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IMPACT OF VIRTUAL REALITY-BASED TASK-ORIENTED MOTOR TRAINING ON UPPER-LIMB MOTOR CONTROL AND FUNCTIONAL INDEPENDENCE IN CHILDREN WITH SPASTIC CEREBRAL PALSY

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ABSTRACT

Objective: Virtual reality offers motivating, repetitive, task-oriented practice, but evidence for its effect on upper-limb motor control and everyday independence in children with spastic cerebral palsy (CP) is mixed, and local data are scarce. This study aimed to evaluate the impact of VR-based task-oriented motor training on upper-limb motor control and functional independence in children with spastic CP.

Methods: A two-arm, assessor-blinded, parallel-group randomized controlled trial was designed for children aged 4–8 years with spastic CP (MACS levels II–IV). The experimental group receives VR-based task-oriented training plus conventional therapy; the control group receives conventional occupational therapy of matched duration. Sessions are 45 minutes, 5 days per week for 8 weeks. The primary outcome is upper-limb motor control measured by the Quality of Upper Extremity Skills Test (QUEST; dissociated movement and grasp domains). Functional independence is measured by the WeeFIM self-care domain. Assessments occur at baseline, post-intervention and 3-month follow-up. Sample size is 60 (30 per arm), allowing 15% attrition.

Results: participants analysed, between-group differences in QUEST and WeeFIM with 95% CI, effect sizes, adherence, adverse events

Conclusions: Upper-limb motor control assessed using the QUEST (dissociated movement and grasp domains), with functional independence measured by the WeeFIM self-care domain at baseline, post-intervention, and 3-month follow-up.

Keywords: Cerebral Palsy; Spastic; Virtual Reality; Task-Oriented Training; Upper Limb; Motor Control; Functional Independence; QUEST; WeeFIM

1. INTRODUCTION

Cerebral palsy is a permanent but non-progressive disorder of movement and posture caused by disturbance of the developing brain, and it is the most common physical disability of childhood [1,2]. Spastic CP is the most prevalent subtype. Increased muscle tone, weakness and poor selective motor control disrupt reaching, grasping and in-hand manipulation, and limit self-care, schooling and play.

Task-oriented training, which practises meaningful functional tasks with graded difficulty, is among the best-supported principles in paediatric neurorehabilitation [3]. Its effects rest on motor-learning and experience-dependent plasticity: practice that is repetitive, salient, challenging and rewarded drives reorganisation of motor circuits [4,5]. The practical difficulty is dose and engagement. Children tire of repetitive drills, and therapist time is limited.

Virtual reality addresses part of this problem. VR platforms provide immersive or screen-based environments in which the child performs goal-directed movements with immediate visual and auditory feedback, adjustable difficulty and game-based motivation [6,7]. Meta-analyses and systematic reviews report that VR can improve upper-extremity function in children with CP, although trial quality, interventions and outcome measures vary widely and the certainty of evidence is moderate to low [8,9,10]. Early case work with commercial gaming consoles showed that such systems are feasible and acceptable to children with CP [11]. Fewer studies measure both movement quality (motor control) and daily-life independence, and Indian data are limited.

The key question for clinics is whether VR-based task-oriented training adds measurable benefit in motor control and in functional independence beyond conventional therapy. Motor control gains that do not carry into self-care have limited value to families, while independence outcomes alone do not show whether movement quality changed.

2. RATIONALE OF THE STUDY

In the host institution's own cohort, a structured task-specific bimanual programme produced large gains on every QUEST domain in 50 children with CP aged 4–8 years (Table 1) [12]. This shows that intensive, task-specific practice works locally and that QUEST detects change in this population. That cohort used manual, therapist-delivered tasks and had no control group. It cannot show whether technology-based delivery adds value, or whether motor gains translate into independence.

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2.1 Limitations of Existing Evidence

Existing VR trials commonly differ in platform (commercial consoles, custom systems, immersive headsets), dose and comparator. Many report motor outcomes only, and few pair a movement-quality measure with a functional-independence measure. Children with moderate-to-severe manual limitation (MACS III–IV) are underrepresented.

2.2 Rationale for the Present Study

This trial applies a standardised, progressive VR task-oriented protocol with matched supervised dose against conventional therapy. It measures motor control (QUEST) and functional independence (WeeFIM) together in the same children, including those with moderate-to-severe manual limitation, and follows them for 3 months. The results are intended to inform whether VR is worth adding to routine upper-limb programmes.

3. AIM AND OBJECTIVES

3.1 Aim

To evaluate the impact of VR-based task-oriented motor training on upper-limb motor control and functional independence in children with spastic CP.

3.2 Objectives

- To describe demographic and clinical characteristics, including MACS level, of participants in each group.
- To compare change in upper-limb motor control (QUEST dissociated movement and grasp) between groups after intervention.
- To compare change in the remaining QUEST domains (weight bearing, protective extension) between groups.
- To compare change in functional independence (WeeFIM self-care) between groups.
- To examine the association between change in motor control and change in functional independence.
- To examine retention of gains at 3-month follow-up.

3.3 Hypotheses

- **H_0:** VR-based task-oriented training plus conventional therapy produces no greater improvement in upper-limb motor control or functional independence than conventional therapy alone.
- **H_1:** VR-based task-oriented training plus conventional therapy produces significantly greater improvement in upper-limb motor control and functional independence than conventional therapy alone.

4. METHODOLOGY

4.1 Study Design

A randomized, assessor-blinded, two-arm parallel-group controlled trial, reported according to CONSORT [13]. Allocation is 1:1 by computer-generated block randomization with concealed allocation. Participants and therapists cannot be blinded; the outcome assessor is blinded to group.

4.1.1 Participants, Eligibility and Setting

Participants are recruited by convenience sampling from a rehabilitation centre. Written informed consent is obtained from the guardian, and ethical approval is obtained before enrolment.

Inclusion criteria:

- Age 4–8 years, either sex
- Diagnosis of spastic CP (unilateral or bilateral)
- MACS level II–IV [14]
- Spasticity grade ≤ 3 in the upper-limb muscles on the Modified Ashworth Scale [15]
- Able to follow simple instructions and attend to a screen-based task for at least 10 minutes
- Guardian consent and commitment to attend, with no planned relocation during the study

Exclusion criteria:

- Dyskinetic or ataxic CP
- Botulinum toxin injection or upper-limb surgery in the previous 6 months
- Fixed contracture compromising passive upper-limb range of motion
- Uncontrolled epilepsy, photosensitive seizures, or major visual or hearing impairment
- Severe cognitive impairment preventing participation
- Cardiorespiratory or rheumatic comorbidity
- Guardian consent not obtained

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4.1.2 Sample Size

In the reference cohort, the QUEST dissociated movement and grasp domains changed by 7.2 and 8.2 points with SDs of change of 3.4 and 3.8 (Table 1). A between-group difference of d = 0.8 (two-sided α = 0.05, power 80%) requires 26 children per group [16]. Adding 15% for attrition gives 30 per group (N = 60).

4.1.3 Interventions

Both groups attend 45-minute supervised sessions, 5 days per week for 8 weeks (40 sessions, 30 hours).

Experimental group — VR-based task-oriented training (VR-TOT). Each session has a 5-minute warm-up, 30 minutes of VR task practice and 10 minutes of cool-down with a functional transfer task. VR games or tasks are selected to target reaching, grasp and release, wrist and forearm movement, and bimanual cooperation, with difficulty progressed by speed, accuracy, target size and range. Therapists supervise posture, give feedback and pace rests. Session records include game, level, time on task and number of repetitions. **[Insert platform: name, hardware, and game list.]**

Control group — conventional occupational therapy. Dose-matched therapist-led upper-limb activities such as play-based reaching, grasping, stacking, stringing beads, dough play, fastening clothing and scissors tasks, without VR [12].

Both groups receive the same caregiver home-practice instructions and diary.

4.1.4 Outcome Measures

- **MACS** (screening only): five-level classification of how children handle objects in daily life [14].
- **QUEST** (primary): 36 items across four domains (dissociated movement, grasp, protective extension, weight bearing); valid for ages 18 months to 8 years; 30–45 minutes [17,18]. Motor control is represented by the dissociated movement and grasp domains.
- **WeeFIM** (secondary): caregiver-reported measure of functional independence in self-care, mobility and cognition; the self-care domain is the key endpoint [19].

Assessments are done at baseline (T0), after 8 weeks (T1) and at 3 months (T2) by a blinded therapist.

4.1.5 Procedure

Children are screened with the MACS and spasticity grade, enrolled, assessed at T0, randomized, treated, and reassessed at T1 and T2. Forms are checked for completeness, coded and entered into a master database. Adverse events (visual fatigue, dizziness, shoulder or wrist discomfort, frustration) and session attendance are recorded.

4.2 Statistical Analysis

Data are analysed with IBM SPSS Statistics version 29, on an intention-to-treat basis. Descriptives summarise baseline data. Normality is checked with the Shapiro–Wilk test. Between-group differences at T1 are tested with ANCOVA adjusted for baseline score and MACS level; non-normal outcomes use the Mann–Whitney U test on change scores, with Wilcoxon signed-rank and paired t-tests within groups. Repeated measures across T0–T2 use a mixed-design ANOVA. The association between QUEST change and WeeFIM change is tested with Pearson or Spearman correlation. Effect sizes are reported as Cohen's d or Hedges' g with 95% confidence intervals; significance is set at $p < 0.05$, with Bonferroni adjustment across the four QUEST domains.

5. RESULTS

All cells in bold brackets are placeholders for trial data.

5.1 Reference Data from the Host Institution (Task-Specific Bimanual Training, n = 50)

The values below come from the thesis and are shown only to justify the sample size and show local responsiveness of QUEST. They are not trial results.

Table 1. QUEST domain scores before and after HABIT in the reference cohort (n = 50)

QUEST domain	Pre mean (SD)	Post mean (SD)	Mean change (SD of change)	Cohen's d (paired)
Dissociated movement	45.36 (2.64)	52.54 (3.33)	7.18 (3.43)	2.10
Grasp	29.46 (6.04)	37.68 (5.95)	8.22 (3.75)	2.19
Weight bearing	26.10 (7.38)	33.40 (6.30)	7.30 (3.30)	2.21
Protective extension	25.34 (2.57)	31.06 (2.60)	5.72 (2.30)	2.48

The thesis text labels the SD of the paired differences (3.427, 3.754, 3.303, 2.304) as "Cohen's d". The true paired effect sizes are those in the last column, which match the thesis's own SPSS output (−2.095 to −2.483). Because that cohort had no control group, these effects also include maturation, practice and regression effects and should not be used as expected between-group effects.

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6. DISCUSSION

Reviews report that VR can improve upper-extremity function in children with CP, with variable effect sizes and moderate-to-low certainty [8,9,10]. **Mechanisms.** VR delivers many goal-directed repetitions with immediate feedback, adjustable difficulty and reward, features that support motor learning and experience-dependent plasticity [4,5,6]. Transfer from virtual tasks to real objects is not automatic, which is why the protocol ends each session with a real-world transfer task [6].

Motor control and independence. [Discuss whether QUEST gains were accompanied by WeeFIM gains. If motor control improved but independence did not, consider the short trial duration, caregiver-reported scoring, and the need for goal-based or participation-level measures.

7. CONCLUSION

If the data support it, a conclusion in the sample paper's style would read: "VR-based task-oriented training [did / did not] produce greater improvement in upper-limb motor control and functional independence than conventional therapy in children with spastic CP. As the findings come from a single-centre trial, larger multicentre studies with longer follow-up are needed.

Limitations

- Single-centre, convenience-based recruitment limits generalisability.
- Therapists and participants cannot be blinded to VR use.
- WeeFIM is caregiver-reported and may be influenced by expectations.
- Follow-up is limited to 3 months.
- Findings apply to the chosen platform and protocol and to ages 4–8 years.
- The sample-size calculation assumes d = 0.8; smaller true differences would need larger trials.

Recommendations

Future work should test home-based and tele-supervised VR, compare VR with equal-dose, equally engaging non-VR task practice, add kinematic and participation outcomes, and report cost per child.

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