WHAT IS THE EFFECT OF CONSTRAINT-INDUCED MOVEMENT THERAPY AND HAND-ARM BIMANUAL INTENSIVE THERAPY IN THE FUNCTION OF THE UPPER LIMB IN HEMIPLEGIC CEREBRAL PALSY?

A COMPARISON

LITERATURE REVIEW

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Preface

This literature review is a thesis submission for the bachelor of physiotherapy graduation assignment at Hanze University of Applied Science, Groningen. The review is a comparative of two interventions; constraint-induced movement therapy and hand-arm bimanual intensive therapy to improve upper limb function in hemiplegic Cerebral Palsy. The basis of this research stemmed from my interest in central neurological pathologies during my bachelor study. I would like to thank the teachers at Hanze University of Applied Sciences for their knowledge and guidance over the years. I would also like to give a special thanks to my supervisor, Anne Griet Brader, for her support, advice and feedback during the completion of this research.

Abstract

Aim: Cerebral palsy is the most common motor disability in early childhood with 29% of patients suffering from hemiplegic Cerebral Palsy. Constraint-induced movement therapy is a proven unimanual intervention to improve upper limb function focusing on the affected side while hand-arm bimanual intensive therapy was created after constraint-induced movement therapy as a bimanual intervention. The purpose of this literature review is to examine the efficacy of constraint induced movement therapy and hand-arm bimanual intensive therapy to improve upper limb function in children with unilateral cerebral palsy and to compare to find the most suitable treatment.

Methods: For this literature review, an extensive search was performed in five electronic databases (Cochrane Library, PubMed, PEDro, Embase, Cinahl and Google Scholar) for relevant literature between February and March 2021. The review was based on the methodology for conducting a systematic review; literature search, inclusion criteria, methodological quality assessment, data extraction and data analysis.

Results: Five Randomised Control Trials were reviewed with a total population of 83 participants. Results state that constraint-induced movement therapy and hand-arm bimanual intensive therapy are both interventions sufficient in improving upper limb function in unilateral Cerebral Palsy. Statistically significant evidence was found that constraint-induced movement therapy shows more improvements in unimanual function of the paretic upper limb in the Quality of Upper Extremity Skills Test and an experimental Reach-Eat-Grasp set up. In a bimanual task experimental set up, hand-arm bimanual therapy displayed significantly more improvements in bimanual function of the upper extremity.

Conclusion: Results of this study show that both interventions improve function of the upper limb with constraint-induced movement therapy having better improvements in unimanual function and hand-arm bimanual intensive therapy delivering more improvements in bimanual function. The concept of specificity of training applies. A hybrid intervention combining the two interventions should be considered. Further research is recommended due to limitations in this study.

Key words: Constraint-induced movement therapy; hand-arm bimanual intensive therapy; bimanual; unimanual; upper limb function; hemiplegic cerebral palsy

Introduction

Unilateral Cerebral Palsy is a motor disability in children which can have major negative effects on the upper extremity function on one side of the body. The purpose of this study is to analyse the efficacy of two therapies aimed at improving upper limb function in hemiplegic cerebral palsy; constraint-induced movement therapy and hand-arm bimanual intensive therapy.

Cerebral palsy (CP) is a general term for non-progressive posture and movement disorders that occurs during infancy or early childhood up to the age of two. Cerebral means association to the brain, while palsy means weakness or difficulty using the muscles. This disorder is caused by abnormal development of the brain or damage to the developing brain which affects one's ability to control muscles (Centre for Disease Control and Prevention, 2020). Reasons for occurrence include; premature birth, maternal infection, hypoxia associated with birth trauma, multiple births, gene mutation or traumatic head injury (Reddappa, 2012).

CP is the most common motor disability found in early childhood. World population-based studies report prevalence ranging from 1.5 to over four per 1,000 live births or children within the specific age range. Incidence and prevalence overall is approximately two per 1,000 live births (Stavsky et al., 2017). A study found that, while the total rate of CP is relatively stable, due to increasing improvements in obstetric and neonatal care, the contribution of premature births and the complications that come with it are steadily increasing the prevalence of this disorder (Stavsky *et al*., 2017). Other associated disabilities are frequently present alongside the motor deficits. These include abnormalities in vision, speech, hearing, seizures, intellectual and learning disabilities. The range of severity of CP can be wide from the ability to talk, carry out self-care independently, walking, running and other skills to total dependency and immobility (Reddappa, 2012).

CP is classified according to the main type of movement disorder that is present and dependant on the area of the brain that is affected. Spastic or hypertonic CP is the most common type of CP. This causes an increase in muscle tone that is velocity dependant causing stiff and sometimes painful limbs. Symptoms include; involuntary movements, continuous muscle spasms, muscle and joint contractures, abnormal gait, upper limb flexion pattern, limited stretching abilities, poor co-ordination and muscle movement control. This makes activities of daily living (ADL's) difficult for these patients (Jansheski, 2020).

Among those who have CP, 29% have hemiplegia which affects one side of their body with the upper limb typically being more affected than the lower. This may cause patients to develop a "learned non-use" in the affected side since it is more efficient to use the non-affected side. It can lead to learning alternative strategies to manage through ADL's and can occur even when there is only mild impairment (Chiu & Ada, 2016).

<u>Constraint-Induced Movement Therapy</u>

The aim of Constraint-induced movement therapy (CIMT) is to prevent and overcome learned non-use of the affected side and to encourage intensive, targeted repetitive practice of unilateral and bimanual activities. CIMT involves restraining of the unaffected upper limb so the affected limb can carry out activities. This enables the patient to find solutions to the movement problem and find alternative strategies involving the affected side.

In the original CIMT protocol, there are three components; 1) intensive graded practice of the affected arm aimed at improving task specific use for up to six hours a day for two weeks; 2) constraining of 'forced use' of the non-affected upper limb with a glove to promote the use of the paretic arm for 90% of waking hours; and 3) applying behavioural methods that enhance adherence to transfer the gains and skills obtained in the clinical settings to the patients everyday environment also called a 'transfer package' (Kwakkel *et al*., 2015).

While CIMT has shown good effectiveness in the available research, a review by Chiu & Ada found that while CIMT is more effective than no intervention, it is no more effective when compared to a 'usual intervention' (not specified) that is dose equivalent. This suggests that the effect may be due to nothing more than large amounts of intense practice involved with the therapy rather than the restraining of the unaffected upper limb in its self (Chiu & Ada, 2016)

<u>Hand-Arm Bimanual Intense Therapy</u>

Hand-Arm Bimanual Intense Therapy (HABIT) is a therapy that was developed after CIMT that takes one of the key components of CIMT, the intense practice, but focuses on improving coordination in both hands using structured task practice in bimanual and functional activities. It uses principles of motor learning and neuroplasticity in the therapy (Gordon *et al*., 2007)

This was developed by Columbia University after researching CIMT. They found promising results for the CIMT approach in paediatric settings but discovered several conceptual problems and limitations; 1) restraining of the child's non-affected limb could potentially be invasive when elicited practice is responsible for improving motor function rather than restraint, 2) CIMT was created for adults with hemiplegia from stroke or traumatic brain injuries to overcome learned non-use whereas some children with CP have never effectively learned how to use their affected limb, 3) CIMT focuses on unimanual treatment when functional independence in everyday life requires coordination and cooperation of both hands. While there are studies suggesting that CIMT can transfer to improvements in bimanual therapy, Gordon *et al*, believed this might be better accomplished by using bimanual skills directly (Gordon *et al*., 2007)

Based on the information above, while there are a lot of similarities to these two therapies in regard to specific task orientated practice and the intense amount of therapy involved, the main approach of the two are quite different. A meta-analysis by Alahmari *et al*, reviewed research between 2000-2018 suggested there is “trivial benefit” in using HABIT over CIMT but the results were non-conclusive (Alahmari *et al*., 2020). Another meta-analysis by Tervahauta *et al*., collected data in 2016 and also found that, with the available research, it was not possible to conclude which one is more effective (Tervahauta *et al*., 2017). Since these reviews were published, there has been more research carried out on this topic.

The objective of this literature review is to do an updated review from 2015 to 2021 on the effects of CIMT and HABIT in hemiplegic CP to determine the most suitable therapy to improve upper limb function. The hypothesis is that CIMT and HABIT will both have improvements in the hemiplegic side but CIMT will show greater improvement. It is also hypothesized that HABIT will have greater improvements in bimanual tasks when compared to CIMT. The hypotheses are based on the theory of training specificity.

Method

Search Strategy

This literature review was based on the methodology in conducting a systematic review: literature search, inclusion criteria, methodological quality assessment, data extraction and data analysis (Van Tulder *et al*., 2003). It was conducted by one researcher in six electronic databases between the 22nd of February and the 6th of March 2021. Databases included were Cochrane Library, PubMed, PEDro, Embase, Cinahl and Google Scholar. PEDro was chosen as it is a physiotherapy specific database with the most relevant randomised control trials. Cochrane was used as it is internationally recognised as the highest standard in evidence-based health care. Cinahl was selected as it is a comprehensive resource of nursing and allied health including physiotherapy for evidence-based research. PubMed and Embase were selected as they are comprehensive medical databases that evaluate physical therapy interventions. Google scholar was used to find any remaining articles that were not found in the other databases.

Search Terms

The search terms and filters used in each databases were created to find the appropriate articles and answer the research question at hand.

Boolean operator "AND" were used to search in Cochrane Library, PubMed, PEDro and Cinahl. Medical Subject Headings (MeSH) terms are applied in Cochrane Library, PubMed and Embase. The final search terms and filters per database can be found in *table 1.* Search strings that led to these final search terms can be viewed in *appendix 1.*

Table 1. Final Search Actions

Database	**Filters**	**Search Terms**
Cochrane Library	2015-2021	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"
PubMed	2015-2021 English	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"
PEDro	2015-2021	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"

Embase	2015-2021	“Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy”
Cinahl	2015-2021 Apply Related Words Search within full text Apply equivalent subjects English	“Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy”
Google Scholar	2015-2021 All word	“Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy”

Selection of studies

The studies obtained from the search strategy were screened through their titles and abstracts in order to find the relevant literature for further analysis. The inclusion criteria consisted of clinical trials, controlled clinical trials and randomised control trials, with hemiplegic/unilateral cerebral palsy, a comparison between unimanual and bimanual therapy and outcome measurements for upper limb function. Exclusion criteria included incomplete research, languages other than English and studies published before 2015. Studies selected were based on their relevance to the study and the inclusion/exclusion criteria (see *table 2*). Articles that match the inclusion/exclusion criteria will then be reviewed by the researcher and an independent reviewer (KA). Any disagreements will be discussed and amended by a third party (PD).

Table 2. Inclusion/Exclusion Criteria

Inclusion Criteria	Population	Unilateral cerebral palsy, hemiplegic cerebral palsy
	Research design	Clinical trials, randomised control trials, controlled clinical trials
	Intervention	Hand-arm bimanual intensive therapy, constraint induced movement therapy
	Outcome measurements	Upper limb function measurements

Exclusion Criteria		Any language other than English, published before 2015, incomplete research

Quality Assessment

The quality of selected literature was analysed according to the PEDro scale. This is a scoring system with 11 criteria to evaluate internal and external validity and to ensure there is sufficient statistical information in order for the results to be interpreted. A point is awarded for the completion of each criteria and a piece of literature can be awarded a total score of ten points (criteria 1 is excluded from the total score). Interpretation of the scoring system can be found in *table 3* (Moseley et al., 2011). The inter-rater reliability of the PEDro scale is demonstrated as “fair” to “excellent” for RCT’s of physiotherapy intervention (Intraclass correlation coefficient (ICC) 0.53-0.91). The convergent validity supported by Van Tulder 2003 scale is 0.71 for trials of physiotherapy intervention (Cashin & McAuley, 2020). Application of the PEDro scale for the chosen literature can be found in *appendix 2*. For reporting quality, each clinical trial was assessed by the Consolidated Standards Of Reporting Trials (CONSORT) 2010 statement checklist. (Schulz *et al*., 2010). Application of the CONSORT 2010 statement can be found in *appendix 3.*

Table 3. PEDro Scale Interpretation

PEDro Score	Interpretation
0-3	“Poor quality”
4-5	“Fair quality”
6-10	“High quality”

Data Extraction

Data was extracted and analysed by one reviewer. Extracted data included study design, author, publication year, title, population, inclusion criteria, details of the intervention for the CIMT group and HABIT group, outcome measurements, results, strengths and weaknesses of the studies. All results extracted can be found in a data comparison table in *table 5* with a summary of the population and intervention characteristic while a more extensive summary of each article can be found in *appendix 4.*

Data Analysis

There was no manipulation of the data extracted from the clinical trials. Results were considered statistically significant when the p-value is below 0.05.

Results

The original search with the final search terms, before filters found 492 potential articles. After filters were applied, 280 potential studies were identified from the search strategy. There were 35 articles that were eliminated due to duplicated articles, a further 234 articles were eliminated through screening abstracts for full text available and relevance. Through the inclusion/exclusion criteria, another six articles were excluded leaving a total of five studies included in the present literature review. It should be mentioned that three of the studies included in this review, which were found through the search strategy, were also present in the meta-analysis by Tervahau *et al.* The flow diagram describing the search results can be found in *figure 1.*

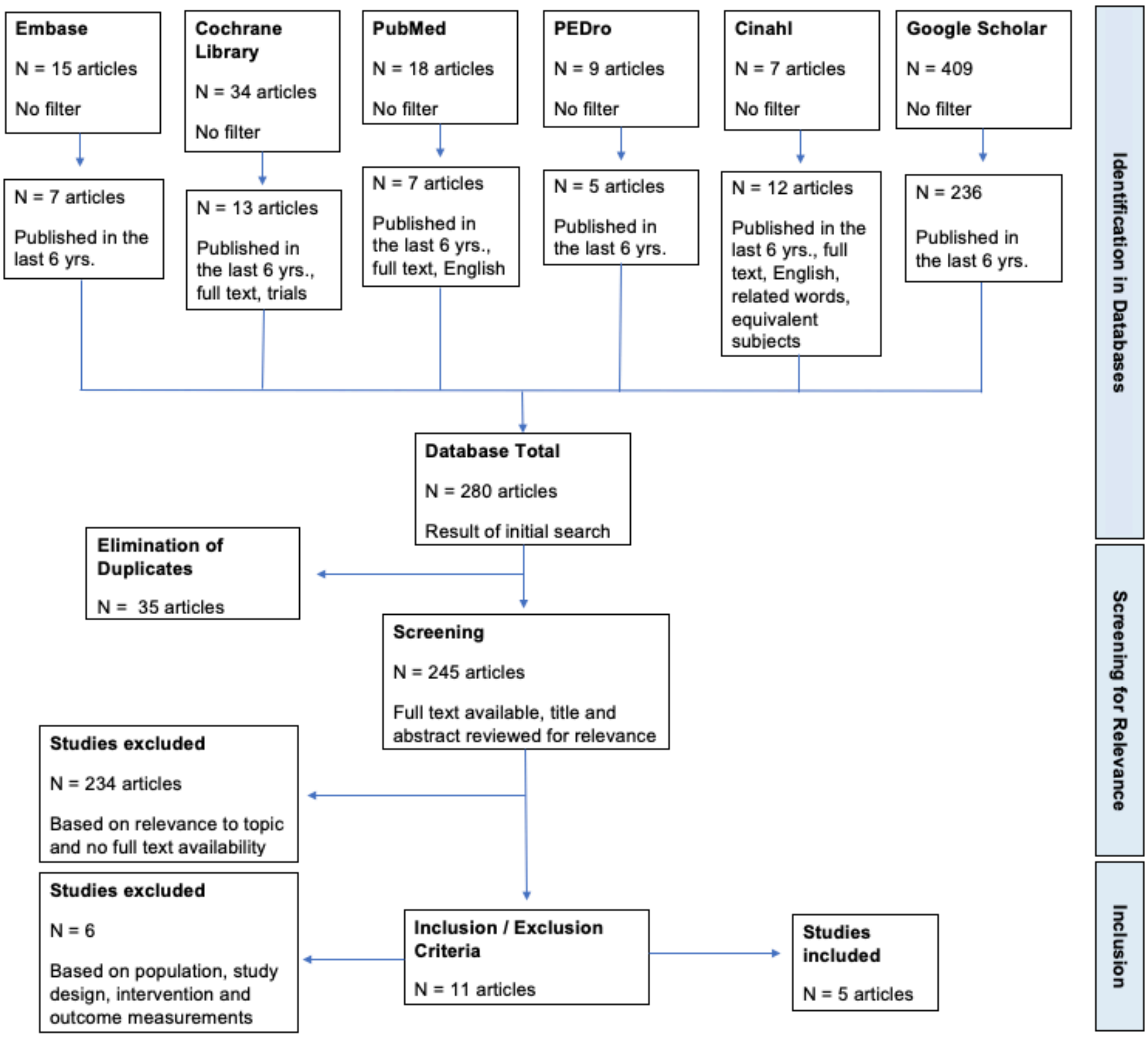

Figure 1 – Flow diagram of search method

Population Characteristics

The five articles included in the presented study are all randomised control trials. Two studies were published in 2015 (Gelkop *et al*., 2015; Sakzewski *et al*., 2015), one study in 2016 (Zafer *et al*., 2016) and two were published in 2020 (Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020). There was a total of 83 participants between the five studies. All studies consisted of a small population with the largest containing 20 participants (Hung, Spingarn, *et al*., 2020) and the smallest consisting of 12 participants (Gelkop *et al*., 2015). They consisted of 47 males and 36 females between the ages of 1.5 to 16 years. There was no statistically significance between participants characteristics in four out of the five studies (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015). One study did not specify the population characteristics of the two groups and hence it is unclear the difference between the interventions (Zafer *et al*., 2016). See *table 2* for details.

The eligibility criteria widely varied across the studies. These can be found for each study in the data extraction table in *appendix 4.*

Interventions Characteristics

All studies included both CIMT and HABIT interventions (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015; Zafer *et al*., 2016). In each study, the CIMT interventions involved a restraint of the less affected upper limb while carrying out unimanual tasks and the HABIT interventions had no restraint and carried out bimanual tasks. The total dosage hours varied across the studies with the largest containing 96 hours which consisted of two hours a day for eight weeks (Gelkop *et al*., 2015). Two other studies had a large dosage that consisted of 90 hours which was divided into six hours a day over 15 consecutive days (Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020). The other two studies had a relatively small total dosage size of 30 hours, that was divided into six hours a day over five days (Sakzewski *et al*., 2015) and 24 hours which was delivered for two hours a day over two weeks (Zafer *et al*., 2016). The type of restraints used in the CIMT intervention was also different across the studies. These included; a glove (Gelkop *et al*., 2015; Sakzewski *et al*., 2015) , a cotton sling with the opening sewn shut (Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020) and a mitt that constrained the hand and sling strapped to the trunk (Zafer *et al*., 2016). While four of the studies interventions were carried out by occupational therapists, physiotherapists or therapist's assistance in a special education setting or training camp (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015), one studies intervention was carried out by the parents in a home setting (Zafer *et al*., 2016). All interventions involved whole or part tasks that involved ADL's and gross and fine motor play activities. A brief summary of interventions can be found in *table 5.* A more extensive description of the intervention of each study can be found in the *data extraction table* in *appendix 4.*

Outcome Characteristics

The assessments used to quantify upper limb function varied across the included studies. Two studies used the Quality of Upper Extremity Skills Test (QUEST) (Gelkop *et al*., 2015; Zafer *et al*., 2016). The Assisted Hand Assessment (AHA) was used in two studies (Gelkop *et al*., 2015; Sakzewski *et al*., 2015). One study used the Melbourne Assessment of Unilateral Upper Limb Function (MUUL) and the Jebson-Taylor Test of Hand function (JTTHF) (Sakzewski *et al*., 2015). Two studies used experimental set ups. One study used a single handed reach-grasp-eat movements to assess unimanual temporal and joint movement control, and motor planning using kinematic analysis (Hung, Spingarn, *et al*., 2020). The other experimental set up was a bimanual task which involved carrying a tray with two hands to assess upper limb movement control also using kinematic analysis (Hung, Shirzad, *et al*., 2020). Description of the results for each outcome can be found under *Outcome results.*

Methodological Quality of Included Studies

The PEDro scale rated four out of the five studies to be of "good quality" (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015) while one study was found to have "fair quality" (Zafer *et al*., 2016). See *table 4* for the results of the PEDro scale and *appendix 2* for the application of the PEDro scale.

Table 4 – Results of the PEDro scale on the included studies

Study	**PEDro Score**	**Interpretation**
Gelkop *et al*. 2015	8/10	"Good quality"
Hung *et al*. Jan 2020	6/10	"Good quality"
Hung *et al*. June 2020	8/10	"Good quality"
Zafer *et al*. 2015	5/10	"Fair quality"
Sakzewski *et al*. 2015	7/10	"Good quality"

The quality of the reporting in each article was assessed by the CONSORT 2010 checklist which consists of 25-items. Two studies had 22 of the 25 items (Gelkop *et al*., 2015; Hung, Spingarn, *et al*., 2020), while another two had 20 of the 25 items (Hung, Shirzad, *et al*., 2020; Sakzewski *et al*., 2015) and one study had 14 of the 25 items (Zafer *et al*., 2016).

The data comparison table in *table 5,* includes the study, study design, a summary of the population, intervention characteristics and the full results extracted. The remaining data extracted from each article can be found in *appendix 4*.

Data Comparison

Table 5. Data comparison table

Study	Participants	Intervention Characteristic	Outcome results		
			CIMT	**HABIT**	**Interaction**
Gelkop ***et al.*** **(2015)** **RCT** **High quality**	**N = 12** (CIMT 6, HABIT 6) **Age:** 1.5 – 7 yrs. CIMT: 4.25 ± 1.58 HABIT: 4.33 ± 1.86) **Gender:** 2 M, 10 F (CIMT + BIT 1 M, 5 F) **Hemiplegic side:** 6 L : 6 R CIMT: 3 L : 3 R HABIT: 3 L : 3 R **MACS:** I - III CIMT: I (1), II (2), III (2) HABIT: I (I), II (3), III (1) **GMFCS** N/A	Both groups received 2 hours of CIMT or HABIT per day (1hr individual, 1hr group), 6 days per week for 8 weeks. Total dose: 96 hours CIMT: Glove worn only 2 hours a day during therapy Whole and part task practice Usual / customary care continued: 2-3 sessions of OT + 2-3 sessions of PT each lasting 45-60 mins per week	**<u>AHA</u>** *(95% CI)* *Post-baseline* • 47.3 (32.4, 62.3) *Immediate post-intervention* • 59.0 (46.7, 71.3) *8 week follow up* • 57.2 (45.7, 68.7) **<u>QUEST total</u>** *(95% CI)* *Post-baseline* • 55.0 (35.4, 74.6) *Immediate post-intervention* • 74.0 (56.9, 91.2) *8 week follow up* • 73.0 (57.9, 88.1) **<u>QUEST PE</u>** *(95% CI)* *Post-baseline* • 44.4 (17.5, 71.3) *Immediate post-intervention* • 60.7 (40.1, 81.2) *8 week follow up* • 58.3 (35.0, 81.7) **<u>QUEST DM</u>** *(95% CI)* *Post-baseline*	**<u>AHA</u>** *(95% CI)* *Post-baseline* • 43.0 (28.0, 58.0) *Immediate post-intervention* • 52.5 (40.2, 64.8) *8 week follow up (95% CI)* • 52.2 (40.7, 63.7) **<u>QUEST total</u>** *(95% CI)* *Post-baseline* • 56.8 (37.2, 76.4) *Immediate post-intervention* • 70.4 (53.3, 87.6 *8 week follow up* • 70.0 (54.9, 85.1) **<u>QUEST PE</u>** *(95% CI)* *Post-baseline* • 49.7 (22.8, 76.6) *Immediate post-intervention* • 57.2 (36.7, 77.7) *8 week follow up* • 58.8 (35.4, 82.2) **<u>QUEST DM</u>** *(95% CI)* *Post-baseline*	**<u>AHA</u>** *Test session effect: p value (η2)* • $p < 0.001$ (0.68) *Interaction (g × ts: p value (η2))* • $p = 0.48$ (0.02) **<u>QUEST total</u>** *Test session effect: p value (η2)* • $p < 0.001$ (0.78) *Interaction (g × ts: p value (η2))* • $p = 0.671$ (.01) **<u>QUEST PE</u>** *Test session effect: p value (η2)* • $p < 0.005$ (0.41) *Interaction (g × ts: p value (η2))* • $p = 0.564$ (0.05) **<u>QUEST DM</u>** *Test session effect: p value (η2)*

		Special education setting	• 58.4 (46.2, 70.6) *Immediate post-intervention* • 79.4 (65.9, 92.9) *8 week follow up* • 73.1 (62.8, 83.5) **QUEST WB** *(95% CI)* *Post-baseline* • 60.7 (27.2, 94.2) *Immediate post-intervention* • 86.8 (56.8, 116.9) *8 week follow up* • 86.4 (62.1, 110.7) **QUEST G** *(95% CI)* *Post-baseline* • 54.8 (38.3, 71.3) *Immediate post-intervention* • 68.9 (54.3, 83.5) *8 week follow up* • 73.3 (57.7, 89.0)	• 65.6 (53.4, 77.8) *Immediate post-intervention* • 70.0 (56.5, 83.5) *8 week follow up* • 73.8 (63.5, 84.1) **QUEST WB** *(95% CI)* *Post-baseline* • 55.6 (22.1, 89.1) *Immediate post-intervention* • 84.4 (54.4, 114.5) *8 week follow up* • 73.2 (49.0, 97.5) **QUEST G** *(95% CI)* *Post-baseline* • 56.6 (40.1, 73.5) *Immediate post-intervention* • 68.9 (54.3, 83.5) *8 week follow up* • 71.9 (56.2, 87.5)	• $p < 0.001$ (0.57) *Interaction (g × ts: p value (η2))* • $p < 0.05$ (0.16) **QUEST WB** *Test session effect: p value (η2)* • $p < 0.001$ (0.57) *Interaction (g × ts: p value (η2))* • $p = 0.883$ (0.01) **QUEST G** *Test session effect: p value (η2)* • $p < 0.001$ (0.68) *Interaction (g × ts: p value (η2))* • $p = 0.566$ (0.03)
			CIMT	**HABIT**	**Interaction**
Hung, Spingarn, *et al.* (2020) **RCT**	**N = 20** (CIMT 10, HABIT 10) **Age:** 6 – 12 yrs. CIMT: 7.6 ± 2.2 HABIT: 7.7 ± 1.7 **Gender:** 11 M : 9 F	Both groups received 6 hours per day of CIMT or HABIT for 15 consecutive weekdays (adjusted for holidays). Total dose: 90 hours	**Temporal Measures** **Reaching movement time mean SD(s) + CV** *Pre-test conditions* • 1.26 (0.55)* + 0.35 (0.29)* *Post-test conditions* • 1.01 (0.42)* + 0.27 (0.23)*	**Temporal Measures** **Reaching movement time mean SD(s) + CV** *Pre-test conditions* • 1.21 (0.38)* + 0.28 (0.15)* *Post-test conditions* • 1.01 (0.27)* + 0.22 (0.15)*	**Temporal Measures** **Reaching movement time mean SD(s) + CV** N/A

High quality	CIMT: 6 M : 4 F HABIT: 5 M : 5 F **Hemiplegic side:** 11 L, 9 R CIMT: 4 L : 6 R HABIT: 7 L : 3 R **Race** 16 Caucasian, 2 Hispanic, 2 African American CIMT: 8 Caucasian : 1 Hispanic : 1 African American HABIT: 8 Caucasian : 1 Hispanic : 1 African American **MACS:** I – II CIMT: I (2), II (8), HABIT: II (2), II (8) **GMFCS** N/A **JTTHF:** CIMT: 221 ± 108 HABIT: 226 ± 100	CIMT: Cotton sling with hands opening sewn shut during therapy Whole and part task practice Training camp	**Grasping movement time mean SD(s) + CV** *Pre-test conditions* • 0.68 (0.81)* + 0.78 (0.63) *Post-test conditions* • 0.44 (0.55)* + 1.05 (0.76) **Eating movement time mean SD(s) + CV** *Pre-test conditions* • 1.41 (0.44)* + 0.24 (0.10) *Post-test conditions* • 1.21 (0.51)* + 0.30 (0.20) **<u>Movement control measures</u>** **Reaching movement mean SD + CV** *Pre-test conditions* Hand curvature • 1.54 (0.17)* + 0.43(0.40)* Trunk involvement (cm) • 13.26 (8.03)* + 0.45(0.26)* Upper arm excursion (º) • 25.85 (5.33) + 0.42(0.28) Elbow excursion (º) • 38.97 (11.04)* + 0.40(0.22) Wrist excursion (º) • 33.50 (10.87)* + 0.62(0.57) *Post-test conditions* Hand curvature	**Grasping movement time mean SD(s) + CV** *Pre-test conditions* • 0.64 (0.43)* + 0.88 (0.47) *Post-test conditions* • 0.43 (0.39)* + 1.12 (0.71) **Eating movement time mean SD(s) + CV** *Pre-test conditions* • 1.35 (0.66)* + 0.25 (0.13) *Post-test conditions* • 1.22 (0.35)* + 0.27 (0.18) **<u>Movement control measures</u>** **Reaching movement mean SD + CV** *Pre-test conditions* Hand curvature • 1.54 (0.21) + 0.49(0.36)* Trunk involvement (cm) • 11.42 (8.74)* + 0.36(0.22)* Upper arm excursion (º) • 30.44 (17.03) + 0.44(0.41) Elbow excursion (º) • 43.86 (16.92)* + 0.43(0.24) Wrist excursion (º) • 26.84 (6.61)* + 0.52(0.34) *Post-test conditions* Hand curvature	**Grasping movement time mean SD(s) + CV** N/A **Eating movement time mean SD(s) + CV** N/A **<u>Movement control measures</u>** **Reaching movement mean SD + CV** Hand curvature • Interaction $g \times ts = p < 0.05$

			• 1.25 (0.09)* + 0.13(0.07)* Trunk involvement (cm) • 8.83 (6.47)* + 0.30(0.24)* Upper arm excursion (º) • 26.63 (6.80) + 0.61(0.38) Elbow excursion (º) • 51.92 (16.04)* + 0.30(0.20) Wrist excursion (º) • 39.07 (10.50)* + 0.66(0.38) **Grasping movement mean SD + CV** *Pre-test conditions* Hand vertical position (cm) • 11.49 (3.12)* + 0.45(0.24) *Post-test conditions* Hand vertical position (cm) • 8.05 (3.32)* + 0.37(0.13) **Eating movement mean SD + CV** *Pre-test conditions* Upper arm excursion (º) • 15.53 (8.72) + 0.48(0.30) Elbow excursion (º) • 51.27 (15.37)* + 0.42(0.29) Wrist excursion (º) • 45.60 (23.66) + 0.43(0.29) Head rotation excursion (º) • 19.56 (9.51)* + 0.49(0.29) Head flexion excursion (º) • 11.78 (3.54) + 0.48(0.26)	• 1.52 (0.18) + 0.20(0.15)* Trunk involvement (cm) • 8.46 (6.60)* + 0.27(0.19)* Upper arm excursion (º) • 28.21 (10.03) + 0.57(0.30) Elbow excursion (º) • 49.21 (14.34)* + 0.50(0.29) Wrist excursion (º) • 39.61 (11.54)* + 0.58(0.24) **Grasping movement mean SD + CV** *Pre-test conditions* Hand vertical position (cm) • 12.12 (2.26) + 0.45(0.23) *Post-test conditions* Hand vertical position (cm) • 11.61 (2.85) + 0.51(0.32) **Eating movement mean SD + CV** *Pre-test conditions* Upper arm excursion (º) • 15.19 (8.13) + 0.59(0.29) Elbow excursion (º) • 50.32 (17.93)* + 0.36(0.27) Wrist excursion (º) • 45.74(20.88) + 0.52(0.38) Head rotation excursion (º) • 19.19(7.24) + 0.47(0.20) Head flexion excursion (º) • 13.73(6.45) + 0.51(0.25)	**Grasping movement mean SD + CV** Hand vertical position (cm) • Interaction g × ts = $p <$ 0.05 **Eating movement mean SD + CV** Head rotation excursion (º) • Interaction $g \times ts = p <$ 0.05

			Post-test condition Upper arm excursion (º) • 14.90 (7.90) + 0.59(0.25) Elbow excursion (º) • 59.66 (16.65)* + 0.59(0.51) Wrist excursion (º) • 49.24 (29.56) + 0.59(0.40) Head rotation excursion (º) • 11.34 (3.77)* + 0.45(0.22) Head flexion excursion (º) • 9.60(3.50) + 0.41(0.19)	*Post-test condition* Upper arm excursion (º) • 17.39 (11.88) + 0.44(0.23) Elbow excursion (º) • 62.62 (18.57)* + 0.59(0.40) Wrist excursion (º) • 51.54 (28.28) + 0.44(0.23) Head rotation excursion (º) • 18.02(7.69) + 0.54(0.37) Head flexion excursion (º) • 14.20(6.39) + 0.59(0.40)	
			CIMT	**HABIT**	**Interaction**
Hung, Shirzad, *et al.* (2020) **RCT** **High quality**	**N = 16** (CIMT 8, HABIT 8) **Age:** 6 – 12 yrs. CIMT: 8.9 ± 2.2 HABIT: 8.3 ± 1.7 **Gender:** 10 M : 6 F CIMT: 4 M : 4 F HABIT: 6 M : 2 F **Hemiplegic side:** 9 L : 7 R CIMT: 4 L : 4 R HABIT: 5 L : 3 R **MACS:**	Both groups received 6 hours per day of CIMT or HABIT for 15 consecutive weekdays. Total dose: 90 hours CIMT: Cotton sling during therapy Training camp	**Upper Extremity Movement Control task** **Vertical hand difference [cm] mean (SD)** *Pre-training condition* • 4.94 (1.26) *Post-training condition* • 5.07 (0.93)* **Lateral hand excursion [cm] mean (SD)** *Pre-training condition* • 5.20 (0.77)* *Post-training condition* • 4.61 (0.22)* **Vertical hand excursion [cm] mean (SD)**	**Upper Extremity Movement Control task** **Vertical hand difference [cm] mean (SD)** *Pre-training condition* • 5.06 (0.63) *Post-training condition* • 3.61 (0.73)* **Lateral hand excursion [cm] mean (SD)** *Pre-training condition* • 5.24 (1.01)* *Post-training condition* • 4.32 (0.58)* **Vertical hand excursion [cm] mean (SD)**	**Upper Extremity Movement Control task** **Vertical hand difference [cm] mean (SD)** N/A **Lateral hand excursion [cm] mean (SD)** N/A **Vertical hand excursion [cm] mean (SD)**

	I – II CIMT: I (2), II (6) HABIT: I (2), II (6) **GMFCS** I – II CIMT: I (3), II (5) HABIT: I (2), II (6)		*Pre-training condition* • 6.20 (1.24) *Post-training condition* • 5.84 (1.13) **Non-paretic limbs elbow excursion [cm] mean (SD)** *Pre-training condition* • 16.11 (5.05) *Post-training condition* • 13.48 (3.51) **Paretic limbs elbow excursion [cm] mean (SD)** *Pre-training condition* • 12.53 (4.80) *Post-training condition* • 12.87 (3.75) **Non-paretic limbs shoulder excursion [°] mean (SD)** *Pre-training condition* • 15.66 (4.02) *Post-training condition* • 15.49 (2.20) **Paretic limbs shoulder excursion [°] mean (SD)** *Pre-training condition* • 14.99 (3.46) *Post-training condition* • 15.95 (4.76)	*Pre-training condition* • 6.08 (1.14) *Post-training condition* • 5.23(1.09) **Non-paretic limbs elbow excursion [cm] mean (SD)** *Pre-training condition* • 15.80 (4.71) *Post-training condition* • 13.77 (4.66) **Paretic limbs elbow excursion [cm] mean (SD)** *Pre-training condition* • 12.58 (3.26) *Post-training condition* • 12.28 (2.97) **Non-paretic limbs shoulder excursion [°] mean (SD)** *Pre-training condition* • 15.31 (5.01) *Post-training condition* • 14.26 (3.10) **Paretic limbs shoulder excursion [°] mean (SD)** *Pre-training condition* • 15.48 (3.96) *Post-training condition* • 15.43 (3.23)	N/A **Non-paretic limbs elbow excursion [cm] mean (SD)** N/A **Paretic limbs elbow excursion [cm] mean (SD)** N/A **Non-paretic limbs shoulder excursion [°] mean (SD)** N/A **Paretic limbs shoulder excursion [°] mean (SD)** N/A

			CIMT	**HABIT**	**Interaction**
Zafer *et al.* (2016) **RCT** **Fair quality**	**N = 18** (CIMT 9, BMT 9) **Age:** 1.5 – 12 yrs. (8.75 ± 3.06) **Gender:** 15 M : 3 F **Hemiplegic side:** N/A **MACS:** N/A **GMFCS** N/A	Both groups received 2 hour per day of CIMT or HABIT, 6 days a week for 2 weeks. Total dose: 24 hours CIMT: mitt and sling worn 6 hours per day. Home setting	**QUEST total** *(Mean ± SD)* *Pre-treatment* • 63.05 ± 5.28 *Post-treatment* • 84.12 ± 3.32 **QUEST PE** *(Mean ± SD)* *Pre-treatment* • 73.69 ± 6.18 *Post-treatment* • 80.80 ± 3.25 **QUEST DM** *(Mean ± SD)* *Pre-treatment* • 52.41 ± 8.14 *Post-treatment* • 85.91 ± 3.12 **QUEST WB** *(Mean ± SD)* *Pre-treatment* • 72.97 ± 6.96 *Post-treatment* • 81.86 ± 7.78 **QUEST G** *(Mean ± SD)* *Pre-treatment* • 53.13 ± 7.20 *Post-treatment* • 87.90 ± 3.13	**QUEST total** *(Mean ± SD)* *Pre-treatment* • 61.27 ± 3.68 *Post-treatment* • 79.97 ± 2.23 **QUEST PE** *(Mean ± SD)* *Pre-treatment* • 72.15 ± 6.07 *Post-treatment* • 78.80 ± 2.24 **QUEST DM** *(Mean ± SD)* *Pre-treatment* • 50.43 ± 7.37 *Post-treatment* • 82.71 ± 2.47 **QUEST WB** *(Mean ± SD)* *Pre-treatment* • 70.42 ± 6.87 *Post-treatment* • 75.36 ± 6.91 **QUEST G** *(Mean ± SD)* *Pre-treatment* • 52.10 ± 5.87 *Post-treatment* • 83.00 ± 3.21	**QUEST total** *Pre-treatment* • *p* value = 0.421 *Post-treatment* • *p* value = 0.007 **QUEST PE** *Pre-treatment* • *p* value = 0.603 *Post-treatment* • *p* value = 0.149 **QUEST DM** *Pre-treatment* • *p* value = 0.597 *Post-treatment* • *p* value = 0.028 **QUEST WB** *Pre-treatment* • *p* value = 0.446 *Post-treatment* • *p* value = 0.080 **QUEST G** *(Mean ± SD)* *Pre-treatment* • *p* value = 0.743 *Post-treatment* • *p* value = 0.005
			CIMT	**HABIT**	**Interaction**
	N = 17		**MUUL** *(95%CI)*	**MUUL** *(95%CI)*	**MUUL**

Sakzew-ski *et al.* (2015) **RCT** **High quality**	(mCIMT 9, BIT 9) **Age:** 5 – 16 yrs. mCIMT: 8.7 ± 1.5 BIT: 8.9 ± 1.5 **Gender:** 9 M : 8 F mCIMT: 5 M : 4 F BIT: 4 M : 4 F **Hemiplegic side:** 7 L : 11 R mCIMT: 3 L : 6 R BIT: 4 L : 5 R **MACS:** I – II mCIMT: I (3) : II (6) BIT: I (1), II (8) **GMFCS:** I – II mCIMT: I (6), II (3) BIT: I (6), II (3)	Both groups received 6 hours per day of CIMT or HABIT for 5 days. Total dose: 30 hours mCIMT: Glove worn during the 6 hours of the camp activities Circus theme camp	*EMD baseline to 3 weeks* • - 1.0 (- 4.6, 2.6) *p* = 0.6 *EMD baseline to 26 weeks* • - 0.9 (- 4.5, 2.7) : *p* = 0.6 **AHA** *(95%CI)* *EMD baseline to 3 weeks* • - 2.0 (- 6.1, 2.1) : *p* = 0.3 *EMD baseline to 26 weeks* • - 0.2 (- 4.3, 3.9) : *p* = 0.9 **JTTHF** *(95%CI)* *EMD baseline to 3 weeks* • 0.2 (- 45. 6, 46.0) : *p* = 0.9 *EMD baseline to 26 weeks* • 9.2 (- 36.6, 55.0) : *p* = 0.7	*EMD baseline to 3 weeks* • - 0.8 (- 4.0, 2.4): *p* = 0.6 *EMD baseline to 26 weeks* • - 0.4 (- 3.6, 2.8): *p* = 0.8 **AHA** *(95%CI)* *EMD baseline to 3 weeks* • 1.3 (- 1.1, 3.8) : *p* = 0.3 *EMD baseline to 26 weeks* • 2.2 (- 0.2, 4.7) : *p* = 0.07 **JTTHF** *(95%CI)* *EMD baseline to 3 weeks* • - 48.2 (- 99.8, 3.4) : *p* = 0.07 *EMD baseline to 26 weeks* • - 42.1 (- 93.7, 9.5) : *p* = 0.1	N/A **AHA** N/A **JTTHF** N/A

*Abbreviations: CIMT = constraint induced movement therapy; mCIMT = modified constraint induced movement therapy; HABIT = hand-arm bimanual intensive therapy; BIM = bimanual Therapy; BMT = bimanual therapy; CP = cerebral palsy; M = male; F = female; L = left; R = right; OT = occupational therapist; PT = physiotherapist; MACS = manual ability classification system; GMFCS = gross motor function classification system; QUEST = quality of upper extremity skills test; PE = protective extension; DM = dissociated movements; WB = weight bearing; G = grasp; MUUL = Melbourne assessment of unilateral upper limb function; AHA = assisting hand assessment; JTTHF = Jebsen Taylor test of hand function; COPM = Canadian occupational performance measure; SD = standard deviation; CV = coefficient of variation; EMD = estimated mean difference; CI = confidence interval; g x ts = group x test session; yrs. = years; mins = minutes; s = seconds; cm = centimetres; º = degrees, * = p < 0.05 pre-test condition compared with post-test condition*

Outcome Results

Assisting hand assessment (AHA)

Two studies used the AHA as part of the upper limb assessment. One study found improvements in both CIMT and HABIT with no difference between the interventions while another study found no significant changes at all.

One study (Gelkop *et al*., 2015) found significant improvements in both CIMT and HABIT groups ($p < 0.001$). The main effect occurred between the post baseline and immediately post intervention with average improvements between 45.2 to 55.8 AHA units ($p < 0.05$) which was maintained at the two month follow up. There was no significant difference between the two interventions ($p = 0.48$). One study (Sakzewski *et al*., 2015) found no significant changes in either CIMT or BIM (bimanual therapy) intervention group at the three week ($p = 0.3$; $p = 0.3$, respectively) or 26 week follow up ($p = 0.9$; $p = 0.07$, respectively). One child receiving CIMT and one receiving BIM achieved a clinically meaningful change whereas in the other study (Gelkop *et al*., 2015), five participants from each group improved ≥5 AHA units, thereby exceeding the smallest detectable difference (Krumlinde-Sundholm, 2012).

Melbourne assessment of unilateral upper limb function (MUUL)

This assessment was used in one study (Sakzewski *et al*., 2015) that found no significant changes for neither CIMT or BIM. The study saw no significant changes at the three week ($p = 0.6$; $p = 0.6$, respectively) or 26 week ($p = 0.6$; $p = 0.8$, respectively) follow up with one child in the CIMT group achieving a change greater than measurement error.

Jebson-taylor test of hand function (JTTHF)

One study (Sakzewski *et al*., 2015) used this test as part of their results and there were no significant changes seen. There were no significant improvements in both CIMT and BIM at the three week ($p = 0.9$; $p = 0.07$, respectively) or 26 week follow up ($p = 0.7$; $p = 0.1$, respectively).

Quality of upper extremity skills test (QUEST)

Two studies used QUEST as part of their upper limb functionality assessment (Gelkop *et al*., 2015; Zafer *et al*., 2016). Both studies found significant improvements in the QUEST total and the dissociated movement subset test. They both saw more improvements in the CIMT groups within the QUEST total and dissociated movement. One study found improvements for both interventions for grasp with CIMT having further progress than HABIT.

QUEST total

One study (Gelkop *et al*., 2015) demonstrated significant improvements in CIMT and HABIT intervention groups in the QUEST total score ($p < 0.001$) displayed primarily between the post baseline (CIMT: 55.0 (95% confidence interval (CI): 35.4, 74.6)) (HABIT: 56.8 (95% CI: 37.2, 76.4)) and immediate post intervention (CIMT: 74.0 (95% CI: 56.9, 91.2)) (HABIT: 70.4 (95% CI: 53.3, 87.6)) with average improvements between 55.9 to 72.1 which was maintained at the two month follow up (CIMT: 73.0 (95% CI: 57.9, 88.1)) (HABIT: 70.0 (95% CI: 54.9, 85.1)). On average, there was 35% and 24% improvement for the CIMT and HABIT group, respectively, with no significant difference between the two groups (p = 0.671). Another study (Zafer *et al*., 2016) also showed significant improvements in both CIMT and HABIT between pre-treatment (Mean ± SD - CIMT: 63.05 ± 5.28, HABIT: 61.27 ± 3.68) and post-treatment (Mean ± SD - CIMT: 84.12 ± 3.32, HABIT: 79.97 ± 2.23) with average improvements of 21% and 19% respectively. Both groups exceeded the "smallest detectable difference" (i.e. 14%) for QUEST (Klingels *et al*., 2008). They also showed significant difference between the two groups (p = 0.007). This value demonstrates further improvements in the CIMT group compared to the HABIT group.

QUEST subset

One of the studies (Gelkop *et al*., 2015) found a significant increase for all QUEST subset scores in both CIMT and HABIT ($p < 0.05$). All subset scores had no significant difference between the group except the dissociated movement test ($p < 0.05$). This difference suggested that the CIMT group showed greater improvements when compared to the HABIT group between post-baseline and immediate post-intervention. A second study (Zafer *et al*., 2016) also found significant differences between CIMT and BIM in dissociated movements subset test ($p = 0.028$) as well as the grasp subset test ($p = 0.005$). These figures demonstrate that CIMT had significantly more improvements than BIM. There was an insignificant difference in the grasp subset of the test in Gelkop *et al*., 2015 (p = 0.566) and insignificant difference for both weight bearing and protective extension in both studies; (Gelkop *et al*., 2015) ($p = 0.883$; $p = 0.564$, respectively) and (Zafer *et al*., 2016) ($p = 0.08$; $p = 0.149$, respectively).

Reach – Grasp – Eat

One study used this experimental reach-grasp-eat setup to test the function of the upper limb (Hung, Spingarn, *et al*., 2020). In this study it was found that while both interventions had improvements overall, CIMT had further development in the reaching movement in regard to time and hand curvature as well as the hand vertical position within the grasp movement. CIMT also had further improvements in head rotation excursion in the eating movement.

Reaching movement

A decrease in the time it took to carry out the reaching movement decreased after both CIMT and HABIT. There was significant improvement in the trunk involvement, elbow flexion/extension excursion and wrist rotation in both groups and also significant improvement for the hand curvature in the CIMT intervention but not the HABIT.

Reaching movement time significantly decreased in both CIMT and HABIT groups (p = 0.007) with no group differences (p = 0.05) as well as a significant decrease in the coefficient of variation (CV) (movement consistency) after intervention (p = 0.011). There was a significant improvement for hand curvature in the CIMT group (p = 0.017) with a significant difference between the interventions (p = 0.034). According to the analysis, the CIMT group decreased curvature of the hand (straighter hand movement) significantly but the HABIT intervention group did not. CV of hand curvature also decreased significantly post intervention (p = 0.002) with no significant values between the two groups (p = 0.945). There was a significant decrease in trunk involvement during the reaching movement (p = 0.013) and significant improvement in elbow flexion/extension excursion and wrist rotation (p = 0.018; p = 0.035, respectively). Trunk involvement also had significant decreased in the CV after intervention (p = 0.012). There were no significant statistics for the upper arm excursion after either intervention (test session: p = 0.80).

Grasping movement

Grasping time decreased for both groups and there was an improvement observed for the vertical position of the hand with CIMT having better results when compared to HABIT.

Grasping movement times significantly decreased after both CIMT and HABIT (p = 0.007) with no group differences ($p > 0.05$). For hand vertical position, there was a significant improvement found (p = 0.049) with a significant difference between the interventions (p = 0.034). According to the findings, children in CIMT group significantly lowered their hand vertical position but the HABIT group did not. For CV, there was no significant improvements for either group (p = 0.24).

Eating movements

For the eating part of the movement, there were improved times in both groups. There were improvements in the elbow flexion/extension, head rotation excursion with further improvements within the CIMT group in regard to the head rotation excursion compared to the HABIT.

Eating movement times significantly decreased after both CIMT and HABIT (*p* = 0.007; *p* = 0.048, respectively) with no group differences (*p* > 0.05). There was no significant change for the upper arm excursion (*p* = 0.73). A significant improvement was seen specifically in the elbow flexion/extension excursion during the eating movement for both groups (*p* = 0.034). There was no significant difference for wrist rotation excursion (*p* = 0.55). Significant improvements were displayed in both groups for the head rotation excursion (*p* = 0.01) as well as a significant difference between the two groups (*p* = 0.045). According to the analysis, there was a significant decreased for the CIMT group during the eating movement, but not the HABIT group. No significant values were found for head flexion excursion (*p* = 0.40). There were no significant changes were found for CV of the upper arm, elbow, wrist rotation, head rotation and head flexion excursion during the eating movement after training.

Walking with tray for upper extremity movement control

One study used this experimental setup to test upper limb movement control (Hung, Shirzad, *et al*., 2020). In the study, a significant difference between the groups was seen for the bimanual movement with HABIT having more improvements than CIMT in regard to the vertical height between the two hands. Both interventions had improvements with the lateral excursion of the tray. There was no improvement in the vertical hand excursion or for the paretic and non-paretic should and elbow.

For the bimanual movement control, there was a significant difference between the groups for the maximum distance between the vertical height of the two hands (*p* = 0.029). According to the study, the HABIT intervention group significantly decreased the maximum height difference between the two hands during the dual task after training but the CIMT group did not. There was a significant decrease in lateral excursion of the tray after both CIMT and HABIT groups (*p* = 0.029). Vertical hand excursion of the tray saw no significant changes after intervention (test session: *p* = 0.104). There were no significant changes for the paretic and non-paretic shoulder as well as the elbow excursion for both interventions (*p* > 0.05).

Discussion

The main goal of this literature review was to do an updated review of the meta-analysis based on recent scientific evidence, on the effectiveness of CIMT and HABIT in hemiplegic cerebral palsy for upper limb function. One meta-analysis found a “trivial benefit” for HABIT over CIMT but more research was needed (Alahmari et al., 2020) and another found that it was “not possible to conclude which therapy is more effective than the other in improving unimanual or bimanual function” (Tervahauta *et al*., 2017). CIMT and HABIT are both interventions that are used to improve hand function in children with CP but there is currently no evidence that can conclude which evidence is better than the other. This review showed that CIMT and HABIT are both interventions which can increase the quality and function of the upper limb. The results also showed that while the CIMT intervention saw better quality of movement and skills in unimanual tasks in the paretic hand, HABIT showed more improvements in bimanual tasks.

Summary of Results

The main objective was to find the most suitable intervention for hemiplegic cerebral palsy patients to improve the function of their upper extremity through the use of intense therapies targeted at such areas. All the included studies had a variation of outcomes measurements. These included; AHA (Gelkop *et al*., 2015; Sakzewski *et al*., 2015), QUEST total and subset (Gelkop *et al*., 2015; Zafer *et al*., 2016), reach-eat-grasp experimental setup (Hung, Spingarn, *et al*., 2020), walking with a tray experimental setup (Hung, Shirzad, *et al*., 2020), MUUL and JTTHF (Sakzewski *et al*., 2015). When looking at the AHA, MUUL and JTTFH, there were no significant difference between the two interventions. However in two studies, the quality of movement recorded in the paretic hand in the QUEST total and dissociated movement subset scores, saw that the CIMT groups had significantly more improvements (Gelkop *et al*., 2015; Zafer *et al*., 2016). One study also found significantly more improvements with CIMT intervention in the grasp subset score (Zafer *et al*., 2016). CIMT also did significantly bigger improvements in the reach-eat-grasp experimental setup in another study (Hung, Spingarn, *et al*., 2020). Whereas in the dual task experimental set up where the participant had to walk with a tray in two hands, the HABIT group had significantly more improvements (Hung, Shirzad, *et al*., 2020). From these results we can say that CIMT improves the use of the paretic hand more than HABIT but when it comes to tasks using both the paretic hand and the non-paretic hand, HABIT does significantly better than CIMT. This confirms the original hypothesis of training specificity. A systematic review by Dong *et al*. reported the same outcome (Dong *et al*., 2013).

The systematic review by Tervahau *et al*. does not support the same findings as Dong *et al.* or this review. This could be due to the fact that newer research and experimental set-ups focusing on unimanual and bimanual tasks were in the present review. Another reason could be that the analysis by Tervahau *et al.* also took into consideration the methodology of the included studies and the effect size. This gives a more detailed overview and systematic evaluation of the studies (Tervahauta *et al*., 2017). As mentioned in the analysis, the study by Zafer *et al.* shows benefit of calculating effect sizes. The effect size of the study favours CIMT but due to large effect sizes not occurring in other studies found, it is hard to make a definite statement about the impact CIMT.

Points of Discussion

According to the PEDro-scale, four out of the five included RCT's were graded as "high quality" evidence (Gelkop et al., 2015; Hung, Shirzad, et al., 2020; Hung, Spingarn, et al., 2020; Sakzewski et al., 2015) while one RCT was graded as "fair quality" (Zafer et al., 2016). The overall strength of reporting quality was carried out by the CONSORT 2010 statement. It was seen that while four out of five of the articles had between 20 – 22 of the 25 items on the checklist (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015), one only had 14 items (Zafer *et al*., 2016). From the quality assessment, it should be noted that the study by Zafer *et al.* is of lower quality than the other four studies in regards to evidence and reporting quality.

Within the included studies, there were three that had a large dose of CIMT and HABIT and two that had a relatively small dose. Three of the studies had a large dose of 90-96 hours (Gelkop *et al*., 2015; Hung, Shirzad, *et al*., 2020; Hung, Spingarn, *et al*., 2020) whereas Zafer *et al.* had a total of 24 hours of interventions over two weeks and Sakzewski had 30 hours of interventions over five days. Even though the study by Zafer *et al.* had a much lower dosage, there were still significant values and differences between the two interventions in the QUEST assessment that were of similar results to Gelkop *et al*. This could be due to the higher pre-treatment QUEST scores for the study by Zafer *et al*. (QUEST total; CIMT- 63.05 ± 5.28, HABIT – 61.27 ± 3.68)) when compared to the pre-treatment scores from Gelkop *et al.* (QUEST total; CIMT – 55.0 (35.4, 74.6), HABIT – 56.8 (36.2, 76.4)). Another reason could be that Zafer *et al.* was the only study that did not specify no botulinum toxin therapy 6 months prior to the study. Botulinum toxin injections help to reduce spasticity, improve range of motion and function, and when combined with occupational therapy it is more effective than the therapy alone at reducing impairments (Hoare et al., 2010). If any patient had a botulinum toxin injection during the study or the months prior, this could have shown further improvement than those without. Sakzewski *et* *al*. did not see any significant changes with its low dose including the AHA where the higher dosed intervention by Gelkop *et al.* did have a significant improvement in both intervention. The study by Sakzewski *et al.* was also compared to previous study by the same researchers in 2011 (Sakzewski et al., 2011). This study compared CIMT and HABIT with a higher dose of 60 hours. When comparing the two doses, they found lower dose to be insufficient in improving upper limb function when compared to the higher dose. In a systematic review by Hoare et al, CIMT was compared to interventions with different dose comparison. It was found that original high dosed CIMT may improve bimanual ability and unilateral capacity more than low dose (Hoare *et al*., 2019). It also found that it was no more effective than an equal dose comparison. This reiterates Chiu & Ada's hypothesis that CIMT's effectiveness may be due to the large amount of intense practice involved with the interventions rather than the restraining itself (Chiu & Ada, 2016).

Across the five studies, there was a wide range of hand function level among the participants. Three studies did not include a GMFCS level (Gelkop *et al*., 2015; Hung, Spingarn, *et al*., 2020; Zafer *et al*., 2016) and one study did not report a MACS level (Zafer *et al*., 2016). The GMFCS is the most well-known and established classification for measuring function in children with CP aged 2-18 years (Paulson & Vargus-Adams, 2017). The MACS level is a specific classification for the upper extremity. This measurement is used to classify the hand and arm function in children with CP and is complementary to the GMFCS (Paulson & Vargus-Adams, 2017). A study found that children with a MACS level I and II develop faster and reach a limitation in development quicker than a child with a MACS level III (Nordstrand *et al*., 2016). There was also a wide range of age in all five studies. The age range across the studies was 1.5 to 16 years. Zafer *et al.* and Sakzewski *et al.* had the largest range with over ten years between participants. A study found that children with unilateral CP show rapid development at a young age between 18 months and eight years (Paulson & Vargus-Adams, 2017). After this age, development begins to slow down (Nordstrand *et al*., 2016). Therefore, it makes it difficult to make a clear statement of the effect of the studies that have included a wide age range and level of hand function.

It should be noted that while four out of the five articles (Gelkop *et al*., 2015; Hung, Spingarn, *et al*., 2020; Sakzewski *et al*., 2015) intervention were carried out by occupational therapists, physiotherapists or therapist assistance, in the study by Zafer *et al*., the intervention was carried out by the parents in a home setting. Therapists initially guided the parents about how to carry out the intervention. The parents were then responsible for the progression and protocol adherence with no supervision. The only point of contact the parent had with the therapist after the initial guidance was through the phone. Although a similar outcome was seen for the QUEST assessment in the study by Gelkop *et al*, the lack of supervision could have had an effect on adherence to protocol, progression and the overall outcome of the study.

One of the final steps of the CIMT protocol is the "transfer package" where the improved unimanual function is integrated with meaningful bimanual ADL's activities. In the studies included in this review, not one included the "transfer package" in the CIMT intervention. Participants in the CIMT group received only unimanual training and participants in the HABIT group only received bimanual training. The systematic review by Tervahau *et al.* found a similar finding where only one study fulfilled the "transfer package" step of CIMT. This leaves out a very important aspect of CIMT and hence, it does not give a true reflection of CIMT and the potential improvement that it could have in improving bimanual function

Limitations

There were a number of limitations in this review that need to be taken into consideration when interpreting the results.

As can be seen in the assessment outcomes of the studies included in this literature review, there is a lack of consensus to which is the most suitable to assess upper extremity function. This is because there are many elements to test including range of motion of several joints, movement fluency and quality of movement which are needed to get a full picture of an individual's upper limb function. There is currently no gold standard to fully assess this. Both Hung *et al*. studies, went for an experimental set up, one using a single-handed task assessment another using bimanual task assessment. These two studies had completely different outcomes in which the study with the unimanual assessment found CIMT to have significantly better outcome and the other assessing bimanual function demonstrated that HABIT is a significantly better outcome. This shows that while these experimental set ups are useful in finding specific outcomes, they are not ideal when looking at the overall picture. There is also values for reliability for these assessments. Whereas, two articles used the QUEST assessment which has a good inter and intra reliability (Intra-class Correlation Coefficient; 0.86; 0.96, respectively) (Thorley et al., 2012) mainly looks at tasks using the affected limb hence its findings were predominantly in favour of CIMT. A better tool or tools for assessment needs to be found that assess both unimanual and bimanual tasks.

The lack of a standardised protocol of in terms of dosage, intensity and duration among the studies may account for variation in the results of some studies. By calculating effect size this could have made comparing studies more accurate but due to the studies having different outcomes, this was not possible.

Recommendations

Further research on the efficacy of CIMT and HABIT should be considered with larger sample sizes, a standard intervention protocol and with a measurement tools assessing both bimanual and unimanual function. Interventions should also include the “transfer package” step within the CIMT protocol in order to see a true reflection on the approach of CIMT. Further research should also be carried out on a hybrid intervention of both CIMT and HABIT. A study that compared a hybrid intervention and a bimanual intervention, concluded that they both had a similar effect for improving the use of the affected hand in bimanual tasks but that the hybrid intervention had more improvements in unimanual function (Cohen-Holzer *et al*., 2017). Deppe *et al.,* also came to the same conclusion (Deppe *et al*., 2013). This shows that a combined intervention could have significant improvements in both the bimanual function and the unimanual function of the paretic hand.

The results of the presented literature review show positive effects for CIMT and HABIT in the upper limb of hemiplegic Cerebral Palsy patients. Therefore, it is recommended to apply these methods in physiotherapy and occupational therapy. The concept of training specificity should be considered before deciding on an intervention since CIMT shows more improvements in unimanual and HABIT in bimanual. With the application of the “transfer package” in the CIMT protocol, further improvement in bimanual skills may be possible. It is also recommended to include the higher dosed interventions as they show more improvements than the lower doses.

Conclusion

The findings of this review found both CIMT and HABIT to be effective forms of therapy to improve upper limb function. The CIMT intervention had further improvements in unimanual function while HABIT had more improvement for bimanual function. Hence, specificity of training should be taken into consideration before deciding a therapy. Further research should be done on the topic due to limitations in this study as well as research into a hybrid intervention combining the two therapies.

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Appendix

Appendix 1: Search String

Search trials per database carried out between the 22nd of February to the 6th of March 2021:

Table 6 – Search String in the Cochrane Library database

Cochrane Library			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	None	N = 17
2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	None	N = 34 articles
3	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	Trials	N = 32 articles
4	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	Trials 2015-2021	N = 13 articles

Table 7 – Search String in the PubMed database

PubMed			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	None	N = 14 articles
2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	None	N = 18 articles
3	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	2015-2021 English	N = 7 articles

Table 8 – Search String in the Embase database

Embase			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	None	N = 14 articles
2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	None	N = 14 articles
3	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	2015-2021 English	N = 7 articles

Table 9 – Search String in the PEDro database

PEDro			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	None	N = 9 articles
2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	None	N = 9 articles
3	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	2015-2021	N = 5 articles

Table 10 – Search String in the Cinahl database

Cinahl			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	None	N = 7 articles

2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	None	N = 7 articles
3	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	Apply related words Also search within the full text of the articles Apply equivalent subjects	N = 26 articles
4	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	Apply related words Also search within the full text of the articles Apply equivalent subjects 2015-2021 English	N = 12 articles

Table 11 – Search string in the Google Scholar database

Google Scholar			
Search attempt	Search terms	Filters applied	Number of hits
1	"Cerebral palsy AND constraint-induced movement therapy AND hand-arm bimanual intensive therapy"	With all of the words	N = 409 articles
2	"Cerebral palsy AND constraint induced movement therapy AND hand arm bimanual intensive therapy"	With all of the words 2015-2021	N = 236 articles

Appendix 2: Method Quality Assessment: PEDro scale

Table 12 – PEDro scale application

Study	**Hung, Springarn *et al.* 2020**	**Hung, Shirzad, *et al.* 2020**	**Gelkop *et al.* 2015**	**Zafer *et al.* 2016**	**Sakzewski *et al.* 2015**
Total Score	**6 / 10**	**8 / 10**	**8 / 10**	**5 / 10**	**7 / 10**
1. Eligibility criteria were specified	1	1	1	1	1
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	1	1	1	1	1
3. Allocation was concealed	1	1	1	0	1
4. The groups were similar at baseline regarding the most important prognostic indicators	1	1	1	1	1
5. There was blinding of all subjects	1	0	0	0	1
6. There was blinding of all therapists who administered the therapy	0	0	1	0	0
7. There was blinding of all assessors who measured at least one key outcome	1	1	0	0	1
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	0	1	1	1	1
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	0	1	1	0	0
10. The results of between-group statistical comparisons are reported for at least one key outcome	0	1	1	1	0
11. The study provides both point measures and measures of variability for at least one key outcome	1	1	1	1	1

Appendix 3: CONSORT 2010 Checklist

Table 13 – CONSORT statement reporting quality

Section / Topic	**Item no.**	**Checklist item**	**Reported**				
			Gelkop *et al.* 2015	**Hung, Springarn *et al.* 2020**	**Hung, Shirzad, *et al.* 2020**	**Zafer *et al.* 2016**	**Sakzew-ski *et al.* 2015**
Total amount of checklist items			**22 / 25**	**22 / 25**	**20 / 25**	**14 / 25**	**20 / 25**
Title and Abstract							
Title and abstract	1	• Identification as a randomised trial in the title • Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	⃠ ✓	⃠ ✓	⃠ ✓	⃠ ✓	⃠ ✓
Introduction							
Background	2	• Scientific background and explanation of rationale • Specific objectives or hypotheses	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Methods							
Trial design	3	• Description of trial design (such as parallel, factorial) including allocation ratio) • Important changes to methods after trial commencement (such as eligibility criteria), with reasons	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Participants	4	• Eligibility criteria for participants • Settings and locations where the data were collected	✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Interventions	5	• The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	✓	✓	✓	✓	✓
Outcomes	6	• Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	✓	✓	✓	✓	✓

		• Any changes to trial outcomes after the trial commenced, with reasons	✓	✓	✓	✓	✓
Sample Size	7	• How sample size was determined • When applicable, explanation of any interim analyses and stopping rules	✓ ✓	✓ ✓	⦸ ✓	⦸ ✓	⦸ ✓
Randomisation							
Sequence	8	Sequence • Method used to generate the random allocation sequence • Type of randomisation; details of any restriction (such as blocking and block size)	✓ ✓	✓ ✓	✓ ✓	⦸ ⦸	✓ ✓
Allocation	9	• Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	✓	✓	✓	⦸	✓
Implementation	10	• Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	✓	✓	✓	✓	✓
Blinding	11	• If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how • If relevant, description of the similarity of interventions	✓ ✓	✓ ✓	✓ ✓	⦸ ✓	✓ ✓
Statistical methods	12	• Statistical methods used to compare groups for primary and secondary outcomes • Methods for additional analyses, such as subgroup analyses and adjusted analyses	✓ ✓	✓ ✓	✓ ✓	⦸ ⦸	✓ ⦸
Results							

Participant flow (a diagram is strongly recommended)	13	• For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome • For each group, losses and exclusions after randomisation, together with reasons	✓ ✓	✓ ✓	⃠ ⃠	⃠ ⃠	✓ ✓
Recruitment	14	• Dates defining the periods of recruitment and follow-up • Why the trial ended or was stopped	⃠ ⃠	✓ ⃠	⃠ ⃠	⃠ ⃠	✓ ⃠
Baseline data	15	• A table showing baseline demographic and clinical characteristics for each group	✓	✓	✓	⃠	✓
Numbers analysed	16	• For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	✓	✓	✓	⃠	✓
Outcomes and estimation	17	• For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval) • For binary outcomes, presentation of both absolute and relative effect sizes is recommended	✓ Not applicable	✓ Not applicable	✓ Not applicable	✓ Not applicable	✓ Not applicable
Ancillary analysis	18	• Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	⃠	⃠	⃠	⃠	⃠
Harms	19	• All-important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	✓	✓	✓	✓	✓
Discussion							
Limitations	20	• Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses Discussion of research, programmatic, or policy implications	✓	✓	✓	✓	✓

Generalisa-bility	21	• Generalisability (external validity, applicability) of the trial findings	✓	✓	✓	✓	✓
Interpretation	22	• Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	✓	✓	✓	✓	✓
Other Information							
Registration	23	• Registration number and name of trial registry	✓	✓	✓	✓	✓
Protocol	24	• Where the full trial protocol can be accessed, if available	✓	✓	✓	✓	✓
Funding	25	• Sources of funding and other support (such as supply of drugs), role of funders	✓	✓	✓	✓	✓

Appendix 4: Data Extraction

Table 14 - Data extracted from the study by Gelkop et al. 2015

Gelkop *et al.* 2015 "Efficacy of Constraint-Induced Movement Therapy and Bimanual Training in Children with Hemiplegic Cerebral Palsy in an Educational Setting"	
Participants	N = 12 (CIMT 6, HABIT 6) Age = 1.5 – 7 years (CIMT: 4.25 ± 1.58, HABIT: 4.33 ± 1.86) Gender = 2 Male, 10 Female (CIMT + BIT 1 Male, 5 Female) Hemiplegic side = 6 Left : 6 Right (CIMT: 3 Left : 3 Right, HABIT: 3 Left : 3 Right) Race = N/A Manual Ability Classification System = I - III (CIMT: I (1), II (2), III (2), HABIT: I (I), II (3), III (1)) Gross Motor Function Classification System = N/A
Eligibility criteria	20º of wrist extension Ability to release objects from the hand Age appropriate cognitive skills No intensive therapeutic interventions involving the upper limb or botulinum toxin therapy in the past 6 months no intention to start new treatment during the study
Intervention	Both interventions received 2 hours/day of intervention (1 hour individual session, 1 hour group session) for 6 days a week for a total of 8 weeks. Total dosage is 96 hours. It was administered during the children's regular preschool or kindergarten hours. Individual sessions were one on one with occupational therapist and group sessions were carried out by two or three occupational therapists and therapist's assistance resulting in a 1:2 or 1:1 interventionist to child ratio

	Both intervention groups had individualised programs specified to their ability and comprised of intense, progressive activities based on motor learning approaches. Assessing task difficulty was done in order to progress difficulty and was dependent on child's own individual progression Each group participated in whole and part task practice based on activities of daily loving and child friendly games, indoors and outdoors with age specific encouragement. Instructions were given to make the intervention enjoyable and intrinsically motivating **CIMT** Custom made gloves were worn on the less affected upper limb and unimanual activities were performed with the affected hand. Glove was worn for 2 hours of CIMT. Children performed unilateral fine and gross motor functional and play activities tailored to the child's age. Interventionists assisted when necessary to complete activities. **HABIT** No restraint was used. Children participated in fine and gross motor bimanual activities tailored to their age. Activities were chosen based on the paretic hand function of each child and focused on using the assisting hand for increasing complex bimanual tasks. Therapists avoided verbal cues to use the paretic hand but instead created tasks that required the use of both hands.
Outcome measurements	Measurements of all assessments were taken "pre-baseline", "post-baseline", "immediate post-intervention" and "2 month post-intervention **Assisting Hand Assessment** – Effectiveness of the child using his/her paretic hand in bimanual activity **Quality of Upper Extremity Skills Test** – identify upper extremity function in four areas; dissociated movement, grasp, protective extension, and weight bearing. **Manual Ability Classification System** – Classify children into 5 levels based on their hand function in daily living

Strengths	Randomization of intervention No difference between populations at baseline Follow up Blinding of participants and assessors No drop outs
Weakness	Small sample size A longer follow up needed No control group
Conclusion	Effectiveness of CIMT and HABIT was seen in improving the quality of bimanual hand-use and movement in children with hemiplegic CP with a modified schedule of 2hr/day for 8 weeks

Table 15 - Data extracted from the study by Hung, Springarn, et al. 2020

Hung, Springarn, *et al.* 2020 “Intensive Unimanual Training Leads to Better Reaching and Head Control than Bimanual Training in Children with Unilateral Cerebral Palsy”	
Participants	N = 20 (CIMT 10, HABIT 10) Age = 6 – 12 years (CIMT: 7.6 ± 2.2, HABIT: 7.7 ± 1.7) Gender = 11 Male : 9 Female (CIMT: 6 Male : 4 Female, HABIT: 5 Male : 5 Female) Hemiplegic side = 11 Left, 9 Right (CIMT: 4 Left : 6 Right, HABIT: 7 Left : 3 Right) Race = 16 Caucasian, 2 Hispanic, 2 African American (CIMT: 8 Caucasian : 1 Hispanic : 1 African American, HABIT: 8 Caucasian : 1 Hispanic : 1 African American) Manual Ability Classification System = I – II (CIMT: I (2), II (8), HABIT: II (2), II (8)) Gross Motor Function Classification System = N/A JTTHF = CIMT: 221 ± 108, HABIT: 226 ± 100

Eligibility criteria	Ability to lift affected arm 15cm above a table and grasp a light object Attend regular school Ability to follow instructions during screening and complete tests No botulinum toxin therapy in the last 6 months No orthopaedic surgery on affected arm in the past year No visual problems that could interfere with the study No current or unstable seizures No other health problems associated with CP
Intervention	Both groups received 6 hours a day of either CIMT or HABIT for 15 consecutive days. Total dosage was 90 hours. It was administered in two separate rooms during a training camp Ratio of interventionist was either 1:1 or 2:1. Interventionist and children were blinded to the study hypotheses. Both interventions involved age appropriate gross and fine motor play activities and whole and part task practice. Whole tasks included board games or eating lunch. Part tasks included motor skills broken into smaller components (pic up small blocks for grasping) while increasing repetitions and skill requirements (putting block further away). **CIMT** A cotton sling with the hand opening sewn shut on the non-paretic arm. Children were asked to complete mostly unimanual activities using the paretic arm. Children were monitored for skill progression (e.g. moving object higher to encourage wrist extension). Interventionist aided when necessary. The paretic arm was as the active manipulator for eating. **HABIT** Children completed bimanual activities with no restraint. Children were monitored for skill progression from passive assist (e.g. stabilising paper while writing), to active assist (e.g. re-orienting paper while cutting paper) to an active manipulator (e.g. flipping cards). The paretic arm was used as the passive or active assisted hand while eating

Outcome measurements	Measurements were taken at pre-intervention and post-intervention **Experimental set up: Reach – eat – grasp** Participants were asked in a seated position to reach forward to grasp a cookie (3 x 7 cm, held vertically with a 1 cm stand) that was 30cm from the edge of the table with the more affected hand and bring it to their mouth. Participants sat 15 cm in front of the table with their elbows at table height and flexed at 90º at the starting position. Their hands were positioned 30 cm apart at the edge of the table and a head rest placed to certify proper head starting position. This was timed and 3D kinematic analysis collected data on movements.
Strengths	Randomization of intervention No difference between populations at baseline No drop outs
Weakness	No follow up No data for reliability and sensitivity of assessment No control group Small sample size
Conclusion	Both CIMT and HABIT resulted in faster movement, increased trunk stability and increased elbow flexion /extension and wrist rotation joint excursions while performing a unimanual reach-grasp-eat task. It was concluded that the CIMT group improved the more affected upper extremity end point path planning, grasp motor planning, and head rotation stability. This could make using the more paretic arm more efficient and increase the amount of use of the limb. Their findings support the concept of specificity of practice

Table 16 - Data extracted from the study by Hung, Shirzad, et al. 2020

Hung, Shirzad *et al.* 2020 “Intensive upper extremity training improved whole body movement control T for children with unilateral spastic cerebral palsy”

Participants	N = 16 (CIMT 8, HABIT 8) Age = 6 – 12 years (CIMT: 8.9 ± 2.2, HABIT: 8.3 ± 1.7) Gender = 10 Male : 6 Female (CIMT: 4 Male : 4 Female, HABIT: 6 Male : 2 Female) Hemiplegic side = 9 Left : 7 Right (CIMT: 4 Left : 4 Right, HABIT: 5 L : 3 R) Race = N/A Manual Ability Classification System = I – II (CIMT: I (2), II (6), HABIT: I (2), II (6)) Gross Motor Function Classification System = I – II (CIMT: I (3), II (5), HABIT: I (2), II (6))
Eligibility criteria	Able to perform task independently Ability to follow instructions during screening and complete tests No botulinum toxin therapy in the last 6 months No orthopaedic surgery on affected arm in the past year No other health problems associated with CP
Intervention	Both CIMT and HABIT group received 6 hours of intervention for 15 consecutive days. Total dosage was 90 hours. Intervention was given in a training camp environment. Interventionist to child ratio was 1:1 with an experienced supervisor constantly present. Training involved age appropriate gross and fine motor play activities. Most activities were performed in sitting with only a few motor activities preformed in standing such as ball activities. **CIMT** A cotton sling was used to restrain the child's non-paretic arm. Training involved using the arm as the active manipulator in activities (e.g. flipping cards). **HABIT**

	Training involved bimanual activities with no restraint (e.g. cutting paper with the non-paretic arm while the paretic arm orientates the paper).
Outcome measurements	Measurements were taken at pre-intervention and post-intervention **Experimental set-up – Walking with a tray** This experimental set up involved the child walking along a flat 4.06m long path at a self-selected pace while carrying a tray at a steady level. Their elbows must be flexed at 90º, without touching the body. The tray (24 x 34 cm) weighed 420 g and had adjustable handle (width range: 34-54 cm) in order to suit the width of the child's shoulders. Demonstrations were performed by the researcher and two trials were given before the assessed trial.
Strengths	Randomization of intervention No difference between populations at baseline No drop outs
Weakness	No follow up No data for reliability and sensitivity of assessment No control group Small sample size
Conclusion	Findings supported the concept of practice specificity. The HABIT group improved more in bimanual coordination than CIMT did.

Table 17 - Data extracted from the study by Zafer et al. 2016

Zafer *et al*. 2016 "Effectiveness of constraint induced movement therapy as compared to bimanual therapy in upper motor function outcome in child with hemiplegic cerebral palsy"	
Participants	N = 18 (CIMT 9, BMT 9) Age = 1.5 – 12 years (8.75 ± 3.06)

	Gender = 15 Male : 3 Female Hemiplegic side = N/A Race = N/A Manual Ability Classification System = N/A Gross Motor Function Classification System = N/A
Eligibility criteria	Age 1.5 to 12 years 10º of wrist extension 10º of finger extension Score 40 – 60 on QUEST grasp and dissociated movement domains
Intervention	Intervention was given to both groups for 2 hour a day, 6 days a week, for 2 weeks. Total dose was 34 hours. It was carried out in the home of the child. Intervention was done by the parent of the child with initial guidance by the therapist about timing of the restraint for CIMT and the intervention applied. After this no supervision of the intervention took place with the parent having full responsibility for the child's adherence and completion of the program. Contact through the phone was maintained to ensure progress and adherence to protocol. Both groups received activities of daily living task training. Tasks compromised of upper extremity reaching, grasping, manipulation, releasing and weight bearing on the limb **CIMT** The non-paretic arm was restrained by a mitt and sling strapped to the trunk in order to constrain the hand and elbow. Restraint was given for 6 hours of the day. Activities given to the parent to carry out with the child included daily and unimanual activities. **HABIT**

	Activities that the parent had to carry out with the child included daily and bimanual activities with no restraint.
Outcome measurements	Measurements were taken pre-intervention and post-intervention **Quality of Upper Extremity Skills Test** – identify upper extremity function in four areas; dissociated movement, grasp, protective extension, and weight bearing.
Strengths	Randomization of intervention No difference between populations at baseline
Weakness	Predominantly male population No follow up No control group Small sample size Small dose No supervision No representation of population characteristics
Conclusion	CIMT is a better approach to improve the function of the paretic arm when compared with BMT. There was significant improvements within grasp and dissociated subset scores in QUEST in CIMT as compared to BMT. CIMT is considered a better approach for unilateral conditions while for bilateral conditions, BMT is more appropriate.

Table 18 - Data extracted from the study by Sakzewski et al. 2015

Sakzewski *et al.* 2015 “Comparison of dosage of intensive upper limb therapy for children with unilateral cerebral palsy: How big should the therapy pill be?”	
Participants	N = 17 (mCIMT 9, BIT 9) Age = 5 – 16 years (mCIMT: 8.7 ± 1.5, BIT: 8.9 ± 1.5)

	Gender = 9 Male : 8 Female (mCIMT: 5 Male : 4 Female, BIT: 4 Male : 4 Female) Hemiplegic side = 7 Left : 11 Right (mCIMT: 3 Left : 6 Right, BIT: 4 Left : 5 Right) Race = N/A Manual Ability Classification System = I – II (mCIMT: I (3) : II (6), BIT: I (1), II (8)) Gross Motor Function Classification System = I – II (mCIMT: I (6), II (3), BIT: I (6), II (3))
Eligibility criteria	Minimal ability to grasp with the impaired upper limb Predominant spasticity interfering with upper limb function No botulinum toxin therapy in the last 6 months No previous surgery to the upper limb
Intervention	Each treatment received 6 hours of intervention per day for 5 days. Total dose was 30 hours. Intervention took place at a circus camp. Intervention and supervision was carried out by occupational therapists, physiotherapists and student and volunteer therapists. Ratio of interventionist to child was 1:2. Both interventions included activity based goal directed therapy using principles of motor learning. Goals were made by the child and family to determine intervention priorities. Intervention was given in groups (10 – 15 children) **CIMT** Children were constrained using an individually made glove on their non-paretic limb. Therapy and circus activities were preformed mainly using the paretic arm. During circus aerial activities, the glove was removed and finger of the non-paretic hand were taped to restrict manipulation. Other than that, the glove was only removed when going to the toilet. **HABIT** Children focused on activities that involved coordination of both hands using repetitive bimanual tasks.

Outcome measurements	Measurements were taken before intervention and 3 weeks and 26 weeks post baseline **Manual Ability Classification System** – Classify children into 5 levels based on their hand function in daily living **Melbourne Assessment of Unilateral Upper Limb Function** – Quality of movement of the paretic limb **Assisting Hand Assessment** – Effectiveness of the child using his/her paretic hand in bimanual activity **Jebson-Taylor Test of Hand Function** – Speed and dexterity of the upper limb
Strengths	Randomization of intervention No difference between populations at baseline No drop outs
Weakness	No follow up No control group Small sample size Small dose
Conclusion	Concluded that a small dose of CIMT is insufficient in improving upper limb motor outcomes.