, strength, and engagement in children and adolescents with CP. The use of VR interventions enhances motivation, supports functional skill development, and serves as a valuable complement to conventional rehabilitation methods. The authors additionally emphasized the need for more high-quality, standardized, and long-term studies to confirm the sustained impact of VR-based physical exercise in this population.[9] (Level 1)
- A systematic review and meta-analysis assessed the effectiveness of VR motor games in improving gross and fine motor skills in children with CP. The study aimed to evaluate whether VR motor games serve as a viable and effective rehabilitation tool for enhancing motor function in this population. Participants were children (up to 18 years of age) diagnosed primarily with spastic cerebral palsy, including types such as spastic diplegia and hemiplegia. These children had varying degrees of motor

impairment and were involved in rehabilitation programs targeting motor skills development. The review evaluated VR motor game interventions, which included tools such as Nintendo Wii Fit, Xbox Kinect, RAPAEL Smart Kids, REAtouch®, and other customized VR gaming systems. Training durations ranged from 3 to 16 weeks. Session frequency ranged from 2 to 7 sessions per week. Each session lasted 15 to 60 minutes. Interventions often combined VR motor games with conventional physical or occupational therapy. The focus was on enhancing gross motor functions (balance, gait, posture) and fine motor skills (manual dexterity, hand coordination, upper limb function). Significant improvements in gross motor skills were observed in children receiving VR interventions compared to control groups receiving conventional rehabilitation. Fine motor skills also improved significantly, although there was more variability across studies. VR motor games demonstrated better outcomes when applied more than 4 times per week and for a period of at least 8 weeks. Subgroup analyses suggested higher intensity and longer duration programs yield better results. Children showed greater engagement and motivation with VR therapy than with traditional methods. The methodological quality of the studies was assessed as having low to moderate risk of bias (Physiotherapy Evidence Database [PEDro] scale). Although most studies reported complete outcome data, some had limitations in blinding (common in rehabilitation research). Overall, the quality of evidence was assessed as moderate to high. The authors concluded that VR motor games are an effective intervention for enhancing gross and fine motor skills in children with CP. These games not only improve motor function but also increase motivation and engagement during therapy. The results suggest that higher training frequency (more than 4 days per week) and longer intervention duration (more than 8 weeks) yield better outcomes. Therefore, VR motor games can be considered a valuable and supportive tool in pediatric rehabilitation for children with CP.[10] (Level 1)

Characteristics Of The Evidence

This summary is based on a structured search of the literature and selected evidence-based health care databases. Evidence in this summary is from:

- A systematic review that included 21 studies (study designs and total number of participants were not reported).[1]
- A systematic review and meta-analysis that included 18 studies (9 RCTs, 5 quasi-experimental and 4 case studies) including 591 children and adolescents.[2]
- A systematic review and meta-analysis that included 19 RCTs with a total of 894 participants (467 intervention group and 427 control group). The average age of participants was between 5 and 16 years old.[3]
- A systematic review that included 15 studies (5 pilot studies, 8 clinical trials, 1 crossover counterbalanced study and 1 case study) with a total of 313 participants.[4]
- A systematic review that included 7 RCTs with a total of 202 children, average age 9.5 years (range 7 to 12 years).[5]
- A systematic review that included 22 RCTs with a total of 746 participants aged between 4 and 20 years.[6]
- A systematic review and meta-analysis that included 9 studies (7 RCTs and 2 study designs not reported) with a total of 258 children aged between 3 and 18 years.[7]
- A systematic review and meta-analysis that included 45 studies (44 RCTs and 1 retrospective cohort) with a total of 1,580 participants (n= 801 intervention and n= 779 controls).[8]
- A systematic review that included 24 articles with a total of 616 participants aged between 4 and 18 years.[9]
- A systematic review that included 19 RCTs with a total of 850 children below 18 years of age.[10]

Best Practice Recommendations

1. Virtual reality-assisted therapy may be considered as an adjunct to conventional rehabilitation for children and adolescents with CP. (Grade B)

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Related JBI Evidence Summaries

- JBI-ES-3176-5-Cerebral Palsy: Dance Therapy
- JBI-ES-144-3-Cerebral Palsy (Children and Adolescents): Hydrotherapy
- JBI-ES-2933-3-Children with Cerebral Palsy: Physiotherapy

Archived Publications

1. JBI-ES-1160-4 (Published at 15 October 2024)
2. JBI-ES-1160-3 (Published at 15 October 2024)
3. JBI-ES-1160-2 (Published at 17 December 2021)
4. JBI-ES-1160-1 (Published at 29 March 2021)

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