Review Article

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Effects of Virtual Reality Applications on Children with Obstetric Brachial Plexus Injury: A Systematic Review

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Abstract

Purpose: To systematically review the effectiveness of virtual reality (VR) applications on children with obstetric brachial plexus injury (OBPI).
Methods: Systematic review of randomized controlled trials including patients with OBPI was conducted on PubMed, Cochrane, Web of Science, and PEDro databases. Methodological quality was assessed by the PEDro score. The outcomes measured were upper limb range of motion (ROM), muscle strength, and functionality.
Results: Four original randomized controlled trials, were published in the English language, with 93 patients included in this systematic review. The interventions, characteristics of the participants, and outcomes were diverse. The largest effect was found when another intervention was combined with conventional physical therapy in the outcomes, with good quality evidence.
Conclusion: The VR applications alone or in combination with physical therapy interventions are effective in improving range of motion, upper limb functions, and muscle strength in children with OBPI. However, studies with a high quality, the larger sample size of patients with OBPI and evaluation of the long-term consequences are required.

Keywords: Obstetric brachial plexus ınjury; virtual reality; physical therapy; rehabilitation; systematic review

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Introduction

Obstetric Brachial Plexus Injury (OBPI) is a clinical condition with an incidence of approximately 1.5 per 1000 live births and is typically seen after a traumatic delivery, with injury to the brachial plexus roots (C5 – T1) (1,2). According to the affected nerve roots, brachial plexus injuries are classified as upper, middle, lower, or total, with upper brachial plexus injuries being the most common (46 percent) (3). With the reduced range of motion, contractures, movement problems, sensory defects, and especially abductors and internal rotators of the shoulder and elbow flexor muscles being impaired in the upper extremity, children's quality of life decreases substantially after OBPI (4,5). As a result, many rehabilitation approaches are utilized to promote functional recovery and treat motor and sensory impairments in patients with OBPI (5).

Virtual reality (VR) technology creates three-dimensional virtual environments and interferes with allowing users to interact with these environments and their elements (6). These systems enable high-intensity, task-oriented motor, and sensory training, which can support child's needs and increase their desire to participate in the rehabilitation process with or without matched disabled contemporaries by making their experience more appealing via the use of real-time feedback and difficulty levels adaptable to the functional level of the child (7,8). Furthermore, game-based VR applications can improve adherence to rehabilitation thanks to their engaging, entertaining, and stimulating nature (9). The efficacy of VR-based rehabilitation treatments remains debatable in the literature. However, the inclusion of low level evidence studies does not allow to support the cause-and-effect relationship between the interventions and outcomes. Systematic reviews, including just randomized controlled trials, are important since they summarize the best evidence of available interventions in order to guide clinical decision-making. To address these gaps, this study aimed to systematically review the effectiveness of VR-based interventions in children with OBPI.

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Materials and Methods

Search Strategy

This study used the 2020 version of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standard to conduct a systematic review (10). Two authors (L.U. and B.D.) independently searched PubMed, Cochrane, Web of Science (WOS), and PEDro (Physiotherapy Evidence Database) in June 2022.

The Cochrane Library's PICOS tool was used as the basis for the search strategy (11): (1) Population, pediatric patients with brachial plexus injury; (2) Intervention, virtual reality; (3) Comparison, virtual reality to other rehabilitation techniques or no intervention; (4) Outcomes, upper extremity range of motion, motor function, muscle strength and quality of life; and (5) Study design, randomized controlled trials. The research was limited to articles published in English. Randomized controlled clinical trials published from January 1st 2000 to June 30th 2022 were included. **Table 1** shows the search strategy used in MEDLINE. Similar key words and search terms were utilized in MEDLINE were also used in PEDro, Cochrane and Web of Science database searching. Duplicates were removed via EndNote 20.5 (Thomson Reuters, USA).

Table 1. Search strategy used in each database.

Search Strategy	Hits
(brachial plexus[MeSH Terms] OR brachial plexus*[Title/Abstract] OR Brachial Plexus Neuropathies[MeSH Terms] OR brachial plexus neuropathy[Title/Abstract] OR brachial plexus disorder*[Title/Abstract] OR brachial plexus disease*[Title/Abstract]) AND (virtual reality[MeSH Terms] OR virtual reality*[Title/Abstract] OR virtual realities*[Title/Abstract])	12

Eligibility Criteria

The inclusion criteria proposed were as follows: (1) randomized controlled trials (including pilot RCTs); (2) RCTs included a sample of pediatric participants aged 0 to 18 years old who had brachial plexus injury; (3) studies that used virtual reality as a rehabilitation intervention (alone or combined with other therapy); (4) studies in which the control group received no intervention or a therapy other than virtual reality; (5) studies that assessed different outcomes related to the motor function of the upper extremity. As exclusion criteria, we used (1) studies with adult participants (2) studies with only one group and (3) articles registered only to clinicaltrials.gov.

Study Selection and Data Extraction

In order to determine the eligibility, three authors (Ö.A, Z.L.U, and T.B.D) have independently screened the titles, abstracts, and the full text of the identified articles. Any disagreement during the screening process was resolved through a consensus meeting. Following information has been extracted from the articles by two different authors (F.A.Ç and R.M): Author, Publication year, Number of Participants, Participant Charachteristics, Affected side, Interventions, Outcome measures, and Results.

Quality of Evidence

We used the PEDro Scale to evaluate the quality of the studies. This scale is a scale that evaluates the quality of the study with 11 questions in studies in the field of physiotherapy and rehabilitation. Quality assessment is achieved by answering these 11 questions as yes/no, respectively: Elimination Criteria, Randomization, Concealed Allocation, Comparebility of baseline values, Blindness of subject/ therapist/ assessor, Adequate Follow-up, Analyse of intention-to-treat, Comparations between the groups, and Presence of point estimates and variability. A maximum of 10 points can be obtained in the PEDro scoring based on the Delphi list. Getting 9 or 10 points from this scoring means that the work is considered excellent. While 6-8 points means good quality work, 4-5 points means that the work is sufficient. Studies below 4 points are defined as low quality (12). All the inluded studies in this review received a minimum score of five points on PEDro scale. Three studies are of good quality with a score of 6 (13) and 7 (14,15) whereas one study is of fair quality with a score of 5 (16). Methodological quality assessment details of studies were shown in **Table 2.**

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Results

The search strategy from all databases yielded 47 records. A total of 18 duplicate and marked as manually ineligible records were removed. After evaluating the title and abstract, 4 studies were assessed for eligibility. Four full-text articles fulfilled the eligibility criteria and were included in the systematic review. The PRISMA flow chart of the search process is shown in **Figure 1.**

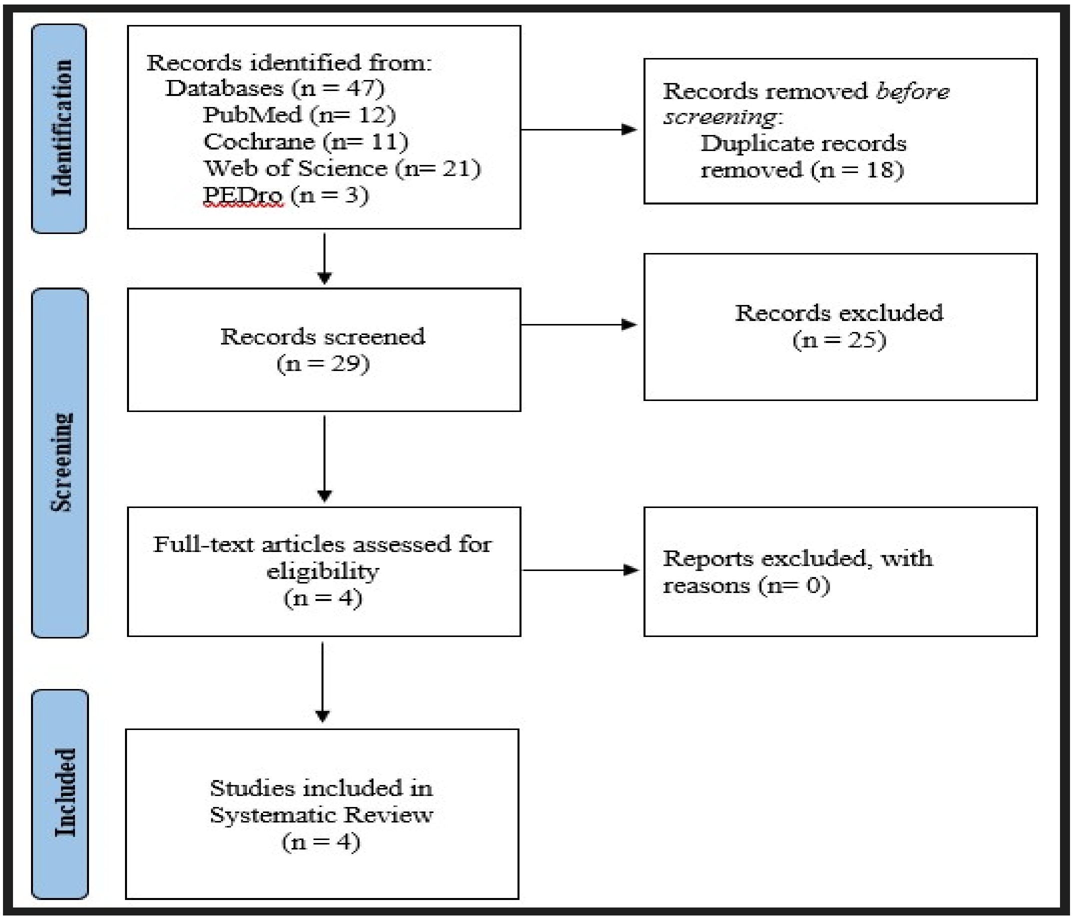

Figure 1. The PRISMA flow chart of the search process

Study Characteristics

Four original RCTs, published in the English language, with 93 patients were included in this systematic review. The characteristics of included studies were summarized in **Table 3**.

There were 52 males and 41 females and the age of the participants varied between 4 to 34 years.

Study Interventions

All the included studies vary in terms of intervention and comparison group. One study compared VR using Nintendo Wii games with conventional physiotherapy (14), another compared VR mirror therapy (MT) with conventional mirror therapy (16) whereas one used VR using Leap Motion Controller-Based Training to compare with conventional rehabilitation program (15) and one compared VR using Armeo spring with conventional physiotherapy program (13).

Outcome Measurements

The summary of inter-and intra-group comparison in terms of Mallet Scoring System (MSS), Range of Motion (ROM), Active Movement Scale (AMS), shoulder muscle strength, Children Hand-use Experience Questionnaire (CHEQ), Jebson Taylor Hand Function Test (JTHFT), Nine-Hole Peg Test (9HPT), grip strength, pinch strengths is available in **Table 3.**

Mallet Scoring System

Two studies (13,14) used Mallet Scoring System (MSS) to evaluate shoulder functions. The effect of VR on MSS was inconsistent across studies. Karas et al. reported no significant improvement in the MSS score whereas, El-Shamy et al. found a significant improvement in the MSS score. The VR group was found to be significantly better than the comparison group in external rotation, hand-to-neck, hand-to-spine, and hand-to-mouth components of MSS.

Range of Motion (ROM)

Two studies evaluated the range of motion using a standard universal goniometer (13) and a digital goniometer (14). Karas et al. evaluated active and passive shoulder flexion, abduction, internal-external rotation, elbow flexion, forearm supination-pronation, and wrist flexion-extension whereas El-Shamy et al. assessed shoulder abduction and external rotation only. Karas et al. reported shoulder flexion, forearm pronation, and wrist flexion ROM improved significantly in VR group after the treatment. However, the result is conflicting in terms of shoulder abduction and external rotation ROM among studies. Karas et al. found significant improvement in shoulder abduction and external rotation ROM in conventional physiotherapy group whereas El-Shamy et al. found significant improvement in VR group. Between group comparison indicated that shoulder external rotation ROM increased significantly in the conventional physiotherapy group whereas shoulder abduction, external rotation, and forearm pronation ROM improved significantly in the VR group (13,14).

Active Movement Scale (AMS)

Only Karas et al. used AMS to evaluate shoulder functions. According to their findings, although shoulder internal rotation improved significantly in the VR group, no significant difference was found between VR and conventional physiotherapy group in terms of shoulder flexion, abduction, and external-internal rotation movements (14).

Shoulder Muscle Strength

Only El-Shamy et al. evaluated shoulder abductors and external rotator muscle strength using a handheld dynamometer. The shoulder muscle strength improved significantly in VR group as compared to conventional physiotherapy group (13).

Upper Extremity Functions

Yeves- Lite et al. evaluated spontaneous use of the affected upper limb by using CHEQ. Compared to conventional physiotherapy group, VR group showed a significant improvement in the use of the affected hand grasp and independent tasks component of CHEQ whereas, the conventional physiotherapy group did not show improvement in any component of CHEQ (16). Tarakci et al. assessed hand function using JTHFT. Both groups improved significantly in JTHFT score after treatment with no statistical difference between the groups (15). In the same study, Tarakci et al. measured hand dexterity using 9HPT. Both groups demonstrated

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statistically significant improvement in 9HPT after treatment with no statistical difference between the groups (15).

Grip Strength

Tarakci et al. measured hand grip strength using a standard hand dynamometer. Both groups showed statistically significant improvement in grip strength after treatment with no statistical difference between the groups (15). In the same study, Tarakci et al. measured pinch strengths (tip, lateral and triple grip) using a hydraulic pinch gauge. Both groups showed statistically significant improvement in pinch strengths except for lateral pinch grip in control group. There were no statistical differences between the groups (15).

Table 2. Methodological Quality Assessment of RCTs Using PEDro Scale.

Studies	**Items**											**Total point**
	1	2	3	4	5	6	7	8	9	10	11	
Karas et al. (14)	1	1	1	1	0	0	1	1	0	1	1	7
El-Shamy et al. (13)	1	1	1	1	0	0	0	1	0	1	1	6
Yeves-Lite et al. (16)	1	1	0	0	0	0	1	0	0	1	1	5
Tarakci et al. (15)	1	1	1	0	1	0	1	0	0	1	1	6

1: Eligibility criteria specified, 2: Random allocation, 3: Concealed allocation, 4: Baseline comparability, 5: Subject blinding, 6: Therapist blinding, 7: Assessor blinding, 8: Less than 15% dropouts, 9: Intention-to-treat analysis, 10: Between-group statistical comparisons, 11: Point measures and variability dat

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Table 3. Characteristics of the studies in the systematic review

Author, Year	Study Design	N (IG/CG)	Participants	Affected Side	Interventions	Outcomes measures	Results
Karas et al. (14) 2022	RCT	22 (11/11)	22 children Male (n= 11) Female (n=11)	Left: 11 Right: 11	IG: VR using Nintendo Wii games + PT program, 40 min, 2 days/week for 6 weeks. CG: PT program (NMES, strengthening exercises, passive, active, active-assistive ROM and stretching, scapula mobilization exercises)	-MSS -ROM -AMS	There was no significant difference in the MSS values of either groups before and after treatment (p>0.05). After the treatment, significant improvement was found in shoulder abduction and externeal rotation ROM in comparison group whereas, shoulder flexion, forearm pronation and wrist flexion ROM showed significant improvement in intervention group (p<0.05). Between group analyisis indicated that shoulder external rotation ROM improved significantly in the comparison group (p<0.05) whereas forearm pronation ROM improved significantly in the intervention group (p<0.05). There was only shoulder internal rotation was increased significantly after the treatment in AMS in the intervention group (p<0.05) and no significant difference was found between the groups. (p>0.05).
Yeves-Lite et al. (16) 2020	RCT	12 (6/6)	12 children Male (n= 6) Female (n= 6)	Left: 4 Right: 8	IG: VR MT 20 min, 3 days/week for 4 weeks. CG: Conventional MT	-CHEQ	After the treatment, statistically significant inter-group and intra-group differences were only obtained for the variable independent tasks and use of the affected hand with grasp in the intervention group (p<0.05).

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Continuation of Table 3.

Tarakci et al. (15) 2020	**RCT**	**19 (9/10)**	**19 children Male (n= 8) Female (n= 11)**	**Left: 2 Right: 17**	**IG: VR using Leap Motion Controller-Based Training, 1 hour, 3 times/week for 8 weeks. CG: PT program (Grasp and release activities using a sensorimotor approach)**	**-JTHFT -9HPT -Grip strength -Pinch strengths**	**The changes after treatment in all outcome measures were statistically significant for intervention group ($p<0.05$) whereas, all outcome measures except for lateral pinch grip were statistically significant in the comparator group ($p<0.05$). There were no significant differences between the groups according to intergroup analysis ($p<0.05$).**
El-Shamy et al. (13) 2017	**RCT**	**40 (20/20)**	**40 children Male (n= 27) Female (n=13)**	**Left: 15 Right: 25**	**IG: VR using Armeo® spring, 45 min, 3 times/week for 12 weeks. CG: PT program (Weight-bearing, joint approximation, PNF, scapulothoracic mobilization, strengthening exercises, active arm-hand exercises and stretching)**	**-MSS -ROM -Shoulder muscle strength**	**After the treatment, there were statistically significant differences between the mean values of Mallet scores ($p<0.05$). Intergroup analysis revealed that all the outcome of the Mallet scale except shoulder abduction was significantly better in the intervention group ($p<0.05$). Inter- and intra-group analysis revealed that a statistically significant difference was observed in abduction and external rotation ROM in the intervention group ($p<0.05$).**

Abbreviations: RCT, Randomized Controlled Trial; IG, Intervention Group; CG, Comparator Group; VR, Virtual Reality; PT, Physical Therapy; NMES, Neuromuscular Electrical Stimulation; MT, Mirror Therapy; PNF, Proprioceptive Neuromuscular Facilitation; MSS, Mallet Scoring System; ROM, Range of Motion; AMS, Active Movement Scale; CHEQ, Children Hand-use Experience Questionnaire; JTHFT, Jebson Taylor Hand Function Test; 9HPT, Nine-Hole Peg Test.

Discussion

The studies included in this review widely varied in terms of intervention types and durations. Therefore, it is quite difficult to be able to evaluate which treatment approach is more effective and the optimal duration of treatment. This paper systematically reviewed the effectiveness of the VR applications in children with OBPI and reported the methodological procedures and main effects related to outcomes. Results were obtained from four randomised controlled studies that compared individual or additional effects of different therapeutic modalities with conventional physical therapy interventions. Our review showed that the VR applications alone or in combination with physical therapy interventions are effective in improving range of motion, upper limb functions, and muscle strength in children with OBPI.

VR applications are a treatment method that is used quite often nowadays. VR has shown to be beneficial for the treatment of OBPI in all of the studies included in this systematic review. Injury to the brachial plexus leads to a decrease in motor performance and in the ability of the upper limb to activity (17). In children with OBPI, the active ROM loss. At the same time, cause to the injured nerves, muscle weakness and a decrease in the functional capacity of the upper extremities are observed (18). Depending on this, the common problems of OBPI are the limitations of activities of daily living (ADLs) such as, feeding, personal care, and dressing that use upper extremity are commonly limited in children and adolescents (19). Therefore, it is important to increase motor performance in rehabilitation. VR applications are a method based on the basics of motor learning and neuroplasticity, therefore helping to improve upper extremity motor performance and motor control (20). Because of that using VR applications in children with OBPI can be considered an effective method. At the same time, these applications enhance children's motivation and participation (7,21,22).

We identified a study (13) that employed VR in combination with a robotic system. The potential to adjust the accuracy, fluency, and speed of movement, apply the principles of motor learning with more repetitions, increasing the persistence of the accurate movement are the primary advantages of using robot technologies in rehabilitation (23,24). Conventional rehabilitation therapy programs are shorter and less intensive to ensure optimal therapeutic results. Furthermore, they seem to be unable to sufficiently increase the child's motivation or encourage activity participation (25). As a result, combining VR and robotics in rehabilitation can improve the efficacy of treatment in children with OBPI.

El- Shamy et al. (13) and Karas et al. (14) use MSS, shoulder abduction and shoulder extansion ROM for outcome measures. El- Shamy et al. (13) found significant difference in MSS, shoulder abduction and external rotation in intervention group, but Karas et al. (14) found significant difference in control group. El- Shamy et al. (13) used VR with robotic devise, Armeo spring whereas Karas et al. (14) used VR without robotic devise. The armeo spring is a robot that has an exoskeleton structure, which allows passive shoulder movements to be performed and aims to strengthen the patient (26). Armeospring is a robot that can improve upper extremities motor function and skills (27). For this reason, combined VR and robotics in OBPI treatment can be more effective compared only VR. Tarakci et al. (15) used Leap Motion Controller (LMC) based training with VR applications. They found significant difference favour in invervention group. Leap Motion-based virtual reality training could facilitate cortical reorganization and might facilitate the motor function and motor recovery of upper limb (28). LMC allows a patient to move fingers and hands without mechanical restrictions. When combined LMC and virtual reality games, patients seems therapy more fun (29,30).

Targeted functional training can enhance motor function in children with motor impairment. Variations in repetitive movements and enriched environments have a significant impact on children's motivation and, as a result, the intensity and efficacy of training (31). VR combined with robotics can provide this treatment intensity and enhanced environment, making it valuable in rehabilitation.Yeves-Lite et al. (16) used VR with Mirror Therapy. Although mirror therapy is mostly used in adults, studies have shown that it enhances motor reorganization in hemiparetic children and that its usage will increase upper extremity function (32,33). Mirror therapy uses visual feedback to increase upper limb motor recovery by activating different brain regions. However, the underlying mechanism is still debatable (34).

The number of studies investigating the impact of VR applications on children with OBPI is quite limited. Likewise, the sample size in these investigations was small. Furthermore, we do not know the long-term consequences of these treatments. Future studies should incorporate a bigger sample size and longer follow-up periods.

Conclusion

This is the first systematic review to evaluate the effectiveness of VR applications in children with OBPI. Our review showed that the VR applications are beneficial to children with OBPI, particularly in the range of motion, upper limb functions, and muscle strength. These interventions can also improve ADL performance since they are motivating and enjoyable. The evidence was supported by a small number of studies with good methodological quality. However, studies with a high quality, the larger sample size of patients with OBPI and evaluation of the long-term consequences are required.

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