Title: Helping Kids with Hemiplegia Summer Camp: Effectiveness of Constraint-Induced Movement Therapy, Neurodevelopmental Therapy, and Lower Extremity Intervention Techniques
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Databases Searched: PubMed, CINHAL, EMBASE

Articles	**Abbreviations**
	CIMT = constraint-induced movement therapy CP = cerebral palsy UE = upper extremity RCT = randomized controlled trial mCIMT = modified CIMT hCIMT = hybrid CIMT OT = occupational therapy NDT = Neuro-Developmental Treatment OTs = occupational therapists PTs = physical therapists PT = physical therapy HABIT = hand-arm intensive bimanual therapy AHA = Kids-Assisting Hand Assessment MUUL = Melbourne Assessment of Unilateral Upper Limb Function QUEST = Quality of Upper Extremity Skills Test PEDI = Pediatric Evaluation of Disability Inventory COPM = Canadian Occupational Performance Measure BIM = bimanual training MAS = modified Ashworth Scale M2PD = Moving two-point discrimination JTTHF = Jebsen Taylor Test of Hand Function ADLs = activities of daily living IBT = intensive bimanual training GAS = Goal Attainment Scale GMFM = Gross Motor Function Measure GMFCS = Gross Motor Function Classification System 1MWT = 1-Minute Walking Test MTUGT = Modified Timed Up and Go Test PBS = Pediatric Balance Scale WeeFIM = Functional Independence Measure for Children SPCM = Seated Postural Control Measure LE = lower extremity HABIT-ILE = hand-arm intensive bimanual therapy including lower extremities MACS = Manual Ability Classification System 6MWT = Six Minute Walk Test BBT = Box and Blocks Test Life-H = Assessment of Life Habits Scale

Author, Year	**Study Design, Purpose, Subjects**	**Intervention**	**Outcomes**	**Results**	**Strengths/ Limitations**
Hoare et al; 2019[1]	Systematic review and meta-analysis Objective: To determine if CIMT improves hemiplegic UE function in	CIMT: Interventions included fine and gross motor activities implementing the principles of shaping or motor learning theories to improve upper extremity function. Administered individually, in a group-based model, or using a combined delivery method	Measures obtained at baseline and immediately post-intervention (0-2 weeks). *Primary:*	The CIMT group experienced greater improvements in AHA and QUEST-Grasp at follow-up compared to the low-dose intervention group; however, the difference was not statistically significant. There was no	Strengths: quality of selected studies, high methodological quality, comprehensive literature search, inclusion of grey literature, random and

	children with unilateral CP Total of 36 studies (35 RCTs and 1 cluster-RCT) <u>Inclusion criteria:</u> RCTs, cluster-RCTs, or clinically controlled trials comparing CIMT, mCMIT, hCIMT, or forced used therapy to low-dose, high-dose, of dose-matched bimanual therapy, standard care, CIMT, and/or no intervention; subjects ages birth to 19 years with a diagnosis of unilateral CP; Primary outcomes measured bimanual performance, unimanual capacity, and manual ability; Secondary outcomes included different forms of self-care, body function, participation, and	by therapists, teachers, parents, students, and other interventionists in a variety of settings including clinical treatment centers, home-based environments, theme camps, or a combination of clinical treatment centers and home, home and school, or camps and home. Constraint methods included mitts, gloves, slings, splints, casts, and bandages. Interventions were provided 0.5-8 hrs per day, 2-7 times a week, for an average of 5 weeks. The mean total dose of CIMT interventions across included studies was 129 hrs. <u>Low-Dose (n = 17):</u> OT, NDT, conventional therapy, usual care, infant massage, and no intervention. Delivered by OTs and PTs. Administered for 20-60 min/day, 0-7 days/week for 2 -10 weeks. Average total dose: 7.9 hrs. <u>High-Dose (n=4):</u> Intensive OT, bimanual OT, or intensive traditional PT rehabilitation. Delivered by OTs and PTs. Administered for 45-min to 4-hrs per day, 1-2 days/week for 4-8-weeks. Average total dose: 37.5-hrs. <u>Dose-Matched (n=15):</u> HABIT, bimanual interventions, or conventional care. Delivered by OTs	AHA (bimanual performance), MUUL (unimanual capacity), QUEST-Grasp (unimanual capacity), ABILHAND-Kids (manual ability) *Secondary:* PEDI – Self Care Functional Skills domain (self-care), COPM – Performance (parent-report performance measure)	significant difference in AHA, MUUL, QUEST-Grasp, PEDI-Self Care, or COMP-Performance scores in the CIMT group compared to the high-dose bimanual, dose-matched bimanual, or different forms of CIMT groups immediately post-intervention. Results indicate that CIMT, high-dose bimanual training, and dose-matched bimanual interventions effectively improve unimanual capacity, bimanual performance, and manual ability, as well as self-care and overall participation in children with unilateral CP. CIMT may be more effective that low-dose bimanual interventions at improving unimanual capacity and bimanual performance.	concealed allocation, duplicate study selection and data extraction, use of appropriate outcomes, discussion of limitations <u>Limitations:</u> low quality conclusions, lack of publication bias assessment, difficult to implement intensive interventions in traditional PT practice

	quality of life measures.	and PTs. Administered for 30-mins to 8 hrs a day, from once every other week to 6 days/week, for 1-10 weeks. Average total dose: 71.4 hrs. <u>Different forms of CIMT (n=3):</u> Interventions delivered at a different dose or in a different environment by OTs and family members. Average total dose*:* 91 hrs (range 42-168 hrs). Therapists provided 90 mins to 3 hrs of intervention 5-7 days/week for 2-3 weeks, totaling 15-63 hrs. Families provided hand-holding interventions for one hour/day, for a total of 42 hrs, over a 10-week period.			
Sakzewski L. et al; 2011[2]	Single-blind matched-pairs RCT <u>Objective:</u> To determine whether CIMT is more effective at improving upper limb function in children with congenital hemiplegia compared to BIM <u>Subjects:</u> 64 children with congenital hemiplegia (ages 5-16 years)	<u>CIMT Group:</u> Intervention consisted of age-appropriate, games and activities focusing on fine and gross motor skill acquisition, functional use, and proper utensil use during meals. The mode of constraint was a tailor-made glove worn on the unaffected UE. <u>BIM Group:</u> Participants received the same, dose-matched interventions as the CIMT group. Children were encouraged to use both their involved and non-involved extremities throughout the day.	Measurements at baseline, 3-, and 26-weeks post-intervention. *Primary:* MUUL (unimanual capacity), AHA (bimanual performance) *Secondary:* grip strength via hand-held dynamometer, M2PD via Disk-criminator,	There was a statistically significant improvement in MUUL scores in the CIMT group compared to the BIM group at 26 weeks. There were no other significant between group differences for primary or secondary outcomes. The CIMT group demonstrated significant improvements in MUUL, AHA, and JTTHF scores at 3-weeks compared to baseline. MUUL and JTTHF scores were further increased at 26-weeks. There was a significant increase in AHA score for the BIM group at	<u>Strengths:</u> level 1b evidence, high methodological quality, good internal and external validity, random and concealed allocation, blinding of outcome assessors, no significant difference between groups at baseline, intention to treat analysis, generalizability of results to a diverse patient population

	CIMT group (n=32) and BIM group (n=30, *2 dropouts*)	Participants were supervised by trained OTs, PTs, and camp volunteers. The intervention was administered 6 hours/day for 10 days.	JTTHF (movement efficiency)	3-weeks compared to baseline that further increased at 26-weeks. Results indicate that both CIMT and BIM interventions effectively improve involved upper limb function in children with congenital CP. While CIMT enhanced unimanual functional capacity and BIM training lead to greater improvements in bilateral performance, the differences in outcomes are not clinically significant.	<u>Weakness:</u> participants and researchers unable to be blinded due to nature of intervention; lack of control group receiving standard non-intensive doses of therapy; use of impairment-based outcome measures (grip-strength and sensation) for activity- and participation-based interventions
Deppe W. et al; 2013[3]	Single-blind RCT <u>Objective:</u> To determine if mCIMT results in greater improvements in motor function and spontaneous use of the paretic arm and hand with ADLs than IBT <u>Subjects:</u> 47 children with unilateral CP or other non-progressive hemiplegia (ages 3.3-11.4yrs)	<u>CIMT group</u>*:* Interventions incorporated shaping principles and focused on the elements of sensation, mobilization, and activity. Interactive tasks progressed from stabilization to manipulation. The mode of constraint was an elastic bandage that fixed the non-involved arm to the trunk from shoulder to fingers. Participants received 3 weeks of unilateral CIMT for 60 hrs and 1 week of bimanual training for 20 hrs. <u>IBT group:</u> Training was encompassed the same principles and elements as the CIMT group. Participants were encouraged to use both UEs during tasks including ADLs and interactive,	*Primary measures obtained at pre- and post-intervention:* MUUL (unimanual capacity), AHA (bimanual performance) *Secondary outcome measure obtained pre-intervention and 2-weeks post-intervention:* PEDI – Self Care (parent report questionnaire on self-care)	There were statistically and clinically significant improvements in MUUL scores in the CIMT group compared to the IBT group post-intervention. Both the CIMT and IBT groups demonstrated significant improvements in AHA and PEDI – Self Care scores at follow-up compared to baseline. Overall, children with lower levels of function at baseline demonstrated greater improvements compared to those with higher levels of function.	<u>Strengths:</u> level 1b evidence, high methodological quality, random and concealed allocation, blinding of outcome assessors, use of valid and appropriate outcome measures <u>Weaknesses:</u> lack of blinding of participants and researchers, weak statistical power for sub-group analysis, withdrawal bias, lack of acknowledgement of differences between groups at baseline

	CIMT group (n=26, *2 dropouts*); IBT group (n=21, *3 dropouts*)	play-based activities. Total of 80 hours of bimanual training. Treatment was administered by PTs, OTs, sports therapists, music therapists, and educators. Supervisor to child ratio was 1:1. Sessions were 60-mins in duration with a frequency of 4 sessions/day, 5 days/week, for a total of 4 weeks.		Results indicate that CIMT and IBT both lead to significant improvements in hand motor function and self-care abilities. While CIMT more effectively improved isolated movement of the hemiplegic upper limb, neither intervention resulted in superior gains in spontaneous use of the involved upper extremity during bimanual tasks.	
Gordon et al; 2011[4]	Randomized clinical trial <u>Objective:</u> To compare the efficacy of CIMT and HABIT on hand function in children with hemiplegic CP <u>Subjects:</u> 42 children with hemiplegic CP (ages 3.5 to 10 years) CIMT group: (n = 22, *1 dropout)*, HABIT group (n = 22, *1 dropout)*	<u>CIMT Group:</u> Interventions consisted of progressive unimanual activities. The mode of constraint was a sling worn on the unaffected limb at all times (except for toileting and breaks) that was secured to the child's trunk and sewn shut distally. <u>HABIT:</u> Interventions consisted of age-appropriate, fine and gross motor activities. Participants were encouraged to use bilateral UEs during all activities. Participants were supervised by PTs, OTS, or trained graduate and undergraduate students, with a 1:1 supervisor to child ratio. The intervention was administered 6 hrs/day for 15 days.	Measures obtained at baseline, immediate post-intervention, and 1- and 6-months follow-up. *Primary:* AHA (bimanual performance), JTTHF (movement efficiency) *Secondary:* QUEST – Grasp and Dissociated Movements (unimanual capacity), GAS (goal progress)	Overall, there were no significant differences in AHA and JTTHF scores between CIMT and HABIT groups. However, both the CIMT and HABIT groups demonstrated significant difference in pre- and post-intervention AHA and JTTHF scores that were maintained at 6-months follow-up. The HABIT group demonstrated significant improvement in GAS score post-intervention compared to the CIMT group. Results indicate that both CIMT and HABIT interventions lead to similar improvements in hand function and performance; however, HABIT may lead to greater progress towards self-determined goals.	<u>Strengths:</u> high methodological quality, random and concealed allocation, outcomes assessors blinded to allocation, no significant difference between groups at baseline, use of valid and appropriate outcomes <u>Weaknesses:</u> lack of blinding of participants and researchers, withdrawal bias, lack of control group receiving standard non-intensive doses of therapy
Dewar et al; 2014[5]	Systematic review	<u>Inclusion Criteria:</u> full articles; published in English, in peer-reviewed journals, after 1980; participants were children		There are moderate levels of evidence supporting the use of	<u>Strengths:</u> high methodological quality,

	<u>Objective:</u> To assess the efficacy of postural control interventions in children with CP 45 studies detailing 13 interventions, published between 1980 and 2013	with CP ages 0-18 years; land-based exercise interventions requiring active participation of child; included >1 outcome measure of postural stability or orientation <u>Exclusion Criteria:</u> non-systematic review or opinion articles; included passive, water-based, medical or surgical interventions; active exercise interventions without outcome measure for postural control *Interventions included:* functional electrical stimulation (n=2), gross motor task training (n=4), hippotherapy (n=9), hippotherapy stimulators (n=3), progressive resistance exercise (n=1), reactive balance training (n=3), treadmill training with no body weight support (n=1), treadmill training with full or particle body weight support (n=5), trunk-targeted training (n=2), upper limb interventions (n=2), visual biofeedback (n=1), virtual reality (n=8), and NDT (comparison n=7, sole intervention n=1).		gross motor task training, hippotherapy, treadmill training with no body weight support, trunk-targeted training, and reactive balance training in improving postural control. Functional electrical stimulation, hippotherapy simulators, NDT, treadmill training with body weight support, virtual reality, and visual feedback have weak or conflicting evidence. There is no evidence supporting the use of progressive resistance exercise to improve postural control.	comprehensive literature search, good external validity, duplicate study selection and data extraction, inclusion of studies high level evidence (levels 1-2) <u>Limitations:</u> lack of inclusion of grey literature, lack of publication bias assessment, inclusion of studies with lower -level evidence (level 3)
Tekin et al; 2018[6]	Prospective cohort study <u>Objective:</u> To demonstrate the effects of NDT on postural control and balance in children with diparetic and hemiparetic CP <u>Subjects:</u> 15 children with diparetic or hemiparetic CP (ages 5-15 years)	Interventions consisted of vestibular and proprioceptive training; dynamic balance training in sitting, kneeling, and standing with eyes open and closed; single limb stance with eyes open and close; balance training using a mirror or trampoline; functional reaching and throwing exercises; sensory stimulation; weight bearing exercises in sitting, quadruped, kneeling, and standing; multi-task training; gait training; and stair training. Participants attended 60-minute sessions, twice a week, for 8 weeks.	*Measurements at baseline and 8-weeks:* GMFCS (gross motor function), GMFM (gross motor function), 1MWT (walking and balance), MTUGT (walking and balance), PBS (balance), WeeFIM (functional independence),	There were statistically significant improvements in post-treatment scores on the GMFM, 1MWT, PBS, WeeFIM, and SPCM compared to baseline. Results indicate that 8-weeks of NDT based interventions effectively improve postural control and balance in children with diparetic and hemiparetic CP. These improvements in posture and balance lead to significant improvements in gross motor function and functional independence.	<u>Strengths:</u> inclusion of participants with GMFCS levels I-III, subject retention, validity and appropriateness of outcome measures, intention to treat analysis <u>Limitations:</u> low level of evidence, lack of control group

		Interventions were administered by a PT specializing in NDT.	SPCM (postural control)		
Tsorlakis et al; 2004[7]	Single-blind, matched pair RCT <u>Objective:</u> To compare the effects of intensive and non-intensive NDT on gross motor function in children with spastic CP <u>Subjects:</u> 34 children with mild to moderate spasticity and hemiplegia, diplegia, or tetraplegia (ages 3 to 14 years)	<u>Group A</u>: Participants received non-intensive NDT treatment in 50-min sessions, 2x/week for 16 weeks. <u>Group B</u>: Intensive NDT was administered in 50-min sessions, 5x/week for 16 weeks. NDT interventions were based on the Bobath approach and individualized to meet each child's clinical needs.	*Measurements at baseline and 16-weeks:* GMFM (gross motor function)	Both groups demonstrated significant improvements in GMFM scores following treatment compared to baseline. Significantly greater improvements in GMFM scores were observed in Group B compared to Group A. Results support that NDT is an effective intervention for improving gross motor function in children with spastic CP. Additionally, results indicate that children benefit from more intensive doses of NDT.	<u>Strengths:</u> high level of evidence, good methodological quality, random and concealed allocation, no significant difference between groups at baseline, assessors blinded to group allocation, adequate follow-up, validity and appropriateness of outcome measures <u>Limitations:</u> participants and researchers unable to be blinded due to nature of intervention, withdrawal bias, lack of intention to treat analysis
Franki et al; 2012[8]	Systematic review <u>Objective:</u> To evaluate the effectiveness of lower limb physical therapy interventions on gait and gross motor function in children with CP	<u>Inclusion Criteria:</u> original articles; published in English; published in peer reviewed journals; publication dates between January 1995 and December 2009; PT interventions targeting the LEs; participants age <18 years with diagnosis of CP <u>Exclusion Criteria:</u> children diagnosed with a pathology other than CP;	Level II evidence supports the use of passive stretching to increase ROM and decrease spasticity. There is conflicting evidence on the impact of massage on body structure and function and activity and participation. Level II evidence found that massage improves spasticity, ROM, fine and gross motor function, and cognitive behavior, while Level IV evidence found no significant effects of massage on		<u>Strengths:</u> good methodological quality, comprehensive literature search, duplicate study selection and data extraction, explored outcomes across multiple ICF domains, discussion of limitations

	83 studies (27 RCTs, 16 systematic reviews, 11 single-subject study designs, and 29 prospective, non-randomized trials).	interventions targeting the UEs or trunk; post-surgical interventions; interventions using mixed approach *Interventions included:* Stretching techniques (n=5) - mean duration=8.2 wks - mean frequency=4.5x/wk Massage (n=4) - mean duration=8.3 wks - mean frequency=2x/wk Electrical stimulation (n=16) - mean duration=40.1 wks - frequency=4.95-9.37/wks Strength training (n=26) - mean duration= 12.4 wks (isotonic), 5.4 wks (functional) - mean frequency=3.8x/wk (isotonic), 2.4x/wk (functional) Endurance training (n=10) - mean duration=13.3 wks Weight-bearing (n=7) - duration=2 wks to 9 mos - frequency= 2-5x/wk Treadmill training (n=13) - mean duration=6.4 wks - mean frequency=6.7x/wk Balance training (n=6) *Intervention outcomes were rated using ICF levels:* body structure and function (spasticity, bone mineral density, energy expenditure, muscle strength, muscle morphology),	PROM. No significant changes in GMFM score were observed following massage. Electrical stimulation was found to effectively improve strength, muscle cross-sectional area, trunk and extremity ROM, spasticity, walking velocity, gait, gross motor function, and satisfaction. Strength training results in significant improvements in muscle strength, gait, gross motor function, and participation, while endurance training significantly improves aerobic and anaerobic capacity, muscle strength, agility, and oxygen uptake. Low to moderate quality evidence supports the use of weight-bearing activities to improve bone mineral density and bowel activity. No significant changes in ADLs, functional performance, and walking speed were observed. Level II and IV evidence found significant improvements in gait parameters and gross motor function following treadmill training. Level II and III evidence supports the efficacy of balance training interventions at improving gross motor function, mechanical efficiency, trunk and LE control, and task-specific improvements in center of pressure and stabilization time. This review provides moderate to low quality evidence supporting a variety of LE interventions to improve body structure and function impairments as well as activity and participation restrictions. Further research	<u>Limitations:</u> inclusion of low-level evidence, grey literature not included in literature search, lack of publication bias assessment, does not establish an optimal intervention dose

		activities and participation (gait, gross motor function, participation, quality of life), personal factors, and environmental factors	is needed to establish optimal frequencies and intensities of interventions given the variability between studies.		
Bleyenheufft et al; 2015[9]	Single-blind, randomized cross-over trial <u>Objective:</u> To evaluate the effectiveness of HABIT-ILE in children with unilateral spastic CP <u>Subjects:</u> 24 children with unilateral spastic CP (ages 6 to 13 years)	<u>Immediate HABIT-ILE Group (IHG):</u> Participants received HABIT-ILE during summer camp followed by 90 hours of conventional/ongoing therapy for an average of 18-weeks. <u>Delayed HABIT-ILE Group (DHG):</u> Participants received 90 hours of conventional/ongoing therapy for an average of 20-weeks before receiving HABIT-ILE during a summer camp. Conventional therapy consisted of PT interventions focused on improving impairments utilizing either Bobath or LeMatayer principles of NDT. Nine participants also received OT interventions focusing on functional abilities. HABIT-ILE was administered by trained interventionalists including PTs, PT students, OTs, and OT students. Participants received therapy 9 hours/day for 10 consecutive days (total = 90 hours). Interventions consisted of structured, repetitive bimanual tasks that progressively required more skilled use of the involved hand.	Outcomes were measured at baseline, post-HABIT-ILE intervention, and post-conventional therapy intervention. *ICF domains:* MACS (manual ability) GMFCS (gross motor function) *Primary measures:* AHA (bimanual performance) 6MWT (walking capacity) *Secondary measures:* ABILHAND-Kids (manual ability) PEDI (parent report questionnaire) BBT (unilateral gross manual dexterity)	Significant improvements in AHA and 6MWT scores compared to baseline were observed following HABIT-ILE assessments, while no significant differences on primary outcome measures were observed following conventional treatment. Improvements on the ABILOCO-Kids questionnaire following HABIT-ILE were retained following cross-over to conventional therapy indicating that improvements in gait following HABIT-ILE are effectively transferred to activities of daily living. There were no significant improvements in body weight distribution with HABIT-ILE compared to conventional therapy. Changes in AHA and ABILIHAND-kids scores were equivalent to those of other studies on intensive bimanual therapy, indicating that inclusion of a	<u>Strengths:</u> good methodological quality, random and concealed allocation, no significant difference between groups at baseline, adequate follow-up, validity and appropriateness of outcome measures <u>Limitations:</u> participants, therapists, and assessors were not blinded to group allocation; no intention to treat analysis; no control group

		Additionally, intervention included progressive functional tasks and play activities incorporating the UE, LE, and trunk that challenged stability, posture, and gross motor function.	Key pinch (finger strength) Mean step length at self-selected and maximal walking speed Body weight distribution over each LE in standing ABILOCO-Kids (locomotion ability) Life-H (social participation)	LE/postural component does not reduce improvements in UE activity outcomes. Improvements in 6MWT distance following HABIT-ILE intervention demonstrates that this HABIT-ILE effectively improves both gait and UE interventions. Additionally, significant increases in PEDI scores following HABIT-ILE indicate that HABIT-ILE effectively improves social participation and parent satisfaction. This study demonstrates that short-duration, high intensity HABIT-ILE is more effective at improving upper and lower extremity functional outcomes than long duration, low intensity conventional training in children with unilateral spastic CP.	
Coker et al; 2010[10]	Prospective cohort study <u>Objective:</u> To explore the effects of mCIMT on gait in pre-school aged children with hemiplegic CP <u>Subjects:</u> 12 children with hemiplegic CP	Two groups of 6-7 children participated in the same mCIMT program at two different points in time. Interventions consisted of task-specific, developmentally appropriate play focusing on fine and gross motor activities. The mode of constraint was a resting hand split covered by a soft puppet glove.	*Spatiotemporal gait characteristics were measured using a GAITrite electronic walkway pre-mCIMT camp and post-mCIMT camp:* Gait velocity Mean normalized cadence	The was a significant decrease in base of support for the majority of the subjects following mCIMT camp. There were significant improvements in velocity, cadence, and step length following mCIMT intervention. Double limb support time decreased following intervention, while single limb support time	<u>Strengths:</u> inclusion of participants with GMFCS levels I-III, subject retention, validity and appropriateness of outcome measures <u>Limitations:</u> low level evidence, no control group, lack of long-term follow-up

	(ages 2 years and 5 months to 6 years and 2 months)	Interventions were administered for 6 hrs/day over the course of 5 consecutive days.	Normalized step length Base of support Single support (% gait cycle) Double support (% gait cycle) Step time difference	either increased or remained the same. Concurrent decreases in base of support and increases in walking speed indicate overall improvements in stability and equilibrium. The results suggest that mCIMT has the potential to improve gait pattern and increased balance in children with hemiplegic CP. Further research is needed to determine long-term effects of mCIMT on balance and stability during gait.	

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