

The effect of a repeated course of Constraint-Induced Movement Therapy, implemented in the home environment, on the functional skills of a young child with cerebral palsy

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ABSTRACT

The lack of research in South Africa related to the use of Constraint-Induced Movement Therapy (CIMT) motivated this single-system (A-B-A-B-A) study. The aim was to investigate whether a repeated course of CIMT would improve self-care, play and functional skills of a young boy with asymmetrical cerebral palsy (CP). The subject's less affected arm was placed in a sling for a period of six hours during the intervention phases. The duration of the CIMT was 10 working days, followed by a two-week withdrawal phase. This sequence was repeated once. The subject was engaged in play and self-care activities in his home environment during the intervention phases. The Pediatric Evaluation of Disability Inventory (PEDI) was used to assess the subject six times: at the start; before and after interventions; and after the last withdrawal phase. The minimal clinically important difference (MCID) was calculated between the first and last assessments to determine the effectiveness of the CIMT. The critical 11 points difference was reached in the PEDI self-care domain for functional skills (such as dressing and washing) and in the social functioning domain for caregiver assistance (indicating that the caregivers were giving less assistance with regards to participation in household chores, communication and play ability).

Key words: Cerebral palsy; Constraint-Induced Movement Therapy; Functional skills; Pediatric Evaluation of Disability Inventory (PEDI); Self-care

INTRODUCTION

Cerebral palsy was first defined in the 1820's and despite several modifications to the definition, conceptual differences can still be found between the United States of America (USA) and Europe¹. In 2004 the United Cerebral Palsy Research, the Educational Foundation and the Castang Foundation in the UK sponsored an international workshop^{2,3}, tasking the invited experts to "... revisit and, if possible, update the definition and classification of CP in the light of emerging understanding of developmental neurobiology and changing concepts about impairments, functional status, and 'participation'"^{3:572}. The working groups consisted of an *Executive Committee for the Definition of Cerebral Palsy* with Martin Bax and Murray Goldstein as Co-chairmen, as well as the *Definition of Cerebral Palsy* working group chaired by Peter Rosenbaum and the *Classification of Cerebral Palsy* working group chaired by Nigel Paneth^{2,3}. The *Report on the Definition and Classification of Cerebral Palsy* was compiled and commentaries were invited from workshop attendees, whereafter the report⁴ was revised and published as a supplement to the February 2007 *Developmental Medicine and Child Neurology* journal. Although a definition was agreed on, a common classification and assessment continued to be elusive and the Gross Motor Function Classification System (GMFCS)⁴ was recommended as a tool to describe children with cerebral palsy, based on their functional mobility or activity limitations.

Historically, the treatment of people with congenital or acquired brain disorders (including cerebral palsy) consisted of managing the symptoms and treating the associated impairment(s), since it was postulated that interventions could not cure the damage in the [developing] brain⁵. The assumption of "neural plasticity" of the brain emerged later, resulting in the development of various treatment approaches to recruit areas adjacent to the damaged cortex to take over the lost functions⁶.

One of the more recent treatment interventions, termed constraint-induced movement therapy (CIMT), was developed by Dr Taub and co-workers and introduced in the 1990's to treat adults

who sustained a stroke^{7,8}. Beneficial effects of CIMT on the cortical reorganisation in adult stroke patients have been reported^{6,9}.

Noticing the improved function in adults, researchers adapted the adult treatment protocols (such as the duration of restraint and choice of activity) to be used with children with cerebral palsy who presented with an asymmetrical motor impairment^{10,11,12,13}. Improvements in motor control and hand function of the affected side were reported^{12,12,13,14}. Studies in children with hemiplegic cerebral palsy also reported on improved movement efficiency and quality of movement in the involved hand^{12,14,14,15,16}. One study, using magnetic resonance imaging and magnetoencephalography measurements before, after and again six months after CIMT in a child with hemiplegia¹⁷, discovered cortical reorganisation. DeLuca et al¹⁸ suggested that the neural pathways are underutilised due to a lack of sensorimotor input, and by using CIMT, are stimulated and therefore result in the noted improvement. Authors postulated that learned non-use, also termed "developmental disregard"^{8:208} when referring to children, can be retreated by using CIMT^{7,8,9,10,12,15}.

CIMT should be distinguished from "forced use"¹⁶. Both interventions consist of restraining the less affected arm, commonly by using an arm sling. During CIMT the individual is exposed to a protocol consisting of a repetitive graded activity programme, including task practice and 'shaping' (part-task practice) to stimulate movement patterns. During forced use no structure is provided, leaving it up to the motivation and means of the individual to engage the more involved arm to execute tasks¹⁶.

Different research designs have been used to study the effect of CIMT, such as case studies^{19,20,21}, single-system designs^{10,14,22}, controlled clinical trials¹² and randomised clinical trials^{23,24}. Only a few of these were conducted in the child's home environment^{11,11,18}. Further research was also recommended to refine the treatment protocols (type of restraint, time of constraint, duration and intensity of intervention) and to establish the optimal duration of the intervals between the interventions (withdrawal phases) when using a single-system design.



In order to describe a CIMT protocol with a four-week follow up period in South Africa, the current study aimed to establish whether a CIMT course in the home environment will result in improved hand function and performance in functional skills (activities of daily living) in a young child with asymmetrical cerebral palsy.

Ethical considerations

Ethical authorisation was obtained from the Human Research Ethics Committee (HREC) at the Faculty of Health Science, Stellenbosch University, number N09/01/005. Informed consent and permission to perform the intervention in the home environment was obtained from the subject's caregivers. Due to the subject being under five years of age, with some cognitive impairment (see next section), assent was not obtained (as explained to, and approved by, the HREC).

METHODS

Study design

A single-system design (A-B-A-B-A), described by Strydom²⁵ as "the genus term denoting the study of a single subject on a repetitive basis"^{25:145} was implemented (see Figure 1). A ten-day CIMT course was followed by a two-week withdrawal phase. This was repeated once but the second withdrawal phase was combined with the follow-up phase for a total of four weeks. Six measurements were taken (described in the data collection section).

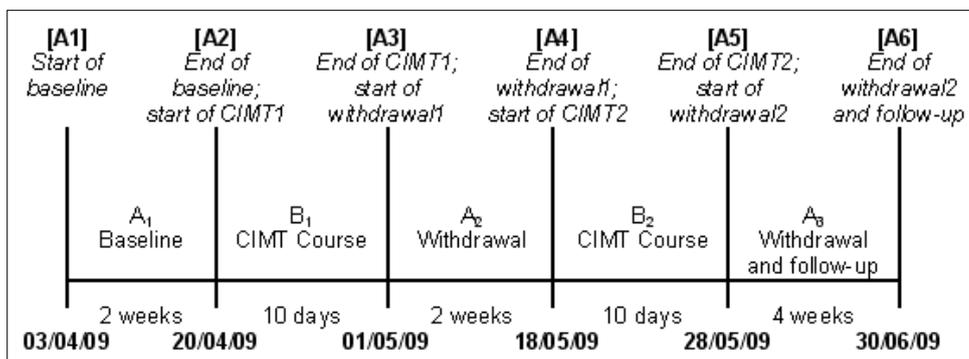


Figure 1: Study design displaying the phases

Participant

A single subject was selected by convenient sampling. The subject was a four year nine month old boy with congenital cerebral palsy and diagnosed with spastic quadriplegia, with a more functional right upper extremity²⁶. The subject lived with his mother and grandmother. The grandmother was regarded as the primary caregiver, since she looked after him after school. When referring to both the mother and grandmother, the term caregivers will be used. The subject was classified as a Level IV on the GMFCS²⁷, with accompanying cognitive impairment. No formal cognitive assessment results were available, but he could follow simple instructions. The subject previously received occupational- and physiotherapy on an irregular basis. Due to staff shortages, therapies were suspended for this subject to all members of the class for four months prior to commencement of this study.

Measurements used

The PEDI²⁸, a norm- and criteria-referenced behaviour checklist and rating scale^{28,29}, was designed for children with disabilities ranging in age from six months to seven and a half years. The researcher recorded the responses given by the caregiver during a structured interview. The PEDI is subdivided into three scales, i.e. *functional skills* (FS), *caregiver assistance* (CA) and the *modification* scales with three domains, namely *self-care*, *mobility* and *social functioning* (see Table 1). The raw scores are converted to scale scores according to the guidelines set out in the manual. Strong inter-rater and intra-rater reliability³⁰ as well as internal consistency were established^{28,30} for the PEDI. Construct³¹, concurrent^{-28,30,31,32,33} discriminant⁻³² and evaluative validities^{32,34} were also found to be strong. An 11 point

difference in scale scores, termed the *minimal clinically important difference* (MCID)³⁵, can be regarded as beneficial and indicate improvement.

Data collection

The study was conducted over a period of three months in the subject's home environment. The PEDI²⁸ was administered on six occasions (see Figure 1): at baseline [A1]; the beginning of the first intervention course [A2]; after concluding the first intervention course [A3]; at the beginning of the second intervention course [A4]; after completing the second intervention course [A5]; and finally after a four-week withdrawal/follow-up phase [A6]. Observations of the treatment sessions were also documented in a journal, with special attention to the time of restraining the less involved upper limb; the choice and duration of the activities; and active movements, range of motion, reach, grasp and release patterns of the more involved upper extremity. The assessments as well as random selections of partial treatment sessions were recorded with audio-visual equipment to supplement the first author's (the researcher) observations and to allow for peer debriefing by the study supervisors.

Intervention

The first author provided the CIMT daily, six hours per day for 10 consecutive working days, during the intervention phases (B1 and B2). No intervention was given over the weekend. A sling was used to

restrain the child's less affected right upper extremity and the sling was secured with a belt to his body (see Figure 2).

The intervention consisted of play and self-care activities to enable the child to practise the use of the more affected left upper extremity. Care was taken to analyse the activities and to ensure that activities would incorporate the following:

- ❖ Adapting posture to engage in the activities; locating the target/object [involving head and eye movement; and sustaining attention and focus]; reaching for toys [moving arm and hand in space];
- ❖ Manipulation [encouraging different grasps and release]; and prehension [encouraging finer hand function].



Figure 2: Restraint of the less affected right upper extremity during CIMT

No programme was performed during the withdrawal phases except for the caregivers giving verbal encouragement to the child to engage his more affected extremity in activities requiring bilateral hand use.

DATA ANALYSIS

The scale scores of each domain of the PEDI were entered into an

Excel spreadsheet. The differences between the first [A1] and the last [A6] assessment scale scores were calculated to determine if the minimal clinical important difference (MCID) of 11 points³⁵ was reached. Since the single-system design does not rely on complex statistics but uses graphics for visual analysis^{25,36}, line graphs were drawn for visual inspection. The researcher examined the graphs to establish whether regressions during the withdrawal phases were evident. The documented daily treatment sessions and care-giver observations were reviewed to determine qualitative progress.

To minimise observer expectancy bias, the researcher used standardised outcome measures and audiovisual recordings to verify results and enable peer review. The executions of the PEDI as a caregiver interview were performed meticulously according to the questionnaire forms and the supportive explanations provided in the manual²⁸.

RESULTS

A summary of the results on the PEDI are presented in Table 1. The mobility domain on the functional skills (FS) indicated a difference of 5.8 points (not surpassing the MCID of 11 points) in the scale scores from the first [A1] to the last [A6] assessments and did not yield significant improvement for caregiver assistance (CA). The modification scales consisted only of frequency counts and indicated two changes only. This included using the Shona³⁷ buggy more often for seating and using commercially available children's cutlery with built-up grips for self-feeding.

Table 1: Scales and Domains of the PEDI indicating total difference in scores

Domain → Scale ↓	Self-care	Mobility	Social Functioning	Number of items and scoring
Functional Skills (FS)	16.4*	5.8	10.8	197 items 0 = incapability 1 = capability
Caregiver Assistance (CA)	(See Fig 3) 9	0	(See Fig 4) 21.7*	20 items Rating independence from 0 – 5
Modifications	Frequency count difference = 2			20 items Rating from extensive modification to none

Total scale score differences were calculated between Assessments 1 and 6.

*Reaching minimal clinically important difference (MCID) of 11 points.

Self-care domain

The scale scores for the self-care domain are reflected in Figure 3, showing an upward trend over the different phases of the study, more noticeable for FS than CA. The results for the functional skills will be discussed first.

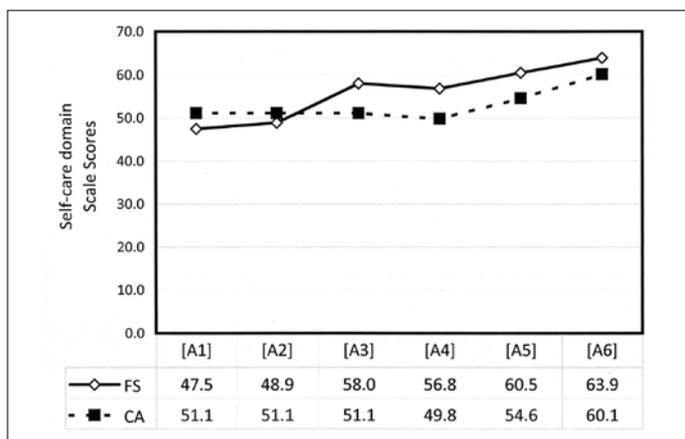


Figure 3: Self-care domain: Scale scores for Functional Skills (FS) and Caregiver Assistance (CA)

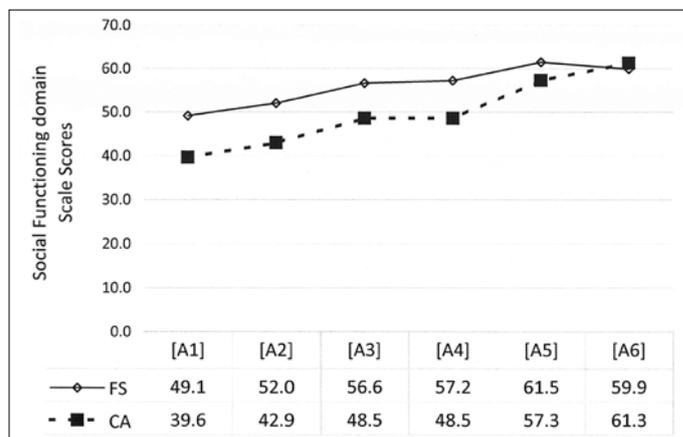


Figure 4: Social functioning domain: Scale scores of for Functional Skills (FS) and Caregiver Assistance (CA)

A slight increase in the self-care scale score was found from the start of the baseline assessment [A1] to the start of the first CIMT course [A2], followed by a more visible improvement after completion of the CIMT course and the start of the withdrawal phase [A3]. After the withdrawal phase [A4] a slight decrease was found, but improvement was recorded during the second CIMT course [A5]. The improvement continued during the second withdrawal and follow-up phase, as seen in the last assessment [A6]. The total increase in self-care, for FS from the baseline to the follow-up measurement, was 16.4 points, which exceeded the MCID of 11 points.

Increased scale scores for CA indicate less caregiver assistance. The CA scale scores in the self-care domain (see Figure 3) remained the same for [A1], [A2], and [A3] indicating that the subject needed the same amount of assistance by the caregiver from the beginning until the end of the first CIMT phase. This was followed by a slight decrease after the first withdrawal phase [A4] showing that the subject actually needed more assistance from the caregiver. From the start of the second CIMT [A4] the amount of assistance decreased steadily, even during the four-week follow-up phase [A6]. The total scale score increase from the first assessment to the last was 9, which did not reach the MCID of 11 points.

Social functioning domain

Figure 4 illustrates the scale scores regarding the social functioning domain for both FS and CA. A steady increase is noted for FS from the beginning [A1] until after the second CIMT course [A5], with a slight decrease during the four-week follow-up phase [A6]. Recorded scores were higher in communication and play skills as well as the subject's performance of household chores. The total scale score difference was 10.8, thus not reaching the MCID of 11 points.

The biggest total increase (21.1 points) was recorded in social functioning for CA, indicating a significant decrease in caregiver assistance in this domain, and exceeding the MCID of 11 points.

QUALITATIVE OBSERVATIONS

The subject tolerated the restraint very well and did not show signs of frustration. The researcher observed an increase in spontaneous use of the left arm and hand. Improved quality of movement, as well as better active range of motion, was noted. This included flexion, extension, abduction and adduction of the shoulder, flexion and extension of his elbow, which allowed him to reach and place objects in a larger radius around himself. Active wrist extension and full extension of fingers remained a problem. His ability to register



touch on his left arm and hand increased as well as his ability to discriminate between textures. The caregivers as well as the teacher reported that the subject showed more spontaneous use of his less functional left hand in bimanual activities, such as eating, washing his hands, dressing and play. The researcher also noted that the subject's engagement in play changed from sensory play (only touching play material) and cause-and-effect play to more construction play. An unexpected improvement occurred in the child's speech development. At first he answered with gestures and was able to express himself in two-word sentences. This improved over the course of the interventions to four- and five-word sentences.

DISCUSSION

The *mobility* domain on the Functional Skills (FS) indicated only a slight difference of 5.8 points in the scale scores from the first [A1] to the last [A6] assessment and did not yield any improvement for Caregiver Assistance (CA). This can be attributed to the severity of the lower extremity dysfunction and to the focus on upper extremity function in this study.

Change in the caregiver's awareness could have influenced the slight increase in the scale scores from the baseline assessment [A1] to the start of the CIMT course [A2] in the *self-care* (FS) and *social functional* (FS and CA) domains (see Figures 3 and 4). After the completion of the first CIMT course, the primary caregiver reported that she became more aware of the various aspects of self-care, and as a result, paid more attention to the tasks. She subsequently observed how the child performed the tasks without increasing her assistance or changing any routines. Both caregivers also reported that they provided more assistance to the child during the first withdrawal phase, but added more tasks to perform because of his improved abilities (e.g. performing self-care skills bimanually, such as washing and managing clothes). This could explain the slight regressing [A4] in the *self-care* (CA) score. The caregivers also provided more assistance in the beginning in an effort to help the subject learn how to perform tasks, e.g. eating with utensils instead of finger-feeding; actively participating in toilet training; and to assist the child when he indicated the need to go to the bathroom instead of just changing the diaper at regular intervals. As the subject learned to involve both hands, they then reduced assistance. This is evident in the subject's improved communication, play and increased participation in household chores and activities later in the *social functioning* domain for CA (see A5 and A6 in Figures 3 and 4, CA scores). The caregivers also reported that they were more confident in the child's skills, therefore giving less assistance.

The increase in FS scores in both the *self-care* (Figure 3) and *social functioning* (Figure 4) domains are supported by the qualitative observations, such as increased spontaneous movement, active range of motion, reach and grasp, strength in push and pull activities, increased finger extension as well as attempts to isolated finger movements.

The subject made continuous progress in his speech development throughout both courses of intervention. The improvement in speech intelligibility after completion of CIMT was also reported by Martin, Burtner, Poole and Philips³⁸. The home environment could have contributed to this, since the subject did not transfer his improved verbal communication skills to the preschool environment. The specifically tailored and graded intervention programme planned and executed by the researcher (such as age appropriate toys, incorporating the subject's own toys) may have produced the continual improvement in play behaviour, supported by Tomopoulos, Dreyer, Tamis-Lemonda and Flynn³⁹.

Limitations

Although the single-system design allowed the investigation of the effects of a repeated course of CIMT on the functional skills of a young child with CP in a one-to-one home environment, it limits the generalisation of the results to a larger population. The cost and time commitment impede the repetition of this study on a wider scale in the home environment, but the benefits warrant repeti-

tions on a limited scale. The cost implication further inhibited the researcher to engage an independent peer reviewer.

CONCLUSION AND RECOMMENDATIONS

The subject in this study overcame the developmental disregard of his left, more-involved arm and achieved considerable gains in his self-care and functional skills, speech and play behaviour. The success of this intervention was partly due to the fact that the child tolerated the restraint, continued to be highly motivated and exhibited an unusual drive to learn, concentrate and complete tasks. Improvement in his communication and play skills was only evident in his home environment, underscoring the importance of therapy in a home environment. This was further emphasised by the ability to directly apply new skills in the home environment. This is supported by findings by other researchers, but it also emphasised the need to investigate how to utilise the strategies to also gain improvement in the school environment.

The planned intervention and withdrawal sequence was sufficient to reach the aim of the study. A second follow-up measurement, e.g. after six months, could have established whether the gains were sustained over a longer period.

Since the intervention is based on motor learning principles, further research on the relationship between body schema and the stages of motor learning (cognitive, associative and autonomous) as well the appropriateness of the age levels, needs to be conducted. Further investigation into the efficacy of a combination of CIMT to overcome non-use as well as implementing bimanual training is recommended. Charles and Gordon⁴⁰ proposed a similar area of investigation by first overcoming non-use with CIMT, followed by bimanual training to form habits.

References

1. Morris C. Definition and classification of cerebral palsy: a historical perspective. *Developmental Medicine and Child Neurology*, 2007; 49(Supplement): 3-7.
2. Baxter P. Foreword. *Developmental Medicine and Child Neurology*, 2007; 49(Supplement): 2-2.
3. Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N, Dan B, Jacobsson B, Damiano D. Proposed definition and classification of cerebral palsy, April 2005. *Developmental Medicine and Child Neurology*, 2005; 47(8): 571-6.
4. Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, Dan B, Jacobsson B. A report: the definition and classification of cerebral palsy April 2006. *Developmental Medicine and Child Neurology*, 2007; 49(Supplement): 8-14. [Online] <<http://proquest.umi.com.ez.sun.ac.za/pqdlink?index=4&sid=1&srchmode>> (29 Aug 2009)
5. Goldstein M. Therapeutic possibilities: Research overview and commentary. In Scutcheon D, Damiano D, Mayston M, editors. *Management of motor disorders of children with cerebral palsy*. 2nd ed. London: Mac Keith Press; 2004:83-192.
6. Liepert J, Bauder H, Miltner W, Taub E, Weiler C. Treatment induced cortical reorganisation after stroke in humans. *Stroke*, 2000; 31(6):1210-6. [Online] <<http://ovidsp.tx.ovid.com.ez.sun.ac.za/spb/ovidweb.cgi?QS2=434f4e1a73d3>> (18 Jul 2008)
7. Taub E. "Constraint-induced movement therapy." *UAB Insight (University of Alabama at Birmingham)*. 2007; Spring. <<http://www.uabhealth.org/16212/>> (18 Jul 2008)
8. Taub E., Ramey, S. L., DeLuca, S., & Echols, K. (2004). Efficacy of constraint-induced movement therapy for children with cerebral palsy with asymmetric motor impairment. *Pediatrics*, 113, 305-312.
9. Blech J. Selbstheilung im Denkgorgan. *Der Spiegel*. 2008; 10:162-4. German.
10. Charles JR, Gordon AM. Repeated course of constraint-induced movement therapy results in further improvement. *Developmental Medicine and Child Neurology*, 2007; 49(10):770-4. [Online] <<http://proquest.umi.com.ez.sun.ac.za/pqdweb?index=4&did=1407791031>> (18 Jul 2008)
11. Charles J, Lavinder G, Gordon AM. Effect of constraint-induced therapy on hand function in children with hemiplegic cerebral palsy. *Pediatric Physical Therapy*, 2001; 13(2):68-76. [Online] <<http://ovidsp.tx.ovid.com.ez.sun.ac.za/spb/ovidweb.cgi?QS2=434f4e1a73>> (8 Aug 2008)



12. Eliasson A-C, Krumlinde-Sundholm L, Shaw K, Wang C. Effects of constraint-induced movement therapy in a young child with hemiplegic cerebral palsy: an adapted model. *Developmental Medicine and Child Neurology*, 2005; 47(4): 266-276. [Online] Available from: <http://proquest>. (8 August 2008)
13. Naylor CE, Bower E. Modified constraint-induced movement therapy for young children with hemiplegic cerebral palsy: a pilot study. *Developmental Medicine and Child Neurology*, 2005; 47: 365-369. [Online] <<http://proquest.umi.com.ez.sun.ac.za/pqdweb?index=13&did>> (8 Aug 2008)
14. Dickerson AE, Brown LE. Pediatric constraint-induced movement therapy in a young child with minimal active arm movement. *American Journal of Occupational Therapy*, 2007; 61(5): 563-753
15. Taub E, Uswatte G, Pidikiti R. Constraint-Induced Movement Therapy: A new family of techniques with broad application. *Journal of Rehabilitation Research and Development*, 1999 Jul; 36(3):237-52. [Online] <<http://proquest.umi.com.ez.sun.ac.za/pqdweb?RQT=572&TS=1254999385>> (6 Oct 2009)
16. Charles J, Gordon AM. A critical review of Constraint-Induced Movement Therapy and forced use in children with hemiplegia. *Neural Plasticity*, 2005; 12(2-3):245-61. [Online] <<http://find.galegroup.com.ez.sun.ac.za/itx/retrieve.do?contentSet>> (24 March 2009).
17. Sutcliffe LT, Gaetz WC, Logan WJ, Cheyne DO, Fehlings DL. Cortical reorganization after modified constraint-induced movement therapy in pediatric hemiplegic cerebral palsy. *Journal of Child Neurology*, 2007 Nov; 22(11):1281-7. [Online] <<http://jcn.sagepub.com.ez.sun.ac.za/cgi/reprint/22/11/1281>> (27 Aug 2009)
18. DeLuca SC, Echols K, Ramey S, Taub E. Pediatric constraint-induced movement therapy for a young child with cerebral palsy: two episodes of care. *Physical Therapy*, 2003 Nov; 83(11):1003-13.
19. Karman N, Maryles J, Baker RW, Simpser E, Berger-Gross P. Constraint-induced movement therapy for hemiplegic children with acquired brain injuries. *Journal of Head Trauma and Rehabilitation*, [Internet]. 2003; 18(3):259-67. [Online] <http://ovidsp.tx.ovid.com.ez.sun.ac.za/spb/ovidweb.cgi?&S=IBLJFPJJBDPCAANCF>> (7 October 2007)
20. Fergus A, Buckler J, Farrell J, Isley M, McFarland M, Riley B. Constraint-Induced Movement Therapy for a child with hemiparesis: a case report. *Pediatric Physical Therapy*, 2008; 20(3):271-83. [Online] <http://ovidsp.tx.ovid.com.ez.sun.ac.za/spa/ovidweb.cgi?WebLinkFrameset=1&S=AGMC>. (24 March 2009)
21. Martin A, Burtner PA, Poole J, Philips J. Case Report: ICF-Level Changes in a Preschooler after Constraint-Induced Movement Therapy. *American Journal of Occupational Therapy*, 2008; 62(3): 282-9. [Online] <http://proquest.umi.com/pqdweb?did=1515027211&sid=1&Fmt=3&clientId>. (25 August 2009)
22. Crocker MD, McKay-Lyons M, McDonnell E. Forced use of the upper extremity in cerebral palsy: a single-case design. *American Journal of Occupational Therapy*, 1997; 51(10):824-33.
23. Charles JR, Wolf SL, Schneider JA, Gordon AM. Efficacy of a child-friendly form of constraint-induced movement therapy in hemiplegic cerebral palsy: a randomized control trial. *Developmental Medicine and Child Neurology*, 2006; 48(8): 635-42. [Online] <http://proquest.umi.com.ez.sun.ac.za/pqdweb?index=9&did=1094468491&SrchMode=3>. (10 August 2009)
24. DeLuca SC, Echols K, Law CR, Ramey S. Intensive Pediatric Constraint-Induced Therapy for children with cerebral palsy: randomized, controlled, cross over trial. *Journal of Child Neurology*, 2006; 21(11):931-8. [Online] <http://web.ebscohost.com.ez.sun.ac.za/ehost/detail?vid=3&hid=108&sid=fd50099d>. (12 August 2008)
25. Strydom H. Single-system design. In: De Vos AS, Strydom H, Fouché CB, Delpont CSL, editors. *Research at grassroots*. 3rd ed. Pretoria: Van Schaik Publishers; 2005:144-58.
26. Shevell, M. I. The terms diplegia and quadriplegia should not be abandoned. *Developmental Medicine and Child Neurology*, 2012; 52: 508-509
27. Palisano R, Rosenbaum P, Bartlett D Livingston M. "Gross Motor Function Classification System Expanded and Revised." *CanChild Centre for Childhood Disability Research Institute for Applied Health Sciences*, McMaster University, Hamilton, Ontario <http://motorgrowth.canchild.ca/en/GMFCSE/expandedandrevised.asp> (25 February 2012)
28. Haley SM, Coster WJ, Ludlow LH, Haliwanger JT, Andrellos PJ. *Pediatric Evaluation of Disability Inventory (PEDI)*. San Antonio (TX): The Psychological Corporation; 1992.
29. Elfant I, Asher MS. *Occupational therapy assessment tools: An annotated index*. 2nd ed. Bethesda, MA: American Occupational Therapy Association. 1996.
30. Nichols DS, Case-Smith J. Reliability and validity of the Pediatric Evaluation of Disability Inventory. *Pediatric Physical Therapy*, [Internet]. 1996 [cited 2009 Jul 7]; 8:15-24. Available from: <http://ovidsp.tx.ovid.com.ez.sun.ac.za/spa/ovidweb.cgi?&S=KHODFPBKGEDDLKHENC>.
31. Feldman AB, Haley SM, Coryell J. Concurrent and construct validity of the Pediatric Evaluation of Disability Inventory. *Physical Therapy*, 1990 Oct; 70(10):602-11. <<http://find.galegroup.com.ez.sun.ac.za/itx/paginate.do?qrySerId>> (8 Jul 2009)
32. Reid TD, Boschen K, Wright V. Critique of the Pediatric Evaluation of Disability Inventory (PEDI). *Physical and Occupational Therapy in Pediatrics*, 1994 Apr; 13(4):57-87. <<http://www.informaworld.com.ez.sun.ac.za/smpp/content~db=all~content>> (8 Jul 2009)
33. Ziviani J, Ottenbacher KJ, Shephard K, Foreman S, Astbury W, Ireland P. Concurrent validity of the Functional Independence Measure for Children (WeeFIM™) and the Pediatric Evaluation of Disabilities Inventory in children with developmental disabilities and acquired brain injuries. *Physical and Occupational Therapy in Pediatrics*, 2002; 21(2):91-101. <http://pdfserve.informaworld.com.ez.sun.ac.za/846879_792625948> (19 Oct 2009)
34. Ketelaar M, Dahmen A, Vermeer JA, Helders PJM. Functional motor abilities of children with cerebral palsy: a systematic review of assessment measures. *Clinical Rehabilitation*, 1998 Oct; 12(5):369-80. <<http://web.ebscohost.com.ez.sun.ac.za/ehost/results?vid=2>> (9 Jul 2009)
35. Iyer LV, Haley SM, Watkins MP, Dumas HM. Establishing minimally clinically important differences for scores on the Pediatric Evaluation of Disability Inventory for inpatient rehabilitation. *Physical Therapy*, 2003 Oct; 83(10):888-99. <<http://web.ebscohost.com.ez.sun.ac.za/ehost/pdf?vid=3&hid=6&sid>> (9 Jul 2009)
36. Deitz JC. Single subject research. In: Kielhofner G, editor. *Research in occupational Therapy*. Philadelphia: F.A. Davis Company; 2006:140-54.
37. Shonaquip: disability training and equipment. [Online] 2009 [http://www.shonaquip.co.za/about.htm?sm\[p1\]\[category\]=276&sm](http://www.shonaquip.co.za/about.htm?sm[p1][category]=276&sm) (5 Oct 2009)
38. Martin A, Burtner PA, Poole J, Philips J. Case Report: ICF-Level Changes in a Preschooler after Constraint-Induced Movement Therapy. *American Journal of Occupational Therapy*, 2008 May/June; 62(3): 282-9. <<http://proquest.umi.com/pqdweb?did=1515027211&sid=1&Fmt=3&clientId>> (25 Aug 2009)
39. Tomopoulos S, Dreyer BP, Tamis-Lemonda C, Flynn V, et al.; Books, Toys, parent-child interaction and development in young Latino children. *Ambulatory Pediatrics*. 2006 March/April; 6(2):72-9. <<http://proquest.umi.com.ez.sun.ac.za/pqdweb?index=3&id=1019482821>> (25 Aug 2009)
40. Charles J, Gordon AM. Development of hand-arm bimanual intensive training (HABIT) for improving bimanual coordination in children with hemiplegic cerebral palsy. *Developmental Medicine and Child Neurology*, 2006; 48(11): 931-7. <<http://proquest.umi.com.ez.sun.ac.za/pqdweb?index=5&did=1161125531>> (24 March 2009).

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