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ORIGINAL ARTICLE

Effect of modified constrained induced movement therapy on improving arm function in children with obstetric brachial plexus injury

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Abstract Many children who sustain birth injuries to the brachial plexus suffer significant functional limitations due to various sequelae affecting the shoulder and elbow or forearm. The aim of this study was to test the feasibility of a treatment program based on the elements of the modified constraint induced movement therapy (MCIMT) to encourage use of the affected arm of a child with obstetric brachial plexus injury (OBPI). Thirty children with OBPI from both sexes ranging in age from three to five years were assigned into two groups of equal number. The control group (group A) who received the exercise program which focused on improving the arm function as well as shoulder abduction and external rotation and the study group (group B) received MCIMT in addition to the same exercise program given to the control group. The arm function was evaluated by the Mallet score system, while active abduction and external rotation range of motion were measured by a standard universal goniometer. The results revealed no significant difference when comparing the pretreatment mean values of the two groups (study and control), while a significant improvement was observed in measuring variables of the two groups when comparing their pre and post treatment mean values. A significant difference was also observed when comparing the post treatment results of the two groups in favor of the study group (group B). The modified constraint movement therapy is an effective method on improving the arm function in children with OBPI.

1. Introduction

Obstetric brachial plexus injury (OBPI) is unfortunately a rather common injury in newborn children. Incidence varies between 0.15 and 3 per 1000 live births in various series and countries [1,2]. Obstetric brachial plexus palsy is a complication of childbirth, which is characterized by one or more nerve conduction blocks within the brachial plexus. These blocks

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range in severity and location within the plexus and primarily affect the child's ability to move and effectively use their affected upper limb [3,4].

The most common sequelae following OBPI may include posterior subluxation or dislocation of the humeral head, winging of the scapula, forearm deformities as pronation or supination contractures, hand deformities, and hypoplasia of the bones in the upper extremity resulting in limb length discrepancy problems [5–8]. Two well-described secondary deformities are the medial rotation contracture of the arm and the fixed supination deformity of the forearm [9]. The medial rotation contracture is a major cause of shoulder deformity in children with OBPI, requiring surgery in more than one third of patients whose injury did not resolve spontaneously [10].

Obstetric brachial plexus palsy is rare, but the limb impairments are manifold and often long-lasting. Physiotherapy, microsurgical nerve reconstruction, secondary joint corrections, and muscle transpositions are employed with success. The role of conservative and operative treatment options should be regularly reviewed. Nonsurgical options include rehabilitation, botulinum toxin injections, and constraint-induced movement therapy. If problems develop with shoulder movement and shoulder joint development, secondary shoulder surgery can become necessary [11].

The goals of rehabilitation management for brachial plexus injuries are to: prevent contractures, which can develop because of muscle imbalances, increase the child's awareness of the paretic limb, and improve muscle strength [12].

Many patients compensate for the affected arm rather than trying to use it, leading to learned nonuse and halting further progress with the functioning of that arm. One of the main objectives of the intervention is to overcome the learned nonuse, defined as the diminished use of the affected extremity due to the perception of failure during the performance of manual tasks [13,14]. Recent evidence suggests that many neurologically disabled children may improve motor performance if provided with sufficient opportunities to practice [15,16].

One treatment approach that provides those opportunities and is becoming increasingly popular is forced use or constraint-induced movement therapy (CIMT) [17]. The constraint-induced movement therapy (CIMT) has been used to promote functional gains in individuals with neurological dysfunctions [18,19]. The constraint-induced movement therapy consists of constraining movement of the non-affected upper extremity and providing intensive training to the involved upper extremity [20]. Theoretically, CIMT can overcome learned nonuse of the affected side through forcing the brain's plasticity toward a more physiological and efficient activation pattern. Therefore, CIMT is hypothesized to work by inducing a use-dependent cortical reorganization that counteracts the adverse brain function changes that occur after nervous system damage and then enhances recovery-associated plastic changes in the brain after a stroke [21,22].

Intensive and repetitive training of the affected limb, or some combination of restraint and training, have been shown to lead to remarkable improvements in the upper- extremity (UE) function. Many studies also found that the changes produced in the brain were enduring rather than short-lived, and greater than those achieved with traditional treatment methods. CIMT increases not only movement and motor skill but also functional use of the extremity in the real-world environment [23,24].

Several previous studies concerning CIMT and its different modified types have proved its efficacy in improvement of the function of the involved UE and enhancing its development in hemiplegic patients [23–25]. However very little researches were done to test the effect of this type of intervention on improving UE functions in other unilateral disorders of various causes [26,27]. The purpose of this study was to examine the effect of modified type of CIMT on improving the shoulder and arm function in children with OBPI.

2. Patients and methods

2.1. Patients

This study was conducted under the guidelines and the approval of Ethics Review Committee of the Faculty of Physical Therapy, Cairo university and parents signed a consent form authorizing the child's participation.

Thirty children of both sexes were initially screened and assessed to determine age, diagnosis and inclusion and exclusion criteria. The inclusion criteria were as follows: The participated children had a confirmed medical diagnosis, by a specialist physician of OBPI in the form of Erb's type (C5–6) injuries. The degree of nerve severance was within the second and third degrees of injury according to Sunderland classification for nerve injuries [28]. Their age ranged from 3 to 5 years. Children were cognitively competent and able to understand and follow instructions. They were medically free with no serious or recurring medical complications according to the medical report signed by their physician. During the study, children were not receiving other interventions to improve the upper extremity (UE) function. Demographic characteristics of participants were illustrated in Table 1.

The exclusion criteria included children who had visual problems that would prevent them from performing the intervention, balance problems, uncontrolled seizures, fixed contractures or stiffness in the affected upper extremity that would limit activity engagement, previous constraint-induced movement therapy or forced use therapy, orthopedic or neurological surgery on their involved upper extremity.

Thirty children had met the inclusion and exclusion criteria. They were divided randomly into two groups of equal number. Following the baseline evaluation of each child, a closed envelope was randomly selected that contained the child's group allocation. The treatment allocation was disclosed to the child and the parents immediately after the baseline evaluation. The control group (A) received physical therapy exercise program focused on improving arm function as well as shoulder abduction and external rotation. The study group (B) engaged in the modified constrained induced movement therapy (MCIMT)

Table 1 Demographic characteristics of participants.

	Control group (A)	Study group (B)
Age (years ± SD)	3.8 ± 0.7	4.2 ± 0.6
Involved side	Rt side (11) Lt side (4)	Rt side (12) Lt side (3)
Sex (Boys/Girls)	6 boys 9 girls	5 boys 10 girls

Rt, right; Lt, left.

program which involves restraining of the movement of the noninvolved upper extremity and repetitive practice of the same exercise program performed by group (A).

2.2. Methods

2.2.1. Methods for evaluation

2.2.1.1. Mallet scale system. All participants were assessed pre-treatment and after 12 successive weeks of treatment using standardized movements of Mallet scale to index active shoulder movements [29].

2.2.1.2. Standard universal goniometer. The range of motion for shoulder abduction and external rotation were measured by using Standard BASELINE® 12-inch plastic goniometer, (Model 12–1000) Fabrication Enterprises, Inc: White Plains, New York. Methods for treatment.

2.2.1.3. Upper extremity sling. A broad range of restraint techniques has been used to restrain the non affected upper limb in the pediatric CIMT studies published to date. In our study we choose upper extremity sling as a method of restraint similar to that prescribed by Gordon et al. [20].

1. Motivational targets (toys or sweets) and different tools such as cubes, blocks, musical toys with different geometric shapes and sizes to encourage the child to perform the needed tasks.

3. Procedures

3.1. Procedures for evaluation

3.1.1. Mallet scale system

All participants were assessed pre-treatment and after 12 successive weeks of treatment by evaluating video recordings of standardized movements of Mallet scale to index active shoulder movements [29]. This scale assesses the function of the shoulder, and it is based on five criteria: The ability to actively abduct the arm, the ability to externally rotate the arm, the ability to place the hand behind the neck as well as behind the back or spine, and the ability to place the hand over the mouth. A total Mallet score is calculated from the scores gained in the performance of the former tasks with a grading scale of I–V giving a maximum score of 25. This system can only be used with a cooperative, older child. This scale is not suitable for use with infants. Mallet scale is a reliable method for evaluating children with OBPI based on the ability to perform functional positioning of the affected limb [30]. All evaluations were conducted by trained therapists.

3.1.2. Standard universal goniometer

Abduction-active range of motion (ROM) was measured in the seated chair position, as in flexion, with the trunk upright. The arm was actively elevated in the strict coronal plane with the thumb pointed up toward the ceiling to allow the required external rotation necessary to avoid impingement of the greater tuberosity on the acromion process [31]. Once active end-range was achieved the measurements were documented.

External rotation- active ROM was tested in the supine position with the hips and knees flexed to approximately 45°. The tested arm was supported on the table in 90° of abduction, elbow flexed to 90°, and the wrist in neutral position. A towel roll was placed under the humerus to ensure neutral horizontal positioning; which required the humerus to be in level to the acromion process based on visual inspection. Once positioned, the participant was asked to rotate their arm back into external rotation to their end available range without discomfort. The participant was instructed not to lift their lower back during this measurement. Once active end-range was achieved the measurement was recorded [32].

3.1.3. Procedures for treatment

The exercise program given to both groups (A and B) was especially designed and adapted to be a child-friendly treatment. The intervention protocol consisted of a list of gross and fine motor activities aimed for improving arm function and shoulder abduction and external rotation. It includes a range of functional, daily living and play activities similar to those they usually practice in any given day of their life to maintain the child's interest and attention.

The treatment protocol addressed the following categories of exercises that encouraged, enhanced and directed shoulder movement toward flexion or extension, abduction and external rotation with extended or flexed elbows forearm in supination position and wrist in neutral position (as possible) from standing or sitting position.

Arm reaching exercises toward target include; Finger ladder exercise, Wall bar exercise and Pulling trolleys in play. Arm–Hand exercises include; Throw ball toward target from standing position either above or below the head level, Bouncing ball from standing position and Catch ball from standing position, either catching ball thrown from different directions or catching bounced ball. Postural reaction exercises include; Protective extensor thrust from sitting on roll forward, backward and sideward and equilibrium reaction from standing on balance board or sitting on ball. Upper limb self-dependent exercises include; Eat with a spoon, Pick up and feed self-sandwich, Drink from cup, Wear and turn off shirt, Brush teeth, Comb hair, Wash face by hands, Place hat on head and Wiping nose or face.

The study group (B) engaged in the modified constrained induced movement therapy (MCIMT) program which involves restrain of the movement of the noninvolved upper extremity and repetitive practice of the same exercise program performed by group (A). The constraint used was the upper extremity sling that was strapped to the child's trunk and the distal end sewn to prevent using the noninvolved hand as an assist. The sling was worn continuously throughout the training period except when a break was requested which did not exceed 15 min every 2 h session [26]. Fastening the sling to the trunk prevents bimanual use or cheating that might occur if the sling was free. The sling was worn only during the treatment session but not throughout the rest of the day. The treatment was carried out 2 h/ day, 6 days per weeks for 12 successive weeks, while there was no training on weekends. Three sessions per week were conducted at clinic and the others were at home.

The parents or other caregivers were trained to carry out the training program at home. A number of measures had been taken to assure the performance of the therapeutic intervention at home in a satisfactory manner. (1) A written list of training tasks was drawn up for the caregiver to carry out at home. (2) The caregiver kept a diary of what was actually done to be revised by therapist at the next session at clinic. (3) Monitoring of compliance by the caregivers with the instructed home routine by a daily phone.

4. Statistical analysis

The collected data from this study represent the statistical analysis of the Mallet score system (five items) and the shoulder active abduction and external rotation range of motion (in degrees) measured pre treatment and post three months of treatment for the two groups. The raw data of the Mallet system were statistically treated by non-parametric statistics: Wilcoxon test to determine mean values pre and post treatment in each group and Mann–Whitney test to determine mean values between the two groups.

The raw data of the range of motion were statistically treated to determine the mean and standard deviation for the two groups and the student *t*-test was then applied to examine the significance of the treatment conducted for each group.

5. Results

The obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in all the measuring variables of the two groups control and study, when comparing their pre and post-treatment mean values of the Mallet score system as shown in Table 2 and 3. After treatment a significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group (B) as shown in Table 4.

There was a significant increase in the mean values of abduction and external rotation range of motion pre and post treatment period in the two groups as shown in Table 5 and 6. Also, there was a significant improvement in the post treatment mean values of the range of motion variable in comparing the two groups in favor of the study group as shown in Figs. 1 and 2.

6. Discussion

The majority of children with obstetric brachial plexus recover with either no deficit or a minor functional deficit, but it is almost certain that some will not regain adequate limb function [33].

Motor and sensory impairments accompanied with different types of OBPI commonly hinder and impede the involvement and utilization of affected UE in different activities. These impairments force and push the affected children to prefer the utilization of non affected UE in different tasks, increase their dependence on normal side in different daily life situations and aggravate the problem of affected side disuse.

A number of recent studies searching and supporting the efficacy of CIMT termed "child- friendly" in improving UE function with hemiplegic children have been run [34–38].

The stage of motor development is likely to have important implications for the type of activity practiced during the intervention. Therefore, the efficacy of constrained induced therapy intervention approaches for the pediatric population may well be dependent on age at the time of treatment. For this reason, the participating children in this study were chosen to be little bit older with age range between 3 and 5 years. This noninvasive study provides support for neural plasticity (the general ability of the brain to reorganize neural pathways based on new experiences) in children with obstetric brachial plexus palsy [22].

The results of our study come in consistent with other studies that clinical changes observed with this intervention as well as who strongly suggested that treatment based on CIMT principles had potential to promote functional gains for children with OBPI [26]. On the other hand, it was found that improvements as a result of CIMT recorded may not be considered substantial [27].

The results of the current study showed that the children in the study group who received MCIMT, improved their shoulder abduction & external rotation ROM and their ability to use the affected upper extremity post treatment. This improvement was significant when comparing these recorded mean scores with their correspondents in the control group.

By considering upper limb preference, it was found that only 17% of children affected by right obstetric brachial plexus palsy prefer the right upper limb for overall movement in contrast to their expectation, in the general population, 90% of children would prefer their right upper limb. Also, children with left obstetric brachial plexus palsy did not significantly differ from the general population in upper limb preference [39].

The improvement obtained in both groups could be explained by facilitating motor skill learning via the intensive course of training for 12 successive weeks on daily base that was directed to enhance affected arm function as well as shoulder abduction and external rotation ROM. The designed exercise program provided the opportunities for the included children to practice involved upper limb movement in different situations with different purposeful and meaningful type of exercises that augment the process of motor learning.

Table 2 Mallet scores pre and post treatment mean values for the control group.

	Abduction	External Rotation	Hand to Neck	Hand to Spine	Hand to mouth
Pre	3.26 ± 0.45	2.93 ± 0.59	2.80 ± 0.94	2.60 ± 0.73	2.40 ± 0.50
Post	4.00 ± 0.65	3.60 ± 0.73	3.53 ± 1.24	3.60 ± 0.73	3.06 ± 0.70
Z-value	−3.317	−3.162	−2.810	−3.873	−3.162
P-value	0.001	0.002	0.005	0.000	0.002
Significance	Sig.	Sig.	Sig.	Sig.	Sig.

Data are expressed as Mean ± Standard deviation (SD), *P*-value: level of significance, Sig.: significance

Table 3 Mallet scores pre and post treatment mean values for the study group.

	Abduction	External-rotation	Hand to neck	Hand to spine	Hand to mouth
Pre	3.06 ± 0.59	2.66 ± 0.48	2.40 ± 0.50	2.40 ± 0.50	2.73 ± 0.79
Post	4.26 ± 0.45	4.06 ± 0.25	3.93 ± 0.59	4.13 ± 0.35	4.26 ± 0.45
Z-value	−3.638	−3.207	−2.606	−3.638	−3.317
P-value	0.000	0.001	0.000	0.000	0.001
Significance	Sig.	Sig.	Sig.	Sig.	Sig.

Data are expressed as Mean ± Standard deviation (SD), *P*-value: level of significance, Sig.: significance.

Table 4 Mallet scores comparison pre and post treatment mean values for both groups.

	Abduction	External-rotation	Hand to neck	Hand to spine	Hand to mouth
Z-value(pre)	−1.659	−1.253	−0.136	−0.638	−1.114
P-value(pre)	0.097	0.210	0.892	0.523	0.265
Significance	Not sig.	Not sig.	Not sig.	Not sig.	Not sig.
Z-value (post)	−3.705	−2.360	−3.106	−2.468	−4.063
P-value (post)	0.000	0.018	0.002	0.014	0.000
Significance	Sig.	Sig.	Sig.	Sig.	Sig.

P-value: level of significance, Sig.: significance.

Table 5 Pre and post treatment mean values of abduction and external rotation range of motion for the control group.

	Abduction ROM		External rotation ROM	
	pre	Post	pre	post
X’	70.00	92.26	35.33	51.73
± SD	10.58	9.48	5.76	5.53
t-test	−17.374		−12.896	
P-value	0.000		0.000	
Significance	Sig.		Sig.	

X’: Mean, SD: Standard deviation, *P*-value: Level of significance, Sig.: Significance.

Table 6 Pre and post treatment mean values of abduction and external rotation range of motion for the study group.

	Abduction ROM		External rotation ROM	
	pre	Post	pre	Post
X’	73.60	116.33	36.06	69.53
± SD	10.54	14.51	5.04	6.45
t-test	−26.431		−31.587	
P-value	0.000		0.000	
Significance	Sig.		Sig.	

X’: Mean, SD: Standard deviation, *P*-value: Level of significance, Sig.: Significance.

Motor learning models focus on the importance of usage and practicing of self-generated, voluntary actions in playful and motivational settings. Motor learning emphasized four main principles: (a) learning is a process of gaining the ability for performing skilled action, (b) learning results from experience or practice, (c) learning is measured from behavior and cannot be measured directly, and (d) learning produces relatively permanent changes in motor skills [40].

The better results gained in group B might be attributed to the usage of modified constrained movement therapy. The MCIMT program was based on the principles of motor learning that provide a common theoretical model for this approach. An important consideration is that it is not the restraint that induces change; rather it is the environment that is used to solicit intensive practice [41].

The modified constrained movement therapy in this study allowed for practice of general aspects of shoulder and arm function rather than the activity itself. The treatment focused on repetitive practice of movements and skills with the affected UE. Using constraint of the unaffected UE and utilizing games and plays were carefully selected to provide sufficient challenge and successful outcomes when using the affected upper limb and hand.

Practicing and repetition is a very important variable in motor learning. In this context, the more practice a therapist can give a patient, the more the patient learns. Thus in creating a CIMT session, the number of mass practice attempts should be maximized. Modified constrained movement therapy intervention includes motivation, activities of an appropriate level of difficulty, and repetition. Motivation and self-intention for success were considered the most important factor in sustainability in practicing and training for a long period of time without complaint or fatigue [42].

For adults with CIMT the internal drive for improvement is the main impetus for the motor skill achievement. But with children, motivation can be kept and persisted throughout maintaining their interest by using funny playing environment, focusing of the therapist and parent to create an enjoyable situation that would involve sufficient challenge and numerous opportunities for repetition .Our intervention in the current study was child-friendly which was tolerable for most children. Intervention techniques were embedded into functional and play activities in which children typically participate and ample social interaction is allotted. Also the difficulties of the task have to be at an appropriate level for successful learning.

Periods of intense structured practice may be more important than the duration of restraint wear [35]. One reason for

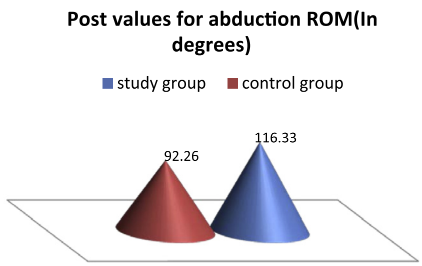

Figure 1 Illustrating post treatment mean values for abduction range of motion in the two groups.

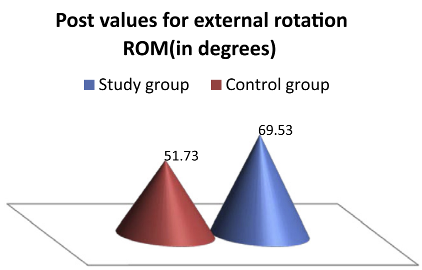

Figure 2 Representing the post treatment mean values for external rotation range of motion in the two groups.

the substantial improvement in motor skills for patients undergoing CIMT is simply the massive number of practice trials they have performed [40].

A relation between CI therapy and neuroplasticity has also been found in several studies involving adults [43,44]. They reported that although there are greater potentiality for CNS neural plasticity in infants and younger children, it may be countered by reduced skill practicing time and little motivation for performance. Older children and adolescents may have greater motivation to improve their own motor function, given their increased awareness of their impairments and desire for social inclusion.

7. Conclusion

From the obtained results of this study it can be concluded that the Modified constrained movement therapy is effective in improving shoulder and arm functions in children with OBPI.

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