Case Report

Constraint-induced movement therapy for a youth with a chronic traumatic brain injury

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ABSTRACT

The purpose of this paper is to report on the use of a modified constraint-induced movement therapy (CIMT) protocol in the treatment of upper limb dysfunction in a 20-year-old male with spastic quadriplegia as a result of a severe traumatic brain injury during infancy. The participant presented with little self-initiated functional movement in his right upper extremity. A physiotherapist treated him for 30 weeks using a modified CIMT protocol consisting of four one-hour sessions per week during which time he practised functional activities such as reaching and grasping with his affected extremity whilst his less affected upper limb was constrained. Throughout the 30 week period, the participant continued with his normal therapy consisting of a stretching and swimming programme, and occupational therapy. After 10 weeks of treatment, improvements in upper extremity function were evident on the Action Research Arm Test with even greater improvement evident after 30 weeks. His caregivers reported improvement in functional use of the arm. These results suggest that modified CIMT may be useful in the treatment of upper extremity dysfunction caused by a childhood brain injury. Miller R, Hale L (2005). Constraint-induced movement therapy for a youth with a chronic traumatic brain injury. New Zealand Journal of Physiotherapy 33(3) 85-90.

Key words: upper extremity, constraint-induced therapy, traumatic brain injury.

INTRODUCTION

The consequences of a traumatic brain injury (TBI) can be diverse involving motor, sensory, cognitive and behavioural deficits, and may result in a number of functional limitations, including reduced upper limb function (Keren et al, 2001; Mazaux and Richie, 1998). Although physiotherapy is usually included in the rehabilitation process following TBI, there is limited evidence to justify its effectiveness (Das-Gupta and Turner-Stokes, 2002; Tolfts and Stiller, 1997). The deficiency in proven protocols of treatment has resulted in the description of many physiotherapy techniques for the rehabilitation of a person with TBI (Tolfts and Stiller, 1997; Umphred, 2001). Generally, upper limb dysfunction caused by TBI has been treated in much the same way as hemiplegia due to stroke, with treatment techniques described by Bobath and Brunnström, and through techniques such as hydrotherapy, Proprioceptive Neuromuscular Facilitation, active exercise, functional activities, Functional Electrical Stimulation and electromyographic biofeedback (Ada et al, 1990; Platz et al, 2001; Tolfts and Stiller, 1997; Umphred, 2001).

Constraint-induced Movement Therapy (CIMT) is a treatment technique with a growing body of evidence for its effectiveness to improve upper limb function following stroke (Blanton & Wolf, 1999; Taub, 1999; Bonifer & Anderson, 2003) and in children with cerebral palsy (Charles et al, 2001; Pierce et al, 2002; Willis et al, 2002). A recent systematic review of the impact of physical therapy following stroke found strong evidence for CIMT (SES 0.46; 95% CI 0.07-0.91) to improve upper limb function (Van Peppen et al, 2004). However, evidence for CIMT from robust, large randomised controlled trials is still lacking (Siegert et al, 2004). Table 1 details studies reviewed in this case report which have investigated the use of CIMT following TBI.

CIMT is a technique that discourages the use of the less affected or unaffected extremity of the person who has suffered a non-progressive lesion to the brain, as occurs in stroke, cerebral palsy or TBI, by constraining the extremity (Taub et al, 1999). At the same time as the unaffected upper extremity is being constrained CIMT encourages the use of the affected upper extremity with the goal of maximising or restoring motor function, a technique known as “shaping”. The objective of shaping is to alter motor behaviours by repetitive use of basic movement tasks, the difficulties of which are progressively increased (Page et al, 2002). Much enthusiastic approval and encouragement is given if activities are performed well while no negative feedback is given if activities are performed poorly (Page et al, 2002).

CIMT is based on the concept of “learned non-use”, a phenomenon which may occur after any injury that results in a large neurological deficit followed by a long period of recovery (Miltnen et al,
If, in the period shortly after a brain insult, a person is unable to use their limbs on the contralateral side of their body, the lack of use appears to persist and perpetuate itself, thus leading to the term “learned non-use” (Miltner et al, 1999; Taub et al, 1999). Repeated failed attempts to use the affected limb and the subsequent successful use of compensatory strategies with the unaffected limb are thought to reinforce the behaviour of learned non-use (Blanton & Wolf, 1999; Taub et al, 1999). The patient experiences negative consequences when attempting to use the affected limb and according to Taub et al (1999), these negative consequences constitute punishment, which leads to suppression of behaviour. There is, however, no formal way of assessing whether an individual has learned non-use (Miltner et al, 1999).

The purpose of this paper is to describe a novel approach to the treatment of upper limb dysfunction, with the use of a modified CIMT protocol, in a 20 year old male in his last year of high school, who suffered a TBI as an infant. (The New Zealand school system allows students with disabilities to remain in school until they are 21 years of age.)

Traditional CIMT protocols are rigorous, involving one-on-one therapy for at least six hours per day, for ten days, over a two-week period and constraint of the less affected upper limb for 90% of waking hours (Miltner et al, 1999; Van der Lee et al, 1999; Taub et al, 1999). Page and Levine (2003) suggested that such an intense protocol may be too demanding for many people with TBI and therefore used a modified approach in a case series of three young adults with TBI. Furthermore, such an intense protocol is difficult to implement within the school treatment setting, and thus a modified approach was implemented in the case reported in this paper.

**METHODS**

**Case Description**

Tom (pseudonym) was a 20-year-old male who received a TBI at the age of eight months. As a result of the TBI, Tom had spastic quadriplegia, which affected his right side more than his left, and he had severe cognitive impairment.

A formal examination of Tom was difficult to accurately conduct, as he frequently did not understand what was required of him, and thus many of the findings reported below are based on general observations of Tom by the author within the school treatment setting. These findings, on initial examination, were:

**Impairment Level**

*Range of motion:* Tom had very little active range of motion in his right shoulder (0-35 degrees both abduction and extension). Passive movement of the right shoulder was limited to 0-75 degrees of both abduction and extension. Shortening of the rhomboid muscles prevented maximum passive rotation of the scapula during right upper extremity movements. Tom lacked 15 degrees of full elbow extension both actively and passively. He displayed very little active right wrist and finger extension movement. The resting position of his right hand and arm was with his wrist flexed at 90 degrees...
from the neutral position and his metacarpal phalangeal joints flexed at 75 degrees from the neutral position.

**Strength** was assessed using the Oxford Scale (Atkins et al, 1989), and was 2/5 for global muscles on the right and 4/5 for those on the left.

**Muscle tone** was measured using the modified Ashworth scale (Bohannon and Smith, 1987) and Tom’s muscles on his right side were assessed as being a 2-3/5. Tom was receiving Baclofen to control his increased muscle tone.

**Ability Level**

Tom was independent in eating finger food and drinking from a cup with his left hand but was dependent on other people for all other personal cares. He usually used a wheel chair, pushed by caregivers, for his mobility.

On observation, Tom did use his more affected (right) upper extremity to prop himself up for long periods of sitting and to move large objects such as a Swiss ball across the floor if he was lying on his less affected side. However, if his less affected (left) arm was available he preferred to use it.

**Previous Rehabilitation**

Tom had received regular physiotherapy and occupational therapy throughout his life within the schools he attended. However, through observations carried out by the previous therapist and caregivers, it appeared he was no longer benefiting from the therapy he was being offered. Previous physiotherapy had consisted, for a number of years, of neurodevelopment physiotherapy based on the Bobath approach, functional electrical stimulation and hydrotherapy and Tom was no longer responding to this therapy. It was decided to implement a modified form of CIMT into his treatment protocol.

Written consent for the use of CIMT, and for publication of this case report, was obtained from Tom’s primary caregiver as Tom was unable to give informed consent himself due to his cognitive difficulties.

**CIMT Treatment**

CIMT became the main intervention in Tom’s treatment. He received four one-hour sessions per week for a total of 30 weeks, which is the equivalent of three school terms. He also received his normal 20 minutes of passive stretches twice daily to help prevent contractures, his regular swimming programme twice weekly and two one-hour sessions of occupational therapy per week, which involved encouraging functional bimanual tasks during the school term.

Constraint was applied during the physiotherapy session by the physiotherapist placing her hand over the less affected, left hand to prevent its movement. Constraint was carried out only during physiotherapy sessions as losing the small amount of independence he had by constraining his hand and arm for long periods in a mitt or sling was not perceived to be desirable or ethical.

At the same time as the constraint of the left hand was taking place Tom was encouraged to take part in shaping activities with the right upper extremity. These shaping activities involved starting with basic tasks or a simple part of an activity and practising them extensively until the activity was mastered, then progressively making the tasks more complex over time. For example, Tom repetitively practiced functional and play activities beginning with reaching to touch a ball and then grasping the ball until he was able to do this competently. He then progressed to throwing balls of various sizes (for example tennis balls and squash balls). He also practised functional activities such as putting finger foods, for example sandwiches, into his mouth and drinking from a sipper bottle. Once he mastered this, he progressed to lighter finger foods requiring more dexterity to manipulate, such as picking up and eating potato chips. All tasks completed successfully received much enthusiastic praise while no negative feedback was given if the task was not completed.

The CIMT sessions were carried out while Tom was strapped in a standing frame, as extending his hip angle has been found to reduce his increased muscle tone. Tom’s caregivers were instructed to encourage the use of his right upper extremity during non-therapy time and to praise him when he did so.

**Outcome Measures**

The author, two months before and again one day before CIMT was implemented, carried out baseline assessments. The same person carried out reassessments after 10 weeks and 30 weeks of CIMT, using the Action Research Arm Test (ARAT) (Lyle, 1981). In this test, the ability to perform each of 19 motor tasks, sub-grouped into the four categories of grasp, grip, pinch and gross movements, are scored on a four-point ordinal scale. A score of zero indicating that the person has no movement and a score of three is given for “movement performed normally”.

Two trials conducted into the effectiveness of CIMT have used the ARAT as the primary outcome measure (Van der Lee et al. 1999; Dromerick et al, 2000). The test has proven to have high test-retest reliability (ICC 0.99, 95%CI 0.16 - 0.76) (Van der Lee et al, 2001a). Van der Lee et al (2001a), found that the ARAT was able to detect a clinically relevant difference of 5.7, which functionally, for example is the difference between not being able to lift and grasp three objects and the ability to move those three objects in an abnormal manner. In a more able subject a functional example of a difference of 5.7 would mean an improvement from initially being able to partially perform a movement involving grasping three differently sized and weighted objects to being able to perform the same movement in a normal manner. It was found...
to be more responsive than the upper extremity section of the Fugl-Meyer motor assessment (Van der Lee et al, 2001b).

The goals set from the initial assessment and in conjunction with Tom’s caregivers were to play with a tennis ball and squash ball with his right hand and to eat independently by using his right hand to assist with pushing food onto a fork. In addition to reassessment using the ARAT the participant’s progress was also measured against these goals.

RESULTS

Improvements were found in two sub test areas of the ARAT after 10 weeks and in four subtest areas of the ARAT after 30 weeks, as is shown in table 2.

After 10 weeks and again after 30 weeks of treatment, Tom’s caregivers reported increased self-initiated use of his right upper extremity. This was confirmed by the observation in treatment sessions of the participant using his right upper extremity during functional activities such as undoing the Velcro in his standing frame and unbuckling the seat belt in his wheelchair. Tom was able to eat potato chips, hot chips, snack bars and sandwiches using his right hand, and often did so without prompting. However, he was not able to use his right hand to assist with pushing food onto a fork as was set out in the goals. Tom independently, and without prompting, played with a Swiss ball, tennis ball and a squash ball using his right hand, so he had achieved this goal.

Tom reached the age of 21 during treatment and was required to leave school; therefore the author was unable to carry out further assessments to test whether these improvements were maintained.

DISCUSSION

This study demonstrated the potential benefits of using a modified CIMT protocol in the treatment of upper extremity dysfunction for a young adult after a severe TBI that occurred during infancy. In this case study the CIMT protocol was modified by constraining only the less affected upper limb for one hour during therapy sessions whilst simultaneously encouraging the participant to practice progressively more difficult hand motor tasks. Although constraint and shaping occurred only for one hour, four times a week, the programme of therapy continued for 30 weeks. Page and Levine (2003) modified the CIMT protocol in a case series of three young adults with TBI. All three participants demonstrated improvements in the amount, quality and functional ability of their upper limb function. The modified protocol consisted of 30 minute sessions of physiotherapy and occupational therapy three times per week for 10 weeks, during which time shaping was performed by the practice of functional tasks. Participants wore a cotton sling on their less affected arm for five hours a day during the 10 week period.

Previously, more intense protocols of CIMT have been successfully used for people with severe upper extremity dysfunction (Bonifer and Anderson, 2003; Sterr et al, 2002; Taub et al, 2004). Bonifer and Anderson (2003) reported on a single case study in which the participant wore a mitt on the less affected hand for 84% of waking hours for 21 days, and received shaping for six hours a day for 15 days. In a randomized, controlled trial conducted by Sterr et al (2002), 13 adults with stroke and two adults with TBI wore a constraint for 90% of waking hours. In this study one group received six hours of shaping and the other group received three hours of shaping. Although both groups benefited, the effects were significantly higher in the six hour shaping group (p=0.01). In a randomized controlled trial involving children with CP (aged 7–96 months, n=18) the experimental group wore casts on their less affected upper limbs for 21 days, during which time shaping was carried out for six hours a day (Taub et al, 2004). The control group received traditional therapy. The group receiving CIMT made significant gains (p<0.0001) and these benefits were maintained at a six month follow-up evaluation.

If, as Taub et al (1999), Miltner et al (1999) and Van der Lee (2000) suggest, the most important aspect of CIMT is massed practice or shaping (long sessions involving continuous repetitive practice), then why did the modified protocol in this report,

| Table 2. Results of the Action Research Arm Test (Four point ordinal scale for each item contained within the domains of grasp, grip, pinch and gross movement. Highest possible score is 57). |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 2 months prior to CIMT beginning. | 1 day prior to CIMT beginning. | After 10 weeks of CIMT. | After 30 weeks of CIMT. |
| Grasp | 0 | 0 | 8 Picked up a cricket ball. | 8 Picked up a cricket ball. |
| Grip | 0 | 0 | 0 | 2 Picked up a 2.25 cm cylinder |
| Pinch | 0 | 0 | 0 | 2 Picked up a large marble between thumb and index finger |
| Gross movement | 0 | 0 | 2 Put hand to up to mouth. | 6 Put his hand behind his head. |
that used less practice, bring about functional improvement? In our study, the beneficial effects may have been as a result of allowing the participant to repetitively perform motor tasks with his right upper extremity during the CIMT sessions, resulting in more movement than he had ever done with this limb in the past, even though the duration of each practice session was shorter (one hour) than that advocated for CIMT (six hours). The participant may also have improved as he achieved “carry-over”, in that he learnt to use his new-found use of the more affected arm in self-initiated activities, such as eating finger foods. It could be argued that the gain achieved for the amount of therapy received does not make CIMT a viable cost-effective proposition. However, it would be best to use an intervention that results in both clinical and functional benefits, however small, than continually using those that only maintain the status quo.

In previous CIMT research carried out on adults, significant cognitive deficits have been used as an exclusion factor (Taub et al., 2004). However, CIMT has been shown to be effective in young children who may have been at a similar cognitive level as the participant in this report (Charles et al., 2001; Pierce et al., 2002; Willis et al., 2002; Taub et al., 2004). It is therefore suggested that a participant’s cognitive ability may not necessarily be regarded as an obstacle to implementing CIMT.

This report used the ARAT to investigate the efficacy of CIMT. Although the ARAT’s reliability, validity and responsiveness have been found to be high in adult populations who have suffered from stroke, there are no studies into its use in youth or people who have severe cognitive impairment. After searching the literature, the only test that has been found to be both valid and reliable in youth that are severely cognitively impaired (with a developmental age of seven years or less) is the Wee Functional Independence Measure (Ottenbacher et al., 1999; Ottenbacher et al., 2000). This test, however, does not look closely at upper extremity function so may not be responsive enough to show any change brought about by CIMT. A test such as the Wolf Motor Function Test, although a reliable and valid test of upper extremity function (Morris et al., 2001; Wolf et al., 2001), is not appropriate for persons similar to the participant in this case report as the test requires the person being tested to comprehend that they must do the activities as quickly as possible.

More investigations need to be carried out into the efficacy of CIMT in the treatment of chronic TBI as no large controlled studies have been conducted in this population (Siegert et al, 2004). The effects of a modified treatment protocol need to be examined to determine whether shorter daily treatments, as would be more suitable within the New Zealand school system, are effective in bringing about improvement. Large, well-designed studies into the amount of shaping and constraint needed are required, as the optimum amount of each is not yet known. Any future studies need to assess whether any improvements gained as a result of CIMT are maintained once treatment has finished.

**CONCLUSION**

There are no scientific studies investigating the effectiveness of CIMT in children and young adults who have suffered from TBI.

This case study suggests that a modified protocol of CIMT may be an effective means of improving upper extremity function in this population, and warrants further investigation. Isolating which of the central components of CIMT, shaping and constraint, are more beneficial would enhance the efficacy of the intervention.

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**REFERENCES**


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