**Introduction**

Cerebral palsy (CP) is the most common pediatric physical disability with the incidence for congenital hemiparesis rising.1 Intervention for hemiplegic CP involves promoting increased use and function of the weak upper limb (UL). Constraint induced movement therapy (CIMT) was originally developed as a treatment intervention for adults following stroke. It has been shown to produce greater improvement in UL function including motor capacity, quality of movement, and functional measures when compared to other dose and duration matched interventions.2

The use of CIMT in children with hemiplegic CP began to be explored in 2001-2002.3  Constraint induced movement therapy involves constraining the unimpaired UL with a cast or other device so that the subject is forced to use the involved upper extremity for performing play and functional tasks. The restraint is worn for 3-24 hours per day for 2-3 weeks depending on the protocol followed.

In the mid 2000’s a paradigm shift occurred which explored bimanual coordination difficulties in children with hemiplegic CP. Charles and Gordon introduced another intervention known as hand-arm bimanual intensive training (HABIT or BIT).4  This intervention involved extensive targeted practice provided in a child-friendly manner without using a physical constraint on the involved UL.4 Activities requiring bimanual coordination are then practiced through play, dressing, and activities of daily living (ADL’s).

The purpose of this literature review is to compare the use of CIMT to BIT to determine which intervention is more effective at improving UL function in children with hemiplegic CP between the ages of 2-16. This is an important clinical question as children with hemiplegic CP exhibit functional limitations secondary to impaired bimanual coordination in addition to their unilateral impairments.5  The most efficacious treatment intervention for children with hemiplegic CP has not been clearly established. This information will provide guidance for therapists and caregivers of children with hemiplegic CP for appropriate and effective clinical treatments to improve impaired UL function.

This review will describe, examine and critically appraise similarities and differences in eight research articles. Areas to be covered include research design, subject characteristics, outcome measures, interventions, methodological considerations, and results. Clinical relevance and Capstone application, discussion of the answer to the PICO question, limitations of the research, conclusions and future research will be included in this review.

**Study Design and Sample Characteristics**

Several randomized controlled trials (RCT)6-9 and randomized trials10-13  have been recently published that compare the effectiveness of CIMT and BIT in children with hemiplegic CP. Children ranged in age from 3.3 to 16 years of age when combining all the studies. Severity of hemiplegic hand function in all studies was classified using the Manual Ability Classification System (MACS).15  Children were classified as MACS I through III with I being less impaired hand function to III defined as more impaired hand function.15  All studies had subjects in the three categories of severity.

All children included in these research studies had a diagnosis of congenital hemiplegia except the study by Deppe et al did include 30% of their subjects with other etiologies of hemiplegia. These children were at least 2 years post onset of hemiplegia.6  In the eight studies, none of the studies reported differences between groups on age, severity of hand involvement, or baseline outcome measures.

**Outcome Measures**

Multiple outcome measures were used in the various research studies which makes precise comparison of functional improvements difficult across studies although studies employing the same outcome measures can be compared. The two most commonly used outcome measures were the Assisting Hand Assessment (AHA) and the Melbourne Assessment of Unilateral Upper Limb Function (MUUL).

The AHA is a performance measure that evaluates how effectively the paretic hand is used for bimanual activities.16  It measures the spontaneous use of the paretic hand as an assisting hand in standardized play and life activities.16  The AHA is a valid and reliable measure and is sensitive to change in subjects.16  It was used as an outcome measure in five of the eight studies which allows direct comparison of these studies.6, 10-13 The MUUL measures the quality and precision of isolated motor functions of the paretic arm and hand and is a capacity based test and assesses items that involve reach, grasp, release and manipulation.17  It was an outcome measures in half of the studies.6,10,11,13

The next most frequently used outcome measure, in three studies, was the Jebsen-Taylor Test of Hand Function (JTTHF).10-12  It measures movement speed in six unilateral activities.10 Three outcome measures were used in 2 different studies including the Pediatric Evaluation of Disability Inventory (PEDI),6,7  the Canadian Occupational Performance Measure (COPM)7,13 and the Besta Scale.8,9  The PEDI and COPM are valid and reliable functional outcome measures. The Besta Scale measures grasp, spontaneous use in play and activities of daily living, and qualitative use of the involved hand in feeding and dressing. No information was found to determine validity, reliability or clinically meaningful change for this scale.

The Quality of Upper Extremity Skills Test (QUEST) measures upper limb quality of movement and focuses on dissociated movements, grasp, weight bearing and protective extension.17  It was the primary outcome measure in studies by Fedrizzi et al and Faccin et al.8,9  One study used the ABILHAND-Kids questionnaire18 where parents rate the difficulty of 21 bimanual activities of daily living the child performs.10

In summary, outcome measures to assess unilateral function include the MUUL, QUEST, and JTTHF. Outcome measures to assess bimanual function include the AHA and Besta scale. The COPM and PEDI measure functional performance and individualized goals. One questionnaire, which measured bimanual activities, was included as an outcome measure in one study. The results using these outcome measures are reported below.

**Interventions**

The studies of CIMT compared to BIT have similarities and differences in the amount of intervention provided. Treatment intervention time ranged from as little as 50 hours10  to as much as 210 hours.8,9  The studies that included 210 hours of intervention used the same subject data set to produce two different published studies.8,9  Two studies, by one author, provided a total of 60 hours of CIMT or BIT treatment.11,13 Gordon et al and de Brito Brandeo et al provided 90 hours of CIMT or BIT.7,12

The RCT by Deppe et al did not provide equal treatment times between the CIMT and BIT group as the CIMT group received a combination of CIMT and an additional 20 hours of BIT.10 The randomized trial by Klingels et al added intensive distal strengthening to the CIMT group thus this group received more treatment intervention than the CIMT alone group.10

In six of the eight articles reviewed, there was no control group to compare the two interventions of CIMT or BIT treatment. An additional two studies compared CIMT to BIT and “traditional treatment.”8,9  Traditional treatment was not well defined or described and was only received for one hour once or twice per week depending on the age of the child.8,9  Thus the “traditional treatment” group received much less intervention time compared to either the CIMT or BIT treatment groups.8,9

Bias is introduced when treatment interventions times aren’t equally applied. It is difficult to determine and generalize the usefulness and benefit of one intervention compared to another intervention when they are not applied equally to the sample as more intervention and practice may be an explanation for improvements in outcome. Lack of a control group also produces bias as another intervention applied for equal time may have also produced positive results.

Several studies shared similar application of either intervention. The interventions were typically applied by experienced and trained therapists and students. The interventions were performed in a camp style model in four studies with child friendly play, activities and even a circus theme to motivate and engage the children.7,11-13  Three studies provided intervention in a rehabilitation center.6,8,9  Klingels et al integrated home based intervention with parents providing the intervention.10  With this model, subject compliance can become an issue which affects results. The authors reported 80% compliance with the interventions.10

**Methodological Considerations**

Five of the eight studies reviewed reported power analysis and had an adequate number of subjects for a statistical power of 80% at an alpha level of .05 to detect differences between groups.8,9,11-13  They were able to maintain the adequate power despite subjects who dropped out of the study. One study was unable to reach required sample size to achieve adequate power.6  No power analysis was reported in the studies by de Brito Brandeo or Klingels.7,10

All studies except the study by de Brito Brandeo had assessors of outcomes who were blinded to group assignment. Blinding the assessor reduces bias and improves the quality of the evidence. The quality of evidence in the 8 studies reviewed ranged from fair to good evidence as measured by the PEDro scales.19  Additionally, as most studies were randomized controlled trials with some blinding this also strengthens the results of evidence to level II.20

**Results**

All studies reported statistically significant improvements of function in subjects receiving CIMT or BIT regardless of intervention time, application of intervention or outcome measures used. Additionally, not only did the subjects show improvement in function, but the gains recorded were retained for as long as 1 year.13

Hand function was shown to improve with both interventions, but Fedrizzi et al and Faccin et al reported CIMT subjects’ immediately improved grasp.8,9  CIMT is advocated by Sakzewski to improve unimanual capacity more than BIT.11  This result was also reported by Gordon et al.12

Interestingly, two studies demonstrated improved motor function on bimanual tasks in subjects in the CIMT group although bimanual tasks weren’t practiced in that group.11,12  Bimanual functional goals and ADL’s were reported as more improved with BIT compared to CIMT.7,9

Two studies reported that children who were more impaired initially showed greater improvement compared to less impaired children.6,10  The generalizability of this conclusion may be limited relative to children with hemiplegic CP. Deppe et al included subjects with hemiplegia from other etiologies other than congenital and the study by Klingels et al also included a strengthening component to CIMT not included in other studies.6,10

Several studies reported long term outcomes of the interventions. Fedrizzi and colleagues reported that improvement in the involved hand persisted at 6 months following intervention regardless of whether the subject received CIMT or BIT treatment intervention.8  Gordon et al confirmed comparable improvement in the CIMT and BIT groups which were maintained at 6 months post intervention.12  This result was echoed by Sakzewski at both 26 weeks and 52 weeks post intervention.11,13  Improvement at 52 weeks was present although no further intervention was received by the subjects.13

**Discussion**

Of the 8 studies reviewed in this literature review, all demonstrated improvements in UL function whether the subject received CIMT or BIT intervention. Motor control and motor learning principles of practice and specificity of training were identified and suggested as factors that influenced improvement.7,8,12

The mechanism for understanding CIMT intervention is being explored. Following stroke in adult subjects, Ro et al, using transcranial magnetic stimulation, showed cortical reorganization and accelerated motor recovery with CIMT intervention.21  For children with hemiplegic CP, Sutcliffe demonstrated cortical reorganization in children following CIMT.22  Functional MRI showed increased contralateral cortical activity following CIMT.22  The cortical reorganization was maintained at 6 month follow up.22  A more recent study by Sterling et al demonstrated that CIMT in children with hemiplegic CP is associated with structural remodeling of the brain specifically increasing gray matter.23

In summary CIMT and BIT work to improve UL function, the results from the intervention lasts for up to a year and the intervention may be influencing positive neuroplastic brain changes.

**Clinical Relevance and Capstone Application**

Several clinically relevant points can be extracted from this literature review. Both CIMT and BIT work to improve functional outcomes in UL function in children with CP with neither technique being superior. Longer term studies have shown that the improvements from either intervention last from 26-52 weeks following intervention and are retained with no further intervention provided.8,11-13  Brain imaging studies are demonstrating neuroplastic changes such as increased contralateral activity and cortical reorganization.

The information gained from this literature review can be applied as a Capstone project to develop educational and training modules for therapists providing interventions to children with hemiplegic CP. Additionally, parents and caregivers of children with hemiplegic CP would benefit from education about the advantages of the two interventions for improving UL function. This will empower them to be actively involved in determining the interventions for their child.

**Limitations**

The majority of the reviewed studies lacked a control group that received equal intervention compared to the CIMT and BIT groups. Additionally, other interventions applied equally may also improve UL function, but this wasn’t explored. One study included subjects diagnosed with other etiologies of hemiplegia other than congenital.6  The generalizability of the results from this particular study to children with congenital, hemiplegic CP may be limited.

Clinically meaningful changes were not always demonstrated in the studies despite reaching statistical significance. No data are reported on the functional use of the hemiplegic UL in “real life” situations outside of a laboratory.

**Conclusions and Future Research**

The evidence in this literature review demonstrates that both CIMT and BIT improve UL function in children with hemiplegic CP which answers the original PICO question. The intervention chosen may depend on the expected goals and outcomes expected to be achieved. Several reliable and valid outcome measures are available to measure improvement with either intervention. Both interventions offer therapists a powerful tool in our toolbox to make lasting changes in a child’s UL functional abilities.

As both interventions yield significant improvements, future research should focus on combining aspects of both interventions to determine if this combination maximizes functional improvements in children with hemiplegic CP. Additionally, finding the combination of CIMT and BIT that produces the best outcome for children with hemiplegic CP needs to continue to be explored. Identifying other modalities such as strengthening combined with CIMT and BIT may yield positive outcomes as well.

Future research may focus on understanding and exploring the neuroplastic brain reorganization that appears to be occurring with CIMT. More imaging and fMRI will need to be integrated to explore and understand these changes. Determining if BIT produces equally positive neuroplastic brain changes needs to be explored. Answers to these questions may provide insight into improving and help guiding the “recipe” for more positive outcomes from future interventions to improve UL function in children with hemiplegic CP.

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