Constraint Induced Movement Therapy for Cerebral Palsied Children with Asymmetric Motor Impairment

Manal Salah El-Dien Abd El Whahab
Department of Physical Therapy for Growth and Developmental Disorders in Children and its Surgery, Faculty of Physical Therapy, Cairo University.

ABSTRACT

Background and Purpose: *Impairment of hand function is a major disability in hemiparetic cerebral palsied children, the resulting sensory and motor impairments compromise movement efficiency, as a result those children often fail to use the involved upper extremity and learn to perform most tasks exclusively with their uninvolved upper extremity, the purpose of this study was to detect the effect of using constraint induced movement therapy of the non-involved upper extremity on the hand functional abilities of the involved upper extremity in hemiparetic cerebral palsied children.* ***Subjects and procedures:*** *twenty spastic hemparetic cerebral palsied children (12 girls and 8 boys) ranged in age between five to seven years ($\bar{X}$ ±SD) was 5.4 ± 0.9 years participated in this study. They were selected from outpatient clinic of Faculty of Physical Therapy, Cairo University. Active range of motion of wrist extension, wrist hand-grip strength and time of reaching and grasping a spongy ball with the involved upper extremity was evaluated for each child before and after twenty-one days of constraining the non-involved upper extremity six hours per day for twenty one successive days and practicing a specific physical therapy treatment program aiming to enhance the function of the involved upper extremity.* ***Results:*** *Mean values of all measured parameters that were collected and statistically treated before and after the suggested period of treatment application showed a statistically significant increase in wrist extension range of motion and wrist grip strength and there was also statistically significant reduction of the duration of reaching and grasping a spongy ball with the involved upper extremity ($P<0.001$).* ***Conclusion:*** *Pediatric constraint induced movement therapy can produce a major and sustained improvement in hand function in children with hemiparetic cerebral palsy.*
Key words: *Hemiparesis-Cerebral palsy-Pediatric Constraint Induced Therapy-Learned nonuse-Upper extremity functions.*

INTRODUCTION

Impairment of hand function in children with hemiplegic cerebral palsy (CP) results in failure of those children to use the involved upper extremity (UE) and learn to perform most tasks exclusively with their noninvolved UE (learned nonuse)[12]. This nonuse, in turn, may lead to additional impairments secondary to neural damage associated with CP[26,28]. The patient tries to use the affected extremity, but cannot due to physiological reactions in the nervous system during the acute phase of an injury; the repeated failure sets up the conditions leading to LNU, which in turn, leads to a contraction of the cortical representation of the affected extremity and prevents the use of the affected extremity in the chronic phase of a patient's recovery[19,24].

Children with hemiparetic cerebral palsy have difficulty with timing and coordination of reaching and grasping movements in addition to lack of coordination of fingertip forces during precision grasp, movement planning and a deficient capacity to modulate postural adjustments during reaching[14,23].

A recent therapeutic intervention, constraint-induced (CI) movement therapy, seems promising for children with hemiplegic

CP. It was developed to help patients to overcome learned nonuse by providing an opportunity to practice repetitively with the involved hand and arm in structured program after restraining the noninvolved upper extremity[25,31].

It was found that repetitive practice of a motor task with the involved hand can result in improved performance in a relatively short time period. This suggests that the involved upper extremity is amenable to treatment and that intensive practice may be beneficial to improve function[4,11].

This study was conducted to examine the relationship between efficacy of a child-friendly form of CI therapy of the uninvolved UE and fine-motor performance of involved hand in hemiparetic CP children.

SUBJECTS AND PROCEDURES

Twenty spastic hemiparetic cerebral palsied children (12 girls and 8 boys) ranged in age between five and seven years ($\bar{X}$ ±SD) was 5.4±0.9 participated in this study. They were selected from the outpatient clinic of faculty of Physical Therapy Cairo University based on the following criteria (1) Having a mild degree of spasticity ranged from grade 1 to 2 according to Ashworth's scale. (2) They had the ability to extend the wrist ≥20° and the metacarpophalangeal joint 10° from full flexion[30], (3) They were able to maintain sitting balance, and (4) They could understand commands and follow simple verbal instructions.

Instrumentations

a) For evaluation:

1- Plastic geniometer: for detecting range of motion of wrist and metacarpal joints.

2- A calibrated hand-held dynamometer: for measuring the wrist grip-strength of the affected hand.

3- Stop-watch: that was used for detecting the duration of reaching and grasping a spongy ball and the time needed to perform the desired tasks.

b) For treatment:

1- Friendly cotton arm sling.

2- Occupational therapy tools as playing dough, cards, cubes and puzzles etc.

Procedures

I) Evaluation procedures

1- Evaluation of range of motion of the wrist extension:

From sitting position, with elbow flexed 90º and forearm supported on the wrist-arm chair and maintained in pronation position with the wrist free from chair the geniometer was placed on the ulnar aspect with the fulcrum on the ulnar styloid process, the fixed arm was placed parallel to the forearm and the movable arm parallel to the ulnar aspect of the child's hand. Each child was asked to extend his/her wrist as much as he/she could and the available reached range was determined in degrees.

2- Evaluation of the grip-strength:

The dynamometer was set at zero level, the child was asked to sit comfortably on upright straight-backed chair with the feet flat on the floor, shoulder adducted and neutrally rotated, elbow flexed 90 degrees, forearm in neutral position, and wrist maintained between 0 and 30 degree extension and between 0 and 15 degree ulnar deviation[22].

The child was asked to hold the handgrip dynamometer vertically in the affected hand with the line of the forearm maintained at the standard forearm and wrist position, then the child was asked to squeeze the dynamometer as hard as he/she could. Recordings measured in kilograms.

3- Time of reaching and grasping a spongy ball:

From sitting position on a back-support chair in front of a suitable height table the child was asked to grasp a spongy ball that was placed on the table in front of him, and the duration from starting to perform the action till complete grasping of the ball was determined (in seconds) by using a stop-watch.

II) Treatment procedures

A cotton sling was fastened around the child's neck and covered the entire arm and hand of the non involved upper extremity. Straps attached to the sling were rounded around the child's waist to secure the child's trunk (figure 1). The child was asked to put on the sling for six successive hours per day for successive 21 days[1].

Fig. (1): A child with the sling that was fastened around the neck and rounded to the child's trunk with a strap to prevent use as an assist.

Physical therapy program:

Treatment application based on the following steps:

- Broken down of all activities into step-by-step tasks that could be worked on individually and then chained together in progressive steps toward the targeted goal.
- Individualized instruction involving the specific practice of designated target movement was given for each child during each session[9].
- Activities were play-based and included use of a variety of toys and objects.
- From sitting on a back rest chair with the feet flat on the floor with hips and knees were kept at 90º in front of a suitable height table that was at the chest level, children were engaged in play and functional activities that provided 2 types of structured practice using the hand of the involved upper extremity including shaping and Repetitive-task practice[17].
- Shaping involved practicing a target movement in isolation of other movements under a time constraint of 30 seconds. Task objects that were frequently used included household objects (eg, jars, eating utensils, spring-loaded clothespins), children's toys (building blocks, marbles, rings and cubes) As soon as the target movement was performed successfully, the difficulty of the task was increased by changing temporal and spatial accuracy task constraints.
- Repetitive-task practice involved performing a target movement in a functional context or in relation to other movements (practicing forearm supination by turning over cards within the context of a game, building tower of 3 cubes, form a ball with rolling dough on the table and reconstructing puzzles.

"Success" was defined as achieving either the same frequency in 3 of 5 trials (30 seconds each). The choice of changing either spatial/accuracy or temporal dimensions depended on the constraints of a particular task and the target movements that were elicited by the task.

RESULTS

This study was conducted to demonstrate the statistical analysis of the mean values of range of motion of wrist extension, wrist grip strength and time of reaching and grasping a spongy ball with the involved upper extremity after constraining the uninvolved UE six hours per day for 21 successive days in hemiparetic CP children.

The collected data for twenty spastic hemiparetic cerebral palsied children were statistically analyzed to show the mean values and standard deviation of the measured parameters before and after treatment application. Minitab statistical analysis program was used to determine the significance of using constraint induced movement therapy in hemiparetic cerebral palsied children.

1) Range of motion of wrist extension:

The post treatment mean values of the range of motion of wrist extension showed a statistically significant improvement. The mean values of range of motion of wrist extension before and after treatment were 36.36±3.49 and 50.62 ±3.57 degrees respectively (P<0.001) as shown in table (1) and illustrated in figure (2).

Table (1): Mean values of the range of motion of wrist extension (degrees) before and after treatment application.

ROM of wrist extension	$\bar{X}$ ±SD	MD	t	P	Sig.
Pre	36.36±3.49	14.26	11.266	<0.001	Sig.
Post	50.62±3.5				

ROM: range of motion $\bar{X}$ ±SD: mean ±standard deviation t: tabulated value
P: probability value Sig.: level of significance

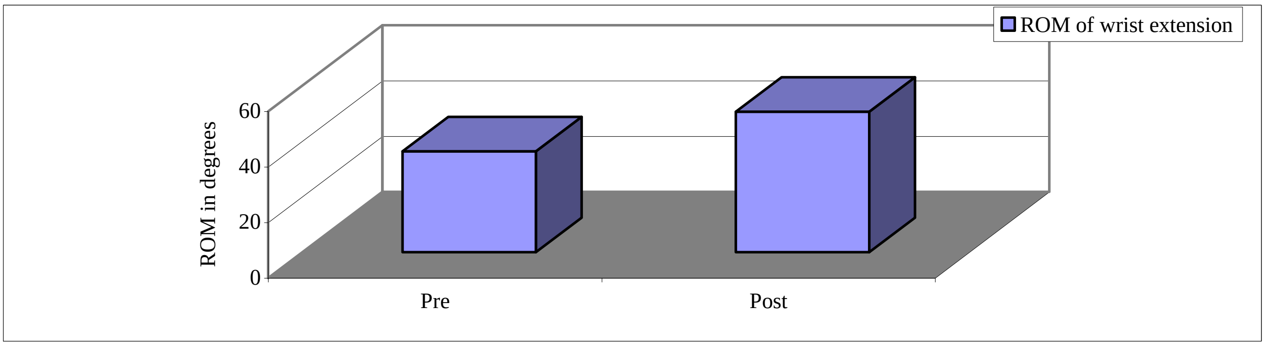

Fig. (2): Mean values of range of motion of the wrist extensors (in degrees) before and after treatment application.

2) Grip-strength:

The post treatment mean values of the wrist grip strength showed a statistically significant improvement. The mean values of wrist grip strength before and after treatment were 3.45±0.47 and 5.59 ±0.72 degrees respectively (P<0.001) as shown in table (2) and illustrated in figure (3).

Table (2): Mean values of wrist grip strength (Kgm) before and after treatment application.

Wrist grip-strength	$\bar{X}$ ±SD	MD	t	P	Sig.
Pre	3.45±0.47	2.14	12.379	<0.001	Sig.
Post	5.59±0.72				

$\bar{X}$ ±SD: mean ±standard deviation t: tabulated value P: probability value
Sig.: level of significance

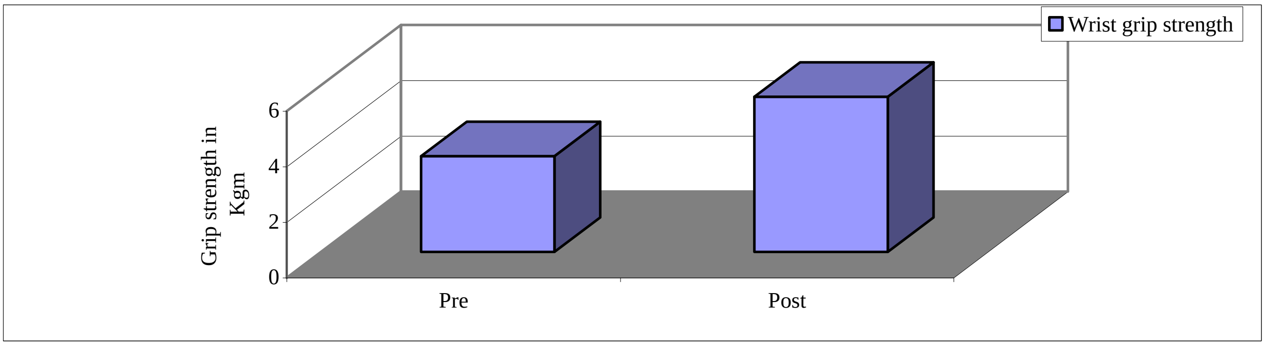

Fig. (3): Mean values of the wrist grip strength (in Kgm) before and after treatment application.

3) Duration of reaching and grasping a spongy ball:

As shown in table (3) and illustrated in figure (4) there was statistically significant decrease of the duration required for reaching and grasping a spongy ball as the mean values of the required duration before and after treatment were 50.62±3.57 and 36.36±3.49 respectively (P <0.001).

Table (3): Mean values of time of reaching and grasping a spongy ball before and after treatment application.

Time of reaching and grasping a ball	$\bar{X}$ ±SD	MD	t	P	Sig.
Pre	50.62±3.57	14.26	11.266	<0.001	Sig.
Post	36.36±3.49				

$\bar{X}$ ±SD: mean ±standard deviation t: tabulated value P: probability value
Sig.: level of significance

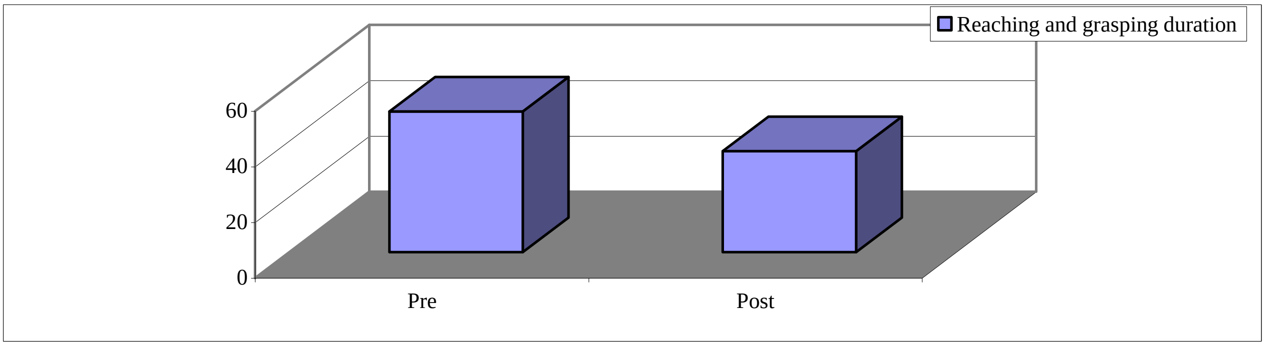

Fig. (4): Mean values of reaching and grasping a spongy ball before and after treatment application.

DISCUSSION

The results of the current study showed a statistically significant improvement in the wrist extension range of motion, grip strength and duration of reaching and grasping a spongy ball with the involved hand in spastic hemparetic cerebral palsied children treated by constraining the uninvolved upper extremity.

Choosing the age sample for this study comes in agreement with many authors[8,13,18] who concluded that in the age division before 8 years coordination of fine finger force development during grasping approximates that of adults by the age of 8 years. within a younger population of children with hemiplegia (aged 1.5-4 years), there was a relationship between age and improvement, with older children actually improving more than younger children in the extent to which they effectively use their involved hand during bimanual tasks[6].

Improvement of the hand functional abilities for children participated in the current study may be explained in two ways, the first depend on the idea that children possess far better brain reorganizational capabilities after lesions than adults[10,16]. Neural plasticity is assumed to be greater in younger children, because the central nervous system is still in the early stages of postnatal development. The neural substrates for hand control continue to develop over the first 2 decades of life[7,20] which suggests the presence of neuroplasticity in older children as well. This notion support the concept that CI therapy is beneficial in older children and adolescents[2,5,15].

The results of the current study comes in agreement with many authors[7,21] who reported that a child with hemiplegic cerebral palsy may have neural tissue that is underutilized, Constraint-induced movement therapy might be especially well suited for use with those children because of the great capacity for plasticity in the developing nervous system. a child with hemiplegic CP may not develop neural pathways involved in movement because of the lack of ability to experience age-appropriate sensorimotor stimuli that lead to the development of UE skills.

Tub et al.,[26] recorded that the second cause of improving hand function after constraint induced movement therapy is significant increased cortical representation of the affected hand which result from increased neuroimaging that resulted from repetitive practice.

The results of the current study comes in agreement with Charles et al.,[2] who reported improvement the functional abilities of the more affected upper extremity with 3 school-age children with hemiparesis after applying combination of both modified version of constraint-induced movement therapy of the less affected UE and intensive training of the more affected UE.

The results of the current study also comes in agreement with Crocker et al.,[3] who recorded positive changes in upper extremity functions such as manual dexterity, sensory discrimination, and limb coordination following constraint-induced movement therapy for the children involved wearing a cotton sling on the less affected UE while an investigator engaged them in various functional and play activities for 6 hours each day for 14 consecutive days.

Willis et al.,[29] compared between two groups of hemiplegic CP the study one was treated by plaster cast of the non affected upper extremity for one month while the other group treated in a traditional way and he recorded a significant improvement for the study group.

The results of this study can also be supported by the work of Tub et al.,[27] who demonstrated improvements in both amount of use and functional abilities in 18 children ranged in age between 7 months and 8 years treated by applying plaster cast for 21 days and received functional training activities for the affected arm for 6 hours a day.

CI therapy has been shown to be effective, but it requires many hours of dedicated one-on-one care between the patient and the physical therapist. Given the vast and growing post-stroke population, the availability of an individual therapist for up to six hours per day is not practical.

Conclusion

Constraint induced movement therapy may be consider as a promising therapy in treatment of hemiplegic cerebral palsied to improve the hand functional abilities by reinforcing the child to use the involved upper extremity.

REFERENCES

1- Andrew, M., Gordon, Jeanne, C. and Steven, L.: Efficacy of Constraint-Induced Movement Therapy on Involved Upper-Extremity Use in Children with Hemiplegic Cerebral Palsy Is Not Age-Dependent. PEDIATRICS. e363-e373, 2006.

2- Charles, J., Lavinder, G. and Gordon, A.: Effects of constraint-induced therapy on hand function in children with hemiplegic cerebral palsy. Pediatric Physical Therapy; 13: 68-76, 2001.

3- Crocker, M.D., MacKay-Lyons, M. and McDonnell, E.: Forced use of the upper extremity in cerebral palsy: a single case design. Am J Occup Ther.; 51: 824-833, 1997. [ISI] [Medline].

4- Duff, S.V. and Gordon, A.M.: Learning of grasp control in children with hemiplegic cerebral palsy. Dev Med Child Neurol.; 45: 746-757, 2003. [CrossRef] [ISI] [Medline].

5- Eliasson, A.C., Bonnier, B. and Krumlinde-Sundholm, L.: Clinical experience of constraint induced movement therapy in adolescents with hemiplegic cerebral palsy: a day camp model. Dev Med Child Neurol.; 45: 357-359, 2003. [ISI] [Medline].

6- Eliasson, A.C., Krumlinde-Sundholm, L., Shaw, K. and Wang, C.: Effects of constraint-induced movement therapy in young children with hemiplegic cerebral palsy: an adapted model. Dev Med Child Neurol.; 47: 266-275, 2005. [CrossRef] [ISI] [Medline].

7- Eyre, J.A., Miller, S. and Ramesh, V.: Constancy of central conduction delays during development in man: investigation of motor and somatosensory pathways. J Physiol.; 434: 441-452, 1991. [Abstract/Free Full Text].

8- Forssberg, H., Eliasson, A.C., Kinoshita, H., Johansson, R.S. and Westling, G.: Development of human precision grip. I: Basic coordination of force. Exp Brain Res.; 85: 451-457, 1991. [ISI] [Medline].

9- Forssberg, H., Kinoshita, H., Eliasson, A.C., Johansson, R.S., Westling, G. and Gordon, A.M.: Development of human precision grip. II. Anticipatory control of isometric forces targeted for object's weight. Exp Brain Res.; 90: 393-398, 1992. [ISI] [Medline].

10- Gardner, W.J., Karnosh, L.J., McClure, J.R. and Gardner, A.K.: Residual function following hemispherectomy for tumour and for infantile hemiplegia. Brain. 78: 487-502, 1955. [Free Full Text].

11- Gordon, A.M. and Duff, S.V.: Fingertip forces during object manipulation in children with hemiplegic cerebral palsy. I: anticipatory scaling. Dev Med Child Neurol.; 41: 166-175, 1999. [CrossRef] [ISI] [Medline].

12- Gordon, A.M., Charles, J. and Wolf, S.L.: Methods of constraint-induced movement therapy for children with hemiplegic cerebral palsy: development of a child-friendly intervention for improving upper-extremity function. Arch Phys Med Rehabil.; 86: 837-844, 2005. [CrossRef] [ISI] [Medline].

13- Gordon, A.M.: Development of hand motor control. In: Kalverboer AF, Gramsbergen A, eds. Handbook of Brain and Behaviour in Human Development. Dordrecht, Netherlands: Kluwer Academic Publishers; 513-537, 2001.

14- Hadders, A., Stremmelar, E.F., Touwen, B.C. and Van, I.B.: Development of posture adjustments during reaching in infants with CP. Dev Med Child Neurol; 46: 746-753, 1999.

15- Hart, H.: Can constraint therapy be developmentally appropriate and child-friendly? Dev Med Child Neurol.; 47: 363, 2005. [CrossRef] [ISI] [Medline].

16- Holthausen, H. and Strobl, K.: Modes of reorganization of the sensorimotor system in children with infantile hemiplegia and after hemispherectomy. Adv Neurol.; 81: 201-220, 1999. [Medline].
17- Kleim, J.A., Hogg, T.M., VandenBerg, P.M., Cooper, N.R., Bruneau, R. and Remple, M.: Cortical synaptogenesis and motor map reorganization occur during late, but not early, phase of motor skill learning. J Neurosci.; 24: 628-633, 2004. [Abstract/Free Full Text].
18- Koh, T.H. and Eyre, J.A.: Maturation of corticospinal tracts assessed by electromagnetic stimulation of the motor cortex. Arch Dis Child.; 63: 1347-1352, 1988.
19- Liepert, J., Bauder, H. and Sommer, M.: Motor cortex plasticity during constraint-induced movement therapy in chronic stroke patients. Neurosci Lett.; 250: 5-8, 1998. [ISI] [Medline].
20- Nezu, A., Kimura, S., Uehara, S., Kobayashi, T., Tanaka, M. and Saito, K.: Magnetic stimulation of motor cortex in children: maturity of corticospinal pathway and problem of clinical application. Brain Dev.; 19: 176-180, 1997. [CrossRef] [ISI] [Medline].
21- Rasmussen, T. and Milner, B.: The role of early left-brain injury in determining lateralization of cerebral speech functions. Ann N Y Acad Sci.; 299:355-369, 1977. [Medline].
22- Richard, L. and Palmiter-Thomas, P.: Grip strength measurement: A critical review of tools, methods, and clinical utility. Critical Review in physical and a rehabilitation Medicine, 46: 87-109, 1996.
23- Steenberben, B. and Van, K.: Control of Prehension in Hemiparetic Cerebral Palsy: similarities and differences between the ipsi and contralesional sides of the body Dev Med Child Neurol; 46: 325-332, 2004.
24- Taub, E. and Crago, J.E.: Behavioral plasticity following central nervous system damage in monkeys and man. In: Julesz B, Kovacs I, eds. Maturational Windows and Adult Cortical Plasticity. SFI Studies in Sciences of Complexity. Redwood City, Calif: Addison-Wesley; 201-215, 1995.
25- Taub, E. and Wolf, S.L.: Constraint induction techniques to facilitate upper extremity use in stroke patients. Top Stroke Rehabil.; 3: 38-61, 1997.
26- Taub, E., Miller, N.E. and Novack, T.A.: Techniques to improve chronic motor deficit after stroke. Arch Phys Med Rehabil.; 74: 347-354, 1993. [ISI] [Medline].
27- Taub, E., Ramey, S.L., DeLuca, S. and Echols, K.: Efficacy of constraint-induced movement therapy for children with cerebral palsy with asymmetric motor impairment. Pediatrics; 113: 305-312, 2004. [Abstract/Free Full Text].
28- Taub, E.: Somatosensory deafferentation research with monkeys: implications for rehabilitation medicine. In: Ince LP, eds. Behavioral Psychology in Rehabilitation Medicine: Clinical Applications. New York, NY: Williams & Wilkins; 371-401, 1980.
29- Willis, J.K., Morello, A. and Davie, A.: Forced use treatment of childhood hemiparesis. Pediatrics; 110: 94-97, 2002. [Abstract/Free Full Text].
30- Wolf, S.L. and Binder-MacLeod, S.A.: Electromyographic biofeedback applications to the hemiplegic patient: changes in upper extremity neuromuscular and functional status. Phys Ther.; 63: 1393-1403, 1993. [ISI] [Medline].
31- Wolf, S.L., Blanton, S., Baer, H., Breshears, J. and Butler, A.J.: Repetitive task practice: a critical review of constraint-induced movement therapy in stroke. Neurologist; 8: 325-338, 2002. [CrossRef] [ISI] [Medline].

الملخص العربي

تأثير تثبيت الذراع المواجه على الأداء الوظيفي لليد عند الأطفال المصابين بالشلل الغير متماثل

الخلفية والغرض : تهدف هذه الدراسة إلى تحديد تأثير تثبيت الذراع المواجه على الأداء الوظيفي لليد المصابة عند الأطفال المصابين بالشلل المخى الغير متماثل الأشخاص . عشرون من الأطفال المصابين بالشلل المخى الغير متماثل تم اختيارهم من العيادة الخارجية لكلية العلاج الطبيعي- جامعة القاهرة (12 بنت و 8 أولاد) . **الطريقة :** تم قياس قوة قبضة اليد المصابة باستخدام جهاز الديناموميتر اليدوي المعاير وكذلك المدى الحركي لمفصل الرسغ كما تم قياس الفترة الزمنية اللازمة للوصول والإمساك بكرة إسفنجية قبل وبعد تثبيت الذراع المواجة للطرف المصاب بواقع ست ساعات يوميا لمدة 21 يوما متصلا وتدريب اليد المصابة باستخدام تكرار الفعل وتشكيل اليد. **النتائج :** أظهرت النتائج زيادة في قوة قبضة اليد والمدى الحركي لمفصل الرسغ مع انخفاض المعدل الزمني اللازم للوصول والإمساك بكرة الإسفنجية .
الخلاصة : يعتبر العلاج باستخدام تثبيت الطرف المواجة للذراع المصاب من الأساليب الفعالة لزيادة الكف اءة الوظيفية لليد المصابة عند الأطفال المصابين بالشلل المخي الغير متماثل .
الكلمات الدالة : العلاج بتثبيت الطرف المواجة–الشلل المخى الغير متماثل –وظائف اليد .