

Effect of Manipulating Object Shape, Size and Weight Combined with Hand-Arm Bimanual Intensive Training (HABIT) in Improving Upper Extremity Function in Children with Hemiplegic Cerebral Palsy-A Randomized Controlled Trial

Chandan Kumar^{1*}, Rucha Mahendra Palshikar² and Vaibhav Choubey²

¹Department of Physiotherapy, School of Allied Health Sciences, Sharda University Neurological Physiotherapy, India

²Department of Physiotherapy, MGM's University of Health Sciences, Aurangabad, India

*Corresponding author: Dr. Chandan Kumar, Associate Professor, Department of Physiotherapy, School of Allied Health Sciences, Sharda University Neurological Physiotherapy, India, Tel: +918087518006; E-mail: ptchandan221@yahoo.co.in

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Abstract

Background: Hand Arm Bimanual Intensive Training (HABIT) has proven to improve upper extremity performance and co-ordination in children with hemiplegia. Children with unilateral spastic cerebral palsy display deficits in motor planning and execution that impact the timing and co-ordination of joint movements, orientation of the hand to object size, shape, weight and use, and calibration of fingertip forces. Bilateral impaired modulation of aperture, decreased bilateral ability to orient the hand prior to object contact based on forthcoming actions with the object was also reported.

Objective: To study the effect of Manipulating object shape, size and weight combined with Hand-arm bimanual intensive training(HABIT) in improving actual use of the more affected arm for completing activities commonly carried out in daily life, child's ability to handle objects and reducing spasticity in children with hemiplegic cerebral palsy.

Material and method: Thirty patients who fulfilled the inclusion criteria were randomly allocated into two groups. Group A-HABIT with Object Manipulation, Group B- HABIT without Object Manipulation with 15 patients in each group. All the patients were evaluated with Pediatric Motor Activity Log, Modified Ashworth Scale and Manual Ability Classification System at pre-and post-treatment level.

Results: There were significant decrease in spasticity MAS ($p=0.001$) & improvement in upper extremity function PMAL-R ($p=0.001$) & MACS ($p=0.001$) in both the groups post intervention. HABIT with object manipulation with different shape & size group had significant improvement on PMAL-R ($p=0.002$) & MACS ($p=0.009$) but no change in spasticity MAS ($p=0.679$) as compared to HABIT with object manipulation with similar shape & size group.

Conclusion: From finding of this study conclude that HABIT with Object Manipulation with different shape and size have positive effect in improving upper extremity function in children with hemiplegic cerebral palsy but not in spasticity reduction after 4 weeks of intervention.

Keywords: Cerebral palsy; Hand arm bimanual intensive training (HABIT); Manipulation; Object shape; Size; Weight

Introduction

Cerebral palsy is defined as an “umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development” [1]. Cerebral palsy (CP) is the most common cause of physical disability in childhood, with an estimated incidence of 2.11/1000 live births [2,3].

The topographic classification of CP is monoplegia, hemiplegia, diplegia and quadriplegia; monoplegia and triplegia are relatively uncommon [4]. Hemiplegia accounts for 35% (1 in 1300) of these children and upper limb (UL) involvement is usually more pronounced than the lower limb. The resulting impairments to upper

extremities may demonstrate abnormal muscle tone with posturing into wrist flexion, ulnar deviation, elbow flexion, and shoulder internal or external rotation in addition to reduced strength, as well as tactile and proprioceptive disturbances. All the previous impairments can result in abnormal development of hand skills and consequently affect functional independence and quality of life as well as skilled independent finger movement [5,6]. Length of the muscle plays an important role in the amount of muscle tension, so decrease in muscle length beyond resting level due to spasticity leads to decrease in the maximum force exerted by the muscles, which in turn affects grasping. Impairments of the involved upper extremity in children with hemiplegic CP may underlie some of the functional limitations that decrease their independence [7,8].

There is some evidence that the impaired hand function is not static during development, as the rate of development of the involved hand of children with CP largely parallels to that of typically developing

children, so one key to rehabilitation is to alter the rate of development that may enable children with CP to more closely approximate the functional independence and social integration observed in typically developing children [9]. Consequently, as children with hemiplegia have impairments in bimanual coordination; an interventional approach to increase functional independence during activities of daily living by using both hands in cooperation in a form of bilateral hand-arm bimanual intensive therapy is needed [10-12].

HABIT is a form of functional training that takes advantage of the key ingredient of CIMT (intensive practice), but focuses on improving coordination of the two hands using structured task practice embedded in bimanual play and functional activities. It uses principles of motor learning (practice specificity, types of practice, feedback), 21 and principles of neuroplasticity (practice-induced brain changes arising from repetition, increasing movement complexity, motivation, and reward) [13-16].

Apart from the purely physical object constraints on the hand pose, there is also a functional correlation between object shapes and the manner in which they are grasped by a hand. The act of grasping is a skilled activity that involves motor planning and fine motor coordination to control multiple degrees of freedom available to the hand and fingers. Children with Unilateral Spastic Cerebral Palsy (USCP) display deficits in motor planning and execution that impact the timing and coordination of joint movements, orientation of the hand to object size and use, and calibration of fingertip forces. There are two important aspects to successful grasp-motor control and the sensorimotor experience. When motor control is impaired, the hand is used less often, limiting the sensorimotor experience [17-22].

Bilateral impaired modulation of aperture (distance between thumb and index finger) to object size, an indicator of hand-shaping was described in children with USCP. Decreased bilateral ability to orient the hand prior to object contact based on forthcoming actions with the object was also reported. Contoured objects require complex configurations of multiple digits for accurate grasp. Aperture alone does not capture the finger coordination patterns used for grasping because joint angles of each digit differ based on object shape [23-28].

Need of the study

Hand Arm Bimanual Intensive Training has proven to effective in improving upper extremity performance and co-ordination in children with hemiplegia [14]. Children with USCP display deficits in motor planning and execution that impact the timing and co-ordination of joint movements, orientation of the hand to object size, shape, weight and use, and calibration of fingertip forces. Bilateral impaired modulation of aperture (distance between thumb and index finger) to object size, an indicator of hand-shaping, was described in children with USCP. Decreased bilateral ability to orient the hand prior to object contact based on forthcoming actions with the object was also reported. So, the need arises to study the effectiveness of manipulating object size, shape and weight combined with hand arm bimanual intensive training in improving hand functions in children with USCP.

Aim of the study

The aim of this study is to find out Effect of manipulating object shape, size and weight combined with hand-arm bimanual intensive training in improving upper extremity function in children with USCP.

Objectives of study

To study the effect of HABIT combined with object manipulation in improving actual use of the more affected arm for completing activities commonly carried out in daily life in children with USCP.

To study the effect of HABIT combined with object manipulation on spasticity in children with USCP.

To study the effect of HABIT combined with object manipulation to see the child's ability to handle objects in children with USCP.

Materials and methodology

- Record or Data Collection Sheet.
- Consent Form.
- Pediatric Motor Activity Log-Revised
- Modified Ashworth Scale
- Manual Ability Classification System
- Objects with different shapes, size and weight
- Chair
- Stool

Methodology:

- Type of Study: Experimental study
- Study Design: Single Blinded Randomized Controlled trial.
- Study Setting: Neuroscience department of Physiotherapy OPD, MGM Hospital Aurangabad, Other hospitals and private clinics of Aurangabad.

- Sample Size: 30

Group A-HABIT with Object Manipulation (Different size, shape and weight)

Group B-HABIT with Object Manipulation (Same size, shape and weight).

- Type of sampling: Simple Random Sampling, Lottery method
- Duration of intervention: 4 weeks
- Duration of study: 1 year

Inclusion criteria:

- Children diagnosed as USCP.
- Age between 4-8 years.
- Both male and females.
- Hand spasticity ranged between 1 and 1+ grades according to the Modified Ashworth Scale
- Able to communicate
- Able to follow commands
- Ability to achieve minimal active grasp with the impaired hand.
- Sufficient co-operation and cognitive understanding to participate.

Exclusion Criteria:

- Children with moderate and severe spasticity

- Visual or auditory impairments
- Previous orthopedic surgery in the UL.
- Fixed upper limb deformities
- Botulinum Toxin injections in the UL within 6 months prior to study entry.
- Suffering from other diseases that interfere with training.
- Any change in spasmolytic medications expected during the study period

Outcome measures

Modified ashworth scale: Modified Ashworth Scale (MAS) is used to assess spasticity in muscles. The Ashworth scale produces a global assessment of the resistance to passive movement of an extremity, not just stretch-reflex hyperexcitability. Specifically, the Ashworth score is likely to be influenced by non-contractile soft tissue properties, by persistent muscle activity, by intrinsic joint stiffness, and by stretch reflex responses [29-31].

Pediatric motor activity log-revised: The PMAL-R is a structured interview intended to examine how often and how well a child uses his/her involved upper extremity (UE) in their natural environment outside the therapeutic setting. The PMAL-R Arm Use scale with the original 6-step structure exhibited high reliability, stability, accuracy, and responsiveness to change in children between 2 to 8 years with a wide range of severity of upper extremity hemiparesis due to CP [32,33].

Manual ability classification system: The Manual Ability Classification System (MACS) has been developed to classify how children with cerebral palsy (CP) use their hands when handling objects in daily activities. The classification is designed to reflect the child's typical manual performance, not the child's maximal capacity. It classifies the collaborative use of both hands together [34,35].

Procedure

Informed Consent: Before implementing the study, informed consent was taken from the parents of the children (Tables 1 and 2) [36,37].

Activity	Description
Dough activities	Roll large ball of dough between the two palms or roll two equal sizes of dough by both hands at the same time on the table
Ball activities	Throwing or catching different sized balls (start with large ones)
Cubes activities	Transferring cube from non-affected to the affected hand and towering cubes. Started with 3 cubes till 6 cubes (first tower with the uninvolved limb and then with the involved one)
Bottle and marbles activities	Put marbles into bottle. First the affected hand stabilized the bottle and the child performed the task with the no affected hand. Task difficulty was increased by using the non-affected hand in putting marbles
Stacking rings	Child held the rings starting with large one and stack with the non-affected hand and put rings on with the affected hand
Stringing beads	Stabilize the rope first with the affected hand and the less affected hand stringing beads. Task difficulty was increased as the non-affected hand holds the rope and the affected hand performs the task. First large beads and thick cord were used progressing to small beads and thin cord
Manipulation activities	* Alternate banging and clapping movements
	* Fastening clothing, button and unbutton buttons, open and close zip
	* Twist the lid of the jar
	* Twist and press a lock and its key
	* Cutting of paper by scissors

Table 1: Description of hand arm bilateral intensive therapy (HABIT).

1	The children with USCP performed 10 lifts with their hands with the object's weight adjusted to 200 g, 400 g, 600 g, 800 g and 1000 g respectively.
2	6 differently shaped objects (rectangular, circular, square, cylindrical, concave and Convex) were used.
3	Object size: small (3 cm height-6 cm wide), medium (4 cm-8 cm) or large (5 cm-10 cm).

Table 2: Object manipulation with different shape, size and weight.

Step 1: Children diagnosed as USCP were recruited from various physiotherapy centers, hospitals.

Step 2: Children fulfilling inclusion criteria were included in the study and randomly allocated to either group.

Step 3: Procedure was explained to the child and parents & written informed consent taken.

Step 4: Children were made to sit on a chair of comfortable height and a table was given in front to place the objects.

Step 5: In Group A HABIT with Object Manipulation with different size, shape and weight were given, which included repetitive functional bimanual reach-to-grasp tasks using objects varying in size, weight, and shape along with conventional physiotherapy program.

Step 6: In the beginning, therapist assisted the child in doing the activities. Progression was done on the basis of successful achievement of repetition with the previous object size, shape and weight.

Step 7: Each exercise was given 10 repetition per set. Intervention was given for 6 days a week for total 4 weeks. Treatment duration of one session was approximately 40 minutes.

Step 8: In Group B HABIT combined with object manipulation was given with single object size, shape and weight for 40 minutes, 6 days in a week for 4 weeks.

Step 9: 6 Square shaped objects, 6 objects 800 g weight each and 6 Medium size objects (4 cm and 8 cm) were given for Group B.

Step 10: Conventional physiotherapy treatments based on ADL were given to both the groups which included: Passive, Active assistive & Active ROM Exercises, Weight bearing & Weight shifting exercises. These exercises prevent complications of immobilization and improve ADL skill at the earliest. This helps in preventing contractures and development of abnormal postures [38,39].

Step 11: At the end of 4 weeks, effect of intervention was seen by Pediatric motor activity log-revised (PMAL-R), Modified Ashworth Scale (MAS), and Manual Abilities Classification System (MACS).

An approval from MGM's Institute of Health Sciences ethical committee was taken before starting the study. The Protocol number of Ethical Committee Approval was MGM-ECRHS/2015/221.

Data Analysis

Data were analyzed and tabulated with SPSS version 22 (Statistical Package for Social Sciences) for windows and Microsoft Office Excel-2007. Mean, standard Deviation, Degree of freedom, confidence level, P value and significance were calculated to express the results. Parametric statistical tests Paired & Unpaired t test were applied in the study.

Levene's Test for has been used Equality of Variances for two groups: Unpaired' test has been done for Inter Group Comparison of Pediatric motor activity log-revised (PMAL-R), Modified Ashworth Scale (MAS), Manual Abilities Classification System (MACS) in between Experimental and Control Group for Pre-and Post-intervention level.

Paired' test has been done for Intra-Group Comparison for Pediatric motor activity log-revised (PMAL-R), Modified Ashworth Scale (MAS), Manual Abilities Classification System (MACS) Experimental and Control Group at Pre-and Post-intervention level.

Results

46 children were assessed for eligibility. Out of which 5 children were excluded because they refused to participate in study, 7 children unable to fulfill the inclusion criteria. Total 34 children were randomized and divided in to two groups. Group A and Group B. There was 4 drop out from study, 2 children from each group. Total 30 children, 15 in each group completed the whole intervention and included for data analysis. Total 19 Males and 11 Females were participated in the study (Table 3).

	Group A	Group B	Df	T Value	P Value
Age	6.67 ± 1.66	6.56 ± 1.87	28	0.164	0.51
Gender	Male	10	9		
	Female	5	6		
Causes of CP	Prenatal	8	9		
	Postnatal	7	6		
Dominant side	Right	10	12		
	Left	5	3		
Hemiplegic side	Right	7	5		
	Left	8	10		
MAS	1.60 ± 0.50	1.40 ± 0.50	28	1.08	1
PMAL-R	1.46 ± 0.51	1.53 ± 0.51	28	-0.354	1
MACS	2.66 ± 0.48	2.40 ± 0.50	28	1.46	0.478

P<0.05* shows a statistically significant result.

Table 3: Mean and SD of age and pre-intervention level comparison between group a and group b for pmal-r, mas and macs.

When comparison of mean and SD between the group A and B was done for pre-values of MAS (p=1.0), PMAL-R (p=1.0), and (p=0.47) the result was not significant (Figures 1-3, Table 4).

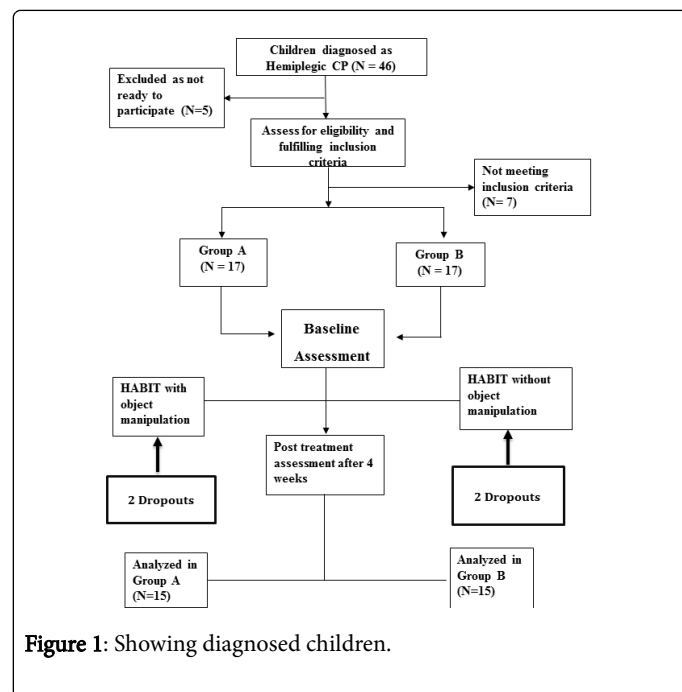


Figure 1: Showing diagnosed children.

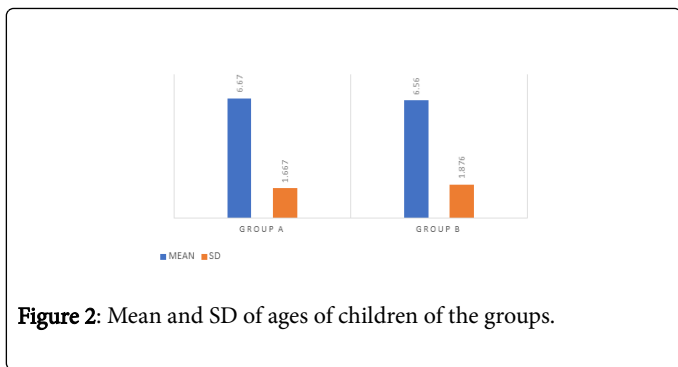


Figure 2: Mean and SD of ages of children of the groups.

Group A	Pre	Post	Df	T Value	P Value
MAS	1.60 ± 0.50	0.733 ± 0.45	14	6.5	0.001
PMAL-R	1.46 ± 0.51	3.46 ± 0.63	14	-14.49	0.001
MACS	2.66 ± 0.48	1.33 ± 0.48	14	8.36	0.001

P<0.05* shows a statistically significant result.

Table 4: Pre-and post-intervention comparison of group a for mas, pmal-r, and maccs.

When comparison of mean and SD within the Group, A was done for pre-and post-values of MAS, PMAL-R, and MACS, the MAS value decreased and PMAL-R and MACS values increased (Table 5).

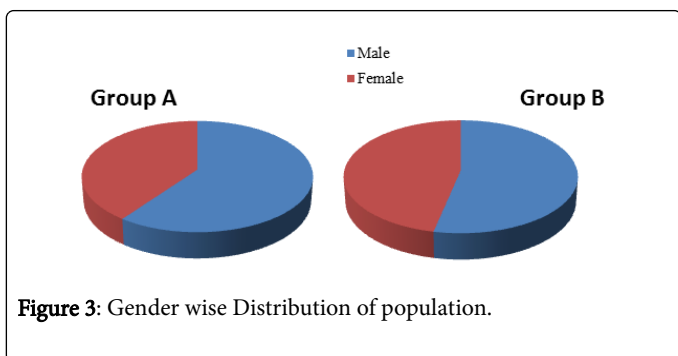


Figure 3: Gender wise Distribution of population.

Group B	Pre	Post	Df	T value	P value
MAS	1.40 ± 0.50	0.80 ± 0.41	14	4.58	0.001
PMAL-R	1.53 ± 0.51	2.40 ± 0.48	14	-4.51	0.001
MACS	2.40 ± 0.50	1.80 ± 0.41	14	3.15	0.007

P<0.05* shows a statistically significant result.

Table 5: Pre-and post-intervention comparison of group b for mas, pmal-r, and maccs.

When pre-and post-values comparison was done for group B for MAS, PMAL-R, and MACS, MAS value decreased and PMAL-R and MACS values increased post intervention (Figure 4, Table 6).

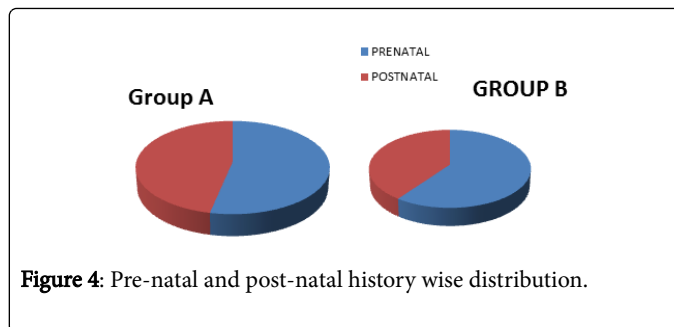


Figure 4: Pre-natal and post-natal history wise distribution.

	Group A	Group B	Df	T Value	P Value
MAS	0.73 ± 0.45	0.80 ± 0.41	28	-0.41	0.679
PMAL-R	3.46 ± 0.63	2.46 ± 0.91	28	3.46	0.002
MACS	1.33 ± 0.48	1.80 ± 0.41	28	-2.82	0.009

P<0.05* shows a statistically significant result.

Table 6: Post intervention level comparison between group a and group b for mas, pmal-r, and maccs.

When post intervention level comparison between group A and B was done for post values of MAS, PMAL-R & MACS, MAS value was similar in both the groups whereas PMAL-R & MACS values was higher in Group A (Figures 5 and 6).

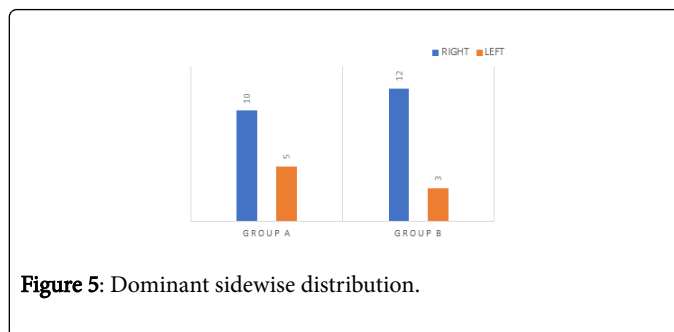


Figure 5: Dominant sidewise distribution.

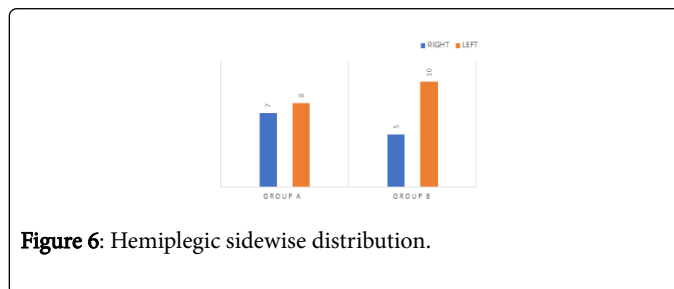


Figure 6: Hemiplegic sidewise distribution.

Discussion

The result of study demonstrates that Hand Arm Bimanual Intensive Training is feasible for USCP, providing preliminary support to improve outcomes on actual use of affected arm, spasticity and handling objects in daily life. These improvements are consistent with previous studies that have shown benefits from the Hand Arm Bimanual Intensive Training (HABIT) [40,41].

A study done by Hung et al. [12] to find out effect of intensive bimanual training on coordination of the hands in children with congenital hemiplegia. Results suggest that bimanual training improves the spatial-temporal control of the two hands [42].

Serrien et al. [43] did study to find out weather Damage to the parietal lobe impairs bimanual coordination, concluded that brain damage associated with hemiplegia often includes areas known to be involved in bimanual coordination such as the supplementary motor area and the parietal lobe [43,44].

A Meta-analysis conducted on Bilateral movement training and stroke motor recovery progress which is also in favor of finding of this study as bimanual training was included along with object manipulation [45].

Lewis et al. didn't find real additional beneficial effect of bilateral practice on 6 post stroke patients. They find, when a positive influence of the bilateral intervention was suggested, it tended to be in tasks with lower performance scores for participants with moderate motor deficits. They also note that the task that had the largest involvement of proximal musculature also had the more reliable facilitatory effects. Given the contribution of bilateral descending pathways to proximal musculature, movements requiring activation of these proximal muscles may profit most from bilateral training protocols [46].

Hand-arm bimanual intensive therapy (HABIT), which simultaneously activates the same neural networks in either hemisphere which decreases the inter-hemispheric inhibition. This is because right and left hemispheres have symmetrical organization for hand control in the motor cortexes which are both activated during bimanual hand training that in turn leads to improvement in inter-hemispheric communication and ipsilateral motor cortex activation of the affected hemisphere. [47] During symmetrical bimanual movements, there is a coupling of movements of the two extremities with one or both of the movements being affected [19-21]. Motor learning principles would suggest that improvement in use of two hands together maximized by repetitive practice of bimanual goal directed tasks [22]. Early bimanual use of both hands is thought to be important for the development of the assisting hand, as the development of motor control is modeled on effective use of the dominant hand [23]. This can be one of the reasons the motor activity log has improved in this study.

On the contrary Jackson and colleagues [48] have argued that a sensorimotor mechanism, based upon proprioceptive coding of limb position and motion, exists to maintain interlimb co-ordination during movement execution. Although untested to date, this would suggest that intact proprioception is a critical prerequisite for beneficial effects with bimanual training protocols [48,49]. Mudie and Matyas [50] reported that, bilateral simultaneous movement promotes inter hemispheric disinhibition which is likely to allow reorganization by sharing of normal movement commands from the undamaged hemisphere. Disinhibition may also encourage recruitment of undamaged neurons to construct new task-relevant neural networks [50].

Related to findings of this study, Wiesendanger and Serrien [43] have concluded that Lesion location alone, therefore, may not be very useful in predicting who will or will not benefit from bimanual training protocols. Given the distributed nature of bimanual coordination, we can also conclude that the majority of our patients will manifest deficits in bimanual coordination, and, therefore,

bimanual training activities should be at least a part of any comprehensive rehabilitation program [51].

MAS is used to see change in spasticity. Significant change was found in spasticity in both the groups at post intervention level. Bilateral simultaneous movement promotes inter hemispheric disinhibition which is likely to allow reorganization by sharing of normal movement commands from the undamaged hemisphere. Disinhibition may also encourage recruitment of undamaged neurons to construct new task-relevant neural networks [46,50]. This can be the reason due to which spasticity has reduced in our subjects. In addition, subjects were also asked to repeat the activities which is also one of the factors that has contributed in reduction of spasticity in this study.

Another finding of this study suggest that, there was no difference in spasticity reduction in both the group at post intervention level but HABIT with Object Manipulation with different size & shape was more effective as compared to Habit with Object manipulation with similar shape & Size. Although upper extremity function improvements were seen in both the groups but greater amount of improvement in upper limb function especially handling objects in daily activities was noted in group A (Hand-Arm Bimanual Intensive Training with different object size, shape and weight manipulation). Therefore, the alternate hypothesis is accepted.

Wolff et al. [52] conducted a study on Differentiation of hand posture to object shape in children with USCP. They concluded in their study that Children with USCP were able to differentiate their hand posture to objects of different shapes, but demonstrated deficits in the timing and magnitude of hand-shaping that were isolated to the affected side. This is in agreement with our findings in which handling objects of different shapes and sizes showed improvement in the handling of objects [52].

On the contrary, study done by Ronnqvist and Rosblad [53] concluded that the less affected hand showed delayed aperture formation during reach and the more affected hand demonstrated no anticipatory shaping at all, while another cohort of children achieved peak aperture at 90% of reach in both hands, compared to 50% in TD children [53].

Another possible explanation of this finding is that when object size and shape varied, while holding an object between the index and thumb, the individual has to generate a shear force in order to overcome the weight of the object and prevent the object from slipping from the fingertips. The magnitude of the shear force is related to the friction coefficient of the object and the magnitude of the pinch force. Therefore, grip force can be modulated as a function of the friction between the fingertips and the object surface and, also, the weight of the object. Slippery and heavier objects will generally require larger grip forces. Usually the grip force is slightly larger than the minimal grip force mechanically required to hold the object, providing a security margin allowing small perturbations to be corrected without dropping the object. Many studies have demonstrated the precise coordination between the grip force and the shear force during the manipulation of an object [54].

The studies done by Flanagan et al. [55] concluded that the motor system adapts to the size-weight illusion within a few lifts, whereas it takes many days of training to overcome the distorted perception of weight. These studies illustrate the fast adaptation of the motor system for lifting but slow adaptation of the perceptual system for the judgment of object size and weight [55].

Bert Steenbergen et al. [56] conducted study on Fingertip force control during bimanual object lifting in hemiplegic cerebral palsy. It was observed that there was a close synchrony of both hands when the task was performed with both hands, despite large differences in duration between both hands when they performed separately, bimanual tasks may have the potential to facilitate force control of the affected hand. The present results suggest a form of asymmetrical mutual adaptation, primarily, but not exclusively, established by the less-affected hand. Importantly, these findings indicate that bimanual movements may help the affected hand to produce more 'regular', or fine, force control. When a property of an object (e.g. weight or texture) changes unexpectedly, the motor system adapts quickly to adjust the forces used to lift the object [56].

No Children in either group reported adverse effects/discomfort with intervention. It is recommended that further research can be conducted by increasing the duration of the study and the sample size. Since the protocol is beneficial in improving motor function, it can be added along with conventional physiotherapy to gain additional effects.

Limitations

- Small sample size and short Study duration i.e., only for 4 weeks.
- The study analyzed only the short-term benefits.
- No follow up after 4 weeks intervention.

Future scope of study

- Follow up can be done to see effect of bimanual training with object manipulation in future clinical trial, on a larger sample size with longer duration.
- Similar Research can be performed on other type of cerebral palsy patients, stroke patients, Parkinson's disease, Multiple Sclerosis patients.

Conclusion

From finding of this study conclude that HABIT with Object Manipulation with different shape and size have positive effect in improving upper extremity function in children with hemiplegic cerebral palsy but not in spasticity reduction after 4 weeks of intervention.

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