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ORIGINAL ARTICLE

Effect of hand-arm bimanual intensive therapy on fine-motor performance in children with hemiplegic cerebral palsy

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Abstract Children with hemiplegic cerebral palsy have impairments in bimanual coordination above and beyond their unilateral impairments.

Aim of the study: The current study was conducted to examine the effect of hand-arm bimanual intensive therapy (HABIT) on the affected upper extremity use in children with hemiplegic cerebral palsy.

Subjects and procedures: Thirty hemiparetic children ranged in age from 3 to7 years with mild to moderate hand involvement participated in this study and they were divided equally into two groups (control and study). Children in the study group were engaged in play and functional activities that provided structured bimanual practice 3 h per day for 12 weeks, while children in the control group received traditional physical therapy program directed toward improving upper extremity use. Each child in the two groups was evaluated before and after the suggested treatment duration for detecting the level of hand performance using the Peabody Developmental Test of Motor Proficiency and hand grip strength by a hand held dynamometer.

Results: Children in both groups demonstrated improved scores on the Hand grip strength while only children in the study group showed significant improvement in fine-motor performance scores ($p < 0.05$).

Conclusion: The results suggest that, hand-arm bimanual intensive therapy appears to have a positive impact on hand function in children with hemiparetic cerebral palsy.

1. Introduction

In hemiplegic cerebral palsy (CP) the resulting movement impairments are largely localized to one side, with the upper extremity usually being affected more than the lower extremity [1,2]. The resulting impairments to upper extremities may

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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 [3,4].

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 [5,6]. During symmetrical bimanual movements there is a coupling of movements of the two extremities with one or both of the movements being affected [7–9].

Impairments of the involved upper extremity in children with hemiplegic CP may underlie some of the functional limitations that decrease their independence [10–13]. There is some suggestion that initial unimanual practice can transfer to improvements in bimanual coordination suggesting that this treatment can ameliorate their poor bimanual coordination. However, this might be best accomplished by practicing bimanual skills directly [9,14].

There is some evidence that the impaired hand function is not static during development [15,16], 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 [17].

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. So the aim of the current study was to detect the effect of HABIT on changing the quality of the affected upper extremity performance in children with hemiplegic CP.

1.1. Methodology

The study was conducted at the outpatient clinic of the Faculty of Physical Therapy Cairo University after the approval of the Faculty of Physical Therapy ethics committee and parents of the children participated in this study. The work was also carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

1.2. Subjects

Thirty hemiparetic CP children (due to prenatal and/or perinatal brain damage according to the Hagberg classification) of both sexes (20 boys, 10 girls) ranged in age from 3 to 7 years with hand spasticity ranged between 1 and 1+ grades according to the Modified Ashworth Scale participated in this study. They were selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University. Children with moderate and severe spasticity or fixed upper limb deformities or children with mental retardation were excluded from this study. Children who followed the previous inclusion criteria were assigned randomly into two groups of equal number of control and study groups. Children in the control group (9 boys, 6 girls) received a selected physical therapy program directed toward improving upper extremity functions, while children in the study group (11 boys, 4 girls) received hand-arm bimanual intensive therapy program (HABIT). The treatment was conducted for twelve successive weeks in each group at the rate of three sessions per week.

1.3. Instrumentation

Peabody developmental motor scale (PDMS-2) was used for the detection of Fine motor skills (grasping section), and a calibrated hand-held dynamometer was used for measuring hand grip strength. Different sizes and shapes of occupational therapy tools including balls, cubes, cards, dough, marbles, scissors, puzzle, keys, zipper, beads, tooth brush and paste, buttons, jar, lock and key were used in the treatment of both groups.

1.4. Procedures

Assessment of fine motor skills of Grasping section in PDMS-2 included administration of 26 subtests that measure child's ability to use his/her hands. It begins with the ability to hold an object with one hand and progresses up to actions involving the controlled use of the fingers of both hands. Application of the scale included detecting entry point (in which 75% of children in the normative sample at that age passed), basal level (the last score of 2 on three items in a row before the 1 or 0 scores) and ceiling level (when the child scores 0 on each of three items in a row) for each child before and after treatment application. The entry point of grasping subtest in the current study was determined at item 21 which starts from 35 to 71 months. This scale is based on scoring each item as follows: 2: The child performs the item according to the criteria specific for mastery. 1: The child performance shows a clear resemblance to the item mastery criteria but does not fully meet the criteria. 0: The child cannot or will attempt the item, or the attempt does not show that skill is emerging.

Evaluation of hand grip strength: It was carried out by asking the child to squeeze the dynamometer while maintaining elbow joint flexed 90°, forearm in mid position and rested on an arm-chair with the wrist joint in neutral position.

Treatment procedures: Children in the control group received a unimanual treatment program for the involved upper extremity directed toward improving upper limb function including reflex inhibiting pattern, hand weight bearing, shaping the affected hand with different occupational therapy tools, and repetitive task practice as dice activities, turning cards, putting marbles into bottle and dough activities.

Patients in the study group received HABIT that focuses on: (1) provision of structured practice increasing in complexity; (2) provision of functional activities that necessitate bimanual hand use.

Bimanual activities were selected that supposed to improve the movement deficits and engage the child in activities of increasing complex bimanual coordination. Demonstration of each task performance and how each hand will be used was clarified to the child before the start of each task to prevent use of compensatory strategies.

A number of age-appropriate fine motor and manipulative gross motor activities that require use of both hands are illustrated in Table 1. Task difficulty is graded as performance improves by requiring greater speed or accuracy, or by providing tasks that require more skilled use of the involved hand and arm (i.e. moving from activities in which the involved limb acts as a stabilizer to activities that require manipulation).

Although specific activities were selected by considering the role of the involved limb in the activity, children were asked to use the involved limb in the same manner as that of the non-dominant limb of a typically developing child. During these activities the children not only received instructions from the therapist but also must engage in their own active problem-solving. Task performance was recorded, and both positive reinforcement and knowledge of performance were used for motivation.

2. Statistical analysis

Results are expressed as mean ± standard deviation (SD) or number (%). Comparison between the mean values of different variables measured post-treatment in the two groups was performed using the unpaired student's *t* test. Comparison between categorical data was performed using the Chi square test. Statistical Package for the Social Sciences SPSS (Descriptive statistics) computer program (version 12 windows) was used for data analysis. *p* value less or equal to 0.05 was considered significant.

3. Results

Basic demographic data as well as the clinical characteristics of the 30 hemiparetic CP participants are presented in Table 2. There was no statistical significant difference between both control and study groups as regards age and sex at the baseline of assessment as mean ± SD of the age of children in the control group was 4.11 ± 0.93, whereas that in the study group was 3.64 ± 0.48 years. The percentage of girls to boys in the control group and study group were 26.7% and 73.3% in the control group and 40% and 60%, in the study group respectively.

Table 2 Demographic and clinical characteristics of patients in both control and study groups.

Item	Control	Study	*P* value
Girls/boys	4/11 26.7%/73.3%	6/9 40%/60%	0.456 (NS)
Age	4.11 ± 0.93	3.64 ± 0.48	0.093 (NS)

3.1. Comparison within each group before and after treatment

There was a significant difference as regards hand grip strength in the control group before and after treatment ($p = 0.05$). Also there was a significant difference in hand grip strength in the study group before and after treatment ($p = 0.04$) (Table 3).

There was an insignificant difference in the control group before and after treatment as regards grasping scores ($p = 0.521$), while there was a significant difference in grasping scores in the study group before and after treatment ($p = 0.022$) (Table 3).

There was also an insignificant difference in the control group before and after treatment application as regards age equivalent (*p* value = 0.432). On the other hand a significant difference was recorded for the same parameter when comparing before and after treatment application mean values in the study group ($p = 0.05$).

3.2. Comparison between groups before and after treatment

There was a statistically insignificant difference between control and study groups before treatment as regards hand grip strength ($p = 0.767$), while there was a significant difference between both groups after treatment ($p = 0.05$) (Table 4) in favor to the study group.

Also there was an insignificant difference between both control and study groups before treatment as regards grasping scores ($p = 0.576$) while a significant difference was recorded between both groups after treatment application ($p = 0.032$) (Table 4).

Table 1 Description of hand arm bilateral intensive therapy.

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 non-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 3 Comparison between mean values of different variables measured pre and post-treatment application within the two groups.

Variable	Pre	Post	*P* value
Grip strength			
Control	1.65 ± 1.2	3.15 ± 1.44	0.05 (S)
Study	1.51 ± 1.21	4.62 ± 1.44	0.04 (S)
Grasping score			
Control	1.53 ± 0.64	2.27 ± 0.46	0.521 (NS)
Study	1.37 ± 0.59	3.60 ± 1.12	0.022 (S)
Age equivalent			
Control	10.80 ± 2.14	13.20 ± 2.38	0.432 (NS)
Study	10.53 ± 2.10	20.47 ± 9.83	0.05 (S)

S: significant, NS: not significant.

Table 4 Comparison of mean values of different variables measured pre and post-treatment application between the two groups.

Variable	Control	Study	*P*
Grip strength			
Pre	1.65 ± 1.2	1.51 ± 1.21	0.767 (NS)
Post	3.15 ± 1.44	4.62 ± 1.44	0.05 (S)
Grasping score			
Pre	1.53 ± 0.64	1.37 ± 0.59	0.576 (NS)
Post	2.27 ± 0.46	3.60 ± 1.12	0.042 (S)
Age equivalent			
Pre	10.80 ± 2.14	13.20 ± 3.38	0.67 (NS)
Post	13.20 ± 2.38	20.47 ± 9.83	0.015 (S)

S: significant, NS: not significant.

Insignificant difference was recorded between the control and study groups before treatment application regarding age equivalent (p value = 0.67). On the other a significant difference was recorded for the same parameter after treatment application (p = 0.05) (Table 4).

4. Discussion

Hemiplegic children may show a delay in the acquisition of various motor functions such as fine motor skills due to spasticity and motor weakness. This consequently will interfere with the hand function performance, so the current study was conducted to detect the effect of hand-arm bimanual intensive therapy on changing the affected upper extremity motor performance in those children.

The results of the current study showed decreased hand grip strength which may be explained by the effect of spasticity that leads to change in the muscle length. This can be supported by Salter and Cheshire [18] who reported that, 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.

Improvement in the study group Peabody scores of the grasping section and age equivalent of motor performance in the current study may be attributed to the effect of hand-arm bimanual intensive therapy as this type of therapy differs from conventional physical and occupational therapy in at least two ways: (1) the intensity of training is far greater, providing sufficient opportunity for practice using principles of motor learning; (2) encouraging the use of the involved hand in any manner as the child was asked to use it as a typically developing child uses their non dominant hand, and in particular to focus on how the hand and arm are performing at the end-point of the movement [19].

The significant difference in Peabody developmental scores between the study and control groups may be attributed to the effect of hand-arm bimanual intensive therapy which allowed patients of the study group to simultaneously receive proprioceptive and visual feedback from the unaffected limb (as in rolling dough against the table) that they do not receive during unilateral practice in which only the affected limb is used in the control group. This explanation is supported by Stephen et al. [20] who reported that when practicing bilaterally, a patient can use the unaffected extremities that have neurologically intact afferent and efferent signals as when looking and feeling movement within the unaffected limb, this will enable him to promote similar movement by the affected limb.

The current study depends on using both upper extremities simultaneously to facilitate the use of the affected upper extremity which is supported by the study of Hussien et al. [21] who recorded improvement in shoulder and elbow joint angular displacement after using arm cycling due to improved coordinated movements between the two sides, as arm cycle provided improvement in bimanual motor performance.

Post-treatment difference between both groups may also be explained as hand-arm bimanual intensive therapy which simultaneously activates the same neural networks in either hemisphere which decreases the interhemispheric 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 interhemispheric communication and ipsilateral motor cortex activation of the affected hemisphere [22,23].

Also Mudie and Matyas [24] reported that, bilateral simultaneous movement promotes interhemispheric 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.

5. Conclusion

Bimanual coordination problems may underlie some of the functional limitations of hemiparetic CP children when they experience activities such as dressing, eating, and playing sports, the results of the current study clarified that hand-arm bimanual intensive therapy has a positive impact on fine-motor performance of those children rather than unimanual training. Thus, improved bimanual coordination might be best accomplished by practicing bimanual skills directly.

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