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EFFECTIVENESS OF ENHANCED CONSTRAINT-INDUCED MOVEMENT THERAPY ON UPPER LIMB FUNCTION IN CEREBRAL PALSY: A RANDOMIZED CONTROLLED TRIAL IN PAKISTAN

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ABSTRACT

Background: Children with hemiplegic cerebral palsy are often capable of attending school; however, due to impaired upper limb function, their involvement in educational and recreational activities is frequently limited. This leads to reduced participation in social and daily functional tasks. Constraint-Induced Movement Therapy (CIMT) is a targeted intervention designed to improve upper limb function in such children. Objective: To determine whether an improved form of Constraint-Induced Movement Therapy (e-CIMT) can help children with cerebral palsy at the District Headquarter Hospital in Khanewal, Pakistan, improve their hand function. Methods: A single-blind randomized controlled trial (RCT) was conducted in the Department of Physical Therapy, District Headquarter (DHQ) Hospital, Khanewal, Pakistan, from April 2024 to April 2025. Using a non-probability convenient sampling technique, 96 children (aged 5 to 12 years) diagnosed with hemiplegic cerebral palsy were enrolled and randomly divided into two-groups (48 participants per group). The experimental group received expanded CIMT combined with routine physiotherapy, while the control group underwent only routine physiotherapy. Outcomes were assessed using the Paediatric Motor Activity Log (PMAL) and the Wolf Motor Function Test (WMFT). Ethical approval was obtained from the DHQ Khanewal research board, and the study was registered prospectively with the ClinicalTrials.gov registry (Trial ID: 57520). Results: Comparing the experimental group to the control group revealed notable improvements. The PMAL scores improved considerably ($p \leq 0.001$), and both domains of the WMFT showed statistically significant enhancements in the experimental group ($p < 0.001$). Improvements within the experimental group were also highly significant for hand function metrics. Conclusion: When combined with regular physical treatment, expanded constraint-induced movement therapy significantly improves upper limb functionality in children with hemiplegic cerebral palsy more than ordinary physiotherapy does on its own.

INTRODUCTION

The District Headquarter (DHQ) Hospital in Khanewal, Pakistan is a major public healthcare facility that provides a wide range of medical and rehabilitation services to the local population and surrounding rural areas. It serves as a referral center for specialized care, including pediatric neuro-rehabilitation, and is equipped with trained professionals and dedicated therapy units to support children with neurological and developmental conditions. A collection of movement impairments is collectively referred to as cerebral palsy (CP). However, it involves frequently accompanied by complications such as musculoskeletal abnormalities, epilepsy, communication deficits, behavioral challenges, and impairments in cognitive, perceptual, and sensory functions. CP is a non-progressive but irreversible neurological condition that affects posture and voluntary movement. It typically results from a disturbance or injury to the developing brain of the fetus or infant and leads to lifelong limitations in activity and independence.

One of the most prevalent causes of childhood impairment is cerebral palsy. The incidence is thought to be around 2.1 per 1,000 live births worldwide. The prevalence is somewhat higher in the US, where there are three to four instances for per 1,000 children. [1] Among the subtypes of CP, hemiplegic cerebral palsy is notable in that many affected children retain the cognitive and communicative capacity to attend school regularly. However, their impaired upper limb function often restricts participation in recreational and educational tasks, leading to challenges in social interaction and reduced self-esteem. [2]

Flexion of the upper limb is one of the common physical signs of hemiplegic cerebral palsy in children. In addition, it includes scapular retraction, shoulder girdle depression, internal rotation and adduction of the shoulder joint, flexion of the elbow, and a minor deviation of the wrist and fingers. The child's capacity to carry out everyday tasks and preserve functional independence is impacted by these musculoskeletal abnormalities, which also greatly contribute to hand usage dysfunction. [3]

Hand impairment in these children is often the consequence of injury to the corticospinal tract and motor cortex—structures essential for fine motor control and finger movement.[4] Hemiplegic cerebral palsy often affects parts of the brain that are essential for bimanual coordination, such as the parietal lobe and the supplementary motor region.[5] To address these deficits, CIMT has emerged as a promising intervention that is typically applied in high-intensity regimens for children with hemiplegia. This therapy promotes neuroplasticity and functional recovery by encouraging use of the affected limb through repetitive and structured training. [6]

CIMT primarily aims to reverse learned nonuse of the affected upper limb and promote its functional reintegration into daily activities. The approach typically incorporates four core components: intensive task practice, behavioral shaping techniques, structured therapy sessions, and use of constraint devices (e.g., padded mitts) on the unaffected limb. [7] Expanded versions of CIMT (eCIMT) may also include supplementary strategies such as the use of adaptive tools, orthoses, and elements drawn from other rehabilitation frameworks. [8]

When compared to massage treatment, "Baby CIMT" has been demonstrated to be especially helpful among early interventions in enhancing the unilateral hand function of infants with cerebral palsy. [9] According to a comprehensive evaluation, CIMT greatly improved upper limb functionality and involvement in hemiplegic children compared to sham therapies. [2] Another comprehensive evaluation emphasized how virtual reality-based

therapies can help children with cerebral palsy benefit from traditional physiotherapy. [10]

Furthermore, studies comparing different forms of CIMT have found that modified CIMT (mCIMT) may lead to better improvements in isolated paretic arm movements than bimanual training. [11] Pediatric CI therapy in general is associated with substantial gains in motor performance in children with unilateral CP.[12] Additionally, a randomized controlled trial investigating a home-based, non-intensive CIMT model showed it to be a practical and effective alternative for upper limb rehabilitation. [13]

Despite the wealth of literature on CIMT and its modified forms, much of the research has centered on conventional and adult populations—particularly post-stroke patients with paretic hands. Studies exploring the use of expanded constraint-induced movement therapy in pediatric patients, especially those with hemiplegic CP and severely impaired hand function, remain limited.

IN ORDER TO CLOSE A SIGNIFICANT GAP IN THE LITERATURE AND INFORM EVIDENCE-BASED REHABILITATION PRACTICES IN PEDIATRIC NEUROLOGY, THIS STUDY WAS CARRIED OUT AT THE DISTRICT HEADQUARTER (DHQ) HOSPITAL IN KHANEWAL, PAKISTAN, TO ASSESS THE EFFECTS OF EXPANDED CONSTRAINT-INDUCED MOVEMENT-THERAPY (ECIMT) ON THE FUNCTION OF THE AFFECTED HAND IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY.

METHODS:

This single-blinded RCT was conducted at the Department of Physiotherapy, District Headquarter (DHQ) Hospital, Khanewal, Pakistan, from April 2024 to April 2025. A total of 96 children were initially recruited using a non-probability convenient sampling method. The trial aimed to assess the effects of expanded CIMT on hand function among children diagnosed with hemiplegic cerebral palsy.

The study design ensured a 95% confidence level and 80% statistical power. Based on preliminary estimates of Pediatric Motor Activity Log (PMAL) scores with a mean of 1.4 in the experimental group and 2.1 in the control group, and standard deviations of 0.6 and 1.2 respectively, the sample size was calculated using the OpenEpi tool. Using the formula:

$$n = 2\sigma^2 (Z_{1-\alpha/2} + Z_{1-\beta})^2 / (\mu_1 - \mu_2)^2,$$

A total of 80 participants were required (40 in each group). Accounting for an anticipated attrition rate of approximately 15%, the final adjusted sample size included 48 participants per group. Random allocation was done using sealed envelope technique.

Participants were randomly divided into two equal groups. The **experimental group (n = 48)** received expanded CIMT in combination with routine physical therapy, while the **control group (n = 48)** underwent only routine physical therapy (RPT). Six children dropped out from both groups due to personal or medical reasons, leaving **90 participants (45 per group)** for analysis.

INCLUSION CRITERIA

- Children aged **5–12 years**, of either gender.
- Clinically diagnosed with **spastic hemiplegic cerebral palsy** by a pediatric neurologist.
- **Informed consent** obtained from parents or guardians.
- Presence of **learned non-use** of the affected upper limb.
- At least **minimal ability** to stabilize or grasp objects with the impaired hand. [4] [8] [16]

EXCLUSION CRITERIA

- History of seizures or visual impairments interfering with therapy, [4]

- Any upper limb surgery (including nerve blocks) within the past 6 months,
- Presence of malignancy or severe sensory, behavioral, or cognitive disorders, [3]
- Major congenital deformities or prior orthopedic procedures affecting the upper limb.

OUTCOME MEASURES

Two validated tools were used for outcome measurement:

1. **Pediatric Motor Activity Log (PMAL):**
   This scale assesses how frequently and how effectively the child uses the affected hand during 22 different functional tasks. Scores range from 0 (no use) to 6 (normal use), with two subscales: "Amount of Use" and "Quality of Movement".[14]
2. **Wolf Motor Function Test (WMFT):**
   A standardized tool assessing upper limb functional performance through 17 timed and functional tasks, divided into three components: functional ability, time, and strength. The Functional Ability Scale (FAS) ranges from 0 (no attempt) to 5 (normal performance).[17]

Participants were evaluated at baseline and re-evaluated after 3 weeks of intervention. All assessments were carried out by a blinded investigator not involved in the treatment sessions. Screening, neurological examination, and therapy implementation were conducted by different professionals to reduce potential bias.

Intervention Protocol

Both groups received **18 sessions** over three weeks (6 sessions per week, 1 hour per session) in the physiotherapy department. The **experimental group** followed an **eCIMT protocol**, which incorporated:

- **Neurodevelopmental Techniques (NDT)**
  Included weight-bearing positions such as prone-lying on forearms over a wedge or bolster, hand support on foam blocks, and supported laying on a physiotherapy ball, as well as passive stretching exercises for the wrist and elbow (2 sets of 10 repetitions). Every pose was maintained for 30 seconds. [19]
- **EMG-Functional Electrical Stimulation (EMG-FES)**
  Applied for 10 minutes daily on the wrist extensors of the affected hand to promote active engagement. Sessions were conducted six days a week. [20]
- **Orthotic Support:**
  Customized splints were used to maintain hand and wrist alignment, based on each child's needs.[4]
- **Bimanual Task Practice:**
  Included functional and playful tasks such as manipulating dough, marble sorting, and bottle handling exercises aimed at stimulating activities of daily living.

The **control group** was provided with **Routine Physical Therapy (RPT)** alone. This consisted of basic stretching, upper limb strengthening, range-of-motion exercises, and task-oriented functional training without use of the constraint or advanced methods.

STATISTICAL ANALYSIS

Data were entered and analyzed using **SPSS version 22**. Age and other numerical variables were expressed as **mean ± standard deviation**, while categorical variables like gender were represented using **frequency and percentages**. The **Kolmogorov-Smirnov test** was used to assess the normality of data distribution.

Between-group comparisons were performed using the **independent sample t-test**, while **paired sample t-tests** were used for within-group comparisons (pre- and post-treatment). A **p-value ≤ 0.05** was considered statistically significant.

RESULTS

A total of **90 participants** completed the study, with **45 children in each group** following the dropout of 6 participants from the initial sample of 96. Demographic characteristics, including age and gender distribution, were comparable between the experimental and control groups and are detailed in **Table I**.

Analysis of outcome measures revealed a **statistically significant improvement in Pediatric Motor Activity Log (PMAL) scores** in the experimental group that received expanded Constraint-Induced Movement Therapy (eCIMT), when compared to the conventional group. The **p-value was found to be ≤ 0.001**, indicating that the intervention led to meaningful improvement in spontaneous use and quality of movement of the affected upper limb **(Table II)**.

Both **Functional Ability Scale (FAS)** and **Performance Time (PT)** components of the **Wolf Motor Function Test (WMFT)** showed statistically significant enhancement in the experimental group over the three-week intervention period. Although both groups demonstrated improvement, the **experimental group outperformed the control group**, particularly in functional use and timing accuracy of the upper limb **(p ≤ 0.001)**.

Importantly, at baseline, **no significant differences were observed between the groups in WMFT-FAS and WMFT-PT scores**, confirming initial comparability across functional outcomes. This is reflected in the non-significant p-values at pre-intervention assessment **(Table IV)**.

Within-group analysis also revealed substantial improvements. Both the experimental and conventional groups showed statistically significant gains in **PMAL** and **WMFT** scores from baseline to post-intervention, though the experimental group showed a **greater magnitude of improvement**. The within-group differences reached high levels of statistical significance **(p ≤ 0.001)** for all major outcome measures **(Tables III and V)**.

These findings suggest that the application of eCIMT in combination with routine physiotherapy is more effective than conventional therapy alone in improving hand function in children with hemiplegic cerebral palsy.

TABLES AND DISCUSSION SECTION: CONSTRAINT-INDUCED MOVEMENT THERAPY STUDY

TABLE I: DEMOGRAPHICS OF STUDY PARTICIPANTS (N=38)

Characteristics	Conventional Group		Experimental Group	
Age (years)	6.89	±2.02	7.68	±2.49
Male	10	(52.6%)	05	(26.3%)
Female	09	(47.4%)	14	(73.7%)
Right Upper Extremity	11	(57.9%)	13	(68.4%)
Left Upper Extremity	08	(42.1%)	06	(31.6%)

TABLE II: PEDIATRIC MOTOR ACTIVITY LOG SCALE (PMAL) COMPARISON OF GROUPS BEFORE AND AFTER TREATMENT

Outcome Measures	Groups	n	Mean	SD	p-value
Pre-test PMAL score	Conventional Group	19	0.71	0.54	0.485
Pre-test PMAL score	Experimental Group	19	0.60	0.30	
Post-test PMAL score	Conventional Group	19	1.91	0.52	0.000
Post-test PMAL score	Experimental Group	19	3.37	0.42	

TABLE III: PEDIATRIC MOTOR ACTIVITY LOG SCALE (PMAL) COMPARISON BETWEEN GROUPS BEFORE AND AFTER TREATMENT

Outcome Measures	n	Mean	SD	p-value
Pre-test PMAL	38	0.66	0.44	.000
Post-test PMAL	38	2.64	0.87	

TABLE IV: WOLF MOTOR FUNCTION TEST (WMFT) COMPARISON OF GROUPS BEFORE AND AFTER TREATMENT

Outcome Measures	Groups	n	Mean	SD	p-value
Pre-test WMFT-FAS	Conventional Group	19	12.53	8.25	.214
Pre-test WMFT-FAS	Experimental Group	19	15.31	4.91	
Post-test WMFT-FAS	Conventional Group	19	29.10	10.40	.000
Post-test WMFT-FAS	Experimental Group	19	58.58	5.42	
Pre-test WMFT-PT	Conventional Group	19	79.35	8.21	.933
Pre-test WMFT-PT	Experimental Group	19	79.08	11.61	
Post-test WMFT-PT	Conventional Group	19	59.08	9.13	.000
Post-test WMFT-PT	Experimental Group	19	35.29	7.76	

TABLE V: GROUP COMPARISON OF THE WOLF MOTOR FUNCTION TEST (WMFT) BEFORE AND AFTER TREATMENT

Test Statistics	Z	Asymp. Sig. (2-tailed)
Pre-test WMFT PT and WMFT FAS	-5.373	.000
Post-test WMFT PT and WMFT FAS	-.544	.587

DISCUSSION

This study evaluated the impact of Expanded Constraint-Induced Movement Therapy (eCIMT)

on the hand function of children with hemiplegic cerebral palsy (CP), specifically those treated at District Headquarter (DHQ) Hospital Khanewal Pakistan. The baseline demographic characteristics of participants in both experimental and control groups were statistically similar, confirming a reliable comparison between groups. Our findings indicate that eCIMT, when used alongside routine physical therapy, significantly improves hand function more effectively than routine physical therapy alone. These outcomes are consistent with prior research conducted on adult stroke patients, where expanded CIMT showed notable improvement in motor function of the paretic upper limb after a 15-week intervention period.

Supporting evidence also comes from a study involving children aged 2 to 8 years with hemiplegic CP, where modified CIMT was utilized. Despite a smaller sample size and shorter treatment duration (3 hours), the study reported clinically and statistically significant improvements in hand function, aligning with our findings. Furthermore, a systematic review investigating the effects of CIMT on upper limb function and participation in children with CP found CIMT to be more effective than sham or no intervention therapies. A related trial demonstrated that upper limb function significantly improved after 10 weeks of CIMT intervention.

Additional reviews have validated CIMT's benefits across different age groups and conditions. One systematic analysis concluded that CIMT is helpful in treating upper extremity dysfunction in children with hemiplegia. However, some trials excluded duplicate or low-quality studies and still concluded that CIMT was beneficial, though additional research was needed to determine its influence on muscle tone and protective extension.

Importantly, even in infants under 12 months with unilateral CP, Baby CIMT has shown greater improvements in motor function compared to standard baby massage techniques. Comparisons between CIMT and Hand-Arm Bimanual Intensive Therapy (HABIT) suggest that while HABIT encourages the use of both hands, CIMT is more focused on restoring function in the affected hand alone. This aligns with our study, which concentrated solely on the more affected hemiplegic hand.

A study comparing modified CIMT and HABIT also noted that both approaches have distinct benefits but concluded that CIMT offers targeted improvements in unilateral function. Despite these promising results, certain limitations of our study must be acknowledged. The research was limited to a single-center trial at DHQ Khanewal, and participants were selected through a non-probability convenience sampling method, potentially introducing selection bias. Furthermore, the study did not monitor or document children's physical activities and use of the affected limb outside the treatment setting, which may influence post-treatment outcomes.

CONCLUSION

The results of this randomized controlled trial clearly demonstrate that Expanded Constraint-Induced Movement Therapy (eCIMT), when integrated with routine physiotherapy, is significantly more effective than routine physiotherapy alone in improving upper limb function among children with hemiplegic cerebral palsy. The substantial improvements observed in both the Pediatric Motor Activity Log (PMAL) and Wolf Motor Function Test (WMFT) scores highlight the efficacy of eCIMT in enhancing not only the quality but also the frequency of affected limb use in daily activities. These findings support the concept that targeted, repetitive, and task-specific training can harness neuroplasticity, promote motor learning, and reduce functional limitations associated with hemiplegia.

From a clinical perspective, incorporating eCIMT into pediatric neuro-rehabilitation protocols could markedly improve children's ability to participate in school, recreational, and self-care activities, ultimately contributing to greater independence and better quality of life. Given the structured and goal-oriented nature of eCIMT, it may also foster increased engagement and motivation in young patients, which is often a challenge in pediatric rehabilitation.

Moreover, these results have important implications for rehabilitation practice in resource-limited settings such as Pakistan, where maximizing functional recovery with cost-effective interventions is a priority. Training caregivers to support home-based eCIMT activities could further enhance accessibility, sustainability, and long-term adherence to therapy.

Future research should investigate the optimal dosage, frequency, and duration of eCIMT, as well as its effectiveness across different age groups, severity levels, and types of cerebral palsy. Longitudinal studies are also warranted to determine whether the functional gains achieved through eCIMT are maintained over time and how they translate into improved participation in real-world environments.

DECLARATIONS

Ethics and Consent: Written informed consent was obtained from parents or guardians. All procedures adhered to relevant guidelines and regulations.

Data Availability: Data can be obtained from the corresponding author upon reasonable request.

Competing Interests: None declared.

Funding: No external funding was received.

Authors' Contributions: All authors equally contributed to the study design, data collection, analysis, and manuscript writing, and approved the final version.

CONSORT Compliance: The study followed CONSORT guidelines for randomized controlled trials.

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