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Contralateral effect of unilateral motor priming on grasping in children with unilateral spastic cerebral palsy

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Abstract

Introduction. Cross-training, as a type of unilateral movement-based priming, could enhance the affected side depending on strengthening of the non-affected side. It was aimed to investigate the effect of unilateral movement-based priming on handgrip strength and fine motor developmental outcomes of the affected upper extremity in children with unilateral spastic cerebral palsy.

Methods. Overall, 32 patients participated in this study; they were randomly classified into 2 groups. Group A subjects engaged in a selected occupational therapy program based on fine motor development, while those in group B received exercises to increase contralateral hand strength followed by application of the same program as group A. The treatment programs were conducted 3 times per week for 10 successive weeks. The outcomes included affected handgrip strength as a primary outcome and age equivalent for grasping in the Peabody Developmental Motor Scale – Fine Motor (PDMS-FM). These measures were recorded before and after the application of the allocated interventions.

Results. There were statistically significant differences when comparing pre- and post-treatment mean values in each group. Also, there was a significant difference in favour of the study group when comparing post-treatment mean values ($p < 0.05$).

Conclusions. Unilateral motor priming through cross-training is effective in improving grasping outcomes of the affected upper extremity concerning strength and fine motor development in children with unilateral spastic cerebral palsy.

Key words: unilateral spastic cerebral palsy, motor-based priming, cross-training, grasping

Introduction

Cerebral palsy (CP) leads to disorders of posture and motor impairment. It is a common cause of disability in childhood. These disorders result from various insults to different areas within the developing nervous system. CP is a group of disorders of movement and posture, often characterized by muscular impairments such as muscle weakness and spasticity [1]. The severity of motor impairment varies widely, depending on the site and severity of brain lesions [2–4].

Spastic hemiplegia is one of the most common types of CP expressing affection for one side of the body. The core problems associated with hemiplegia are gait disorders and hand malfunction. In such cases, the quality of the upper limb is important as it is considered as a criterion for improving upper limb function [5].

Functional limitations are often a cause for a developmental gap in hand use, making it difficult for those with a brain insult to move. The functional impact of unilateral upper limb impairment has been the focus of extensive research undertaken to improve motor performance and independence with daily activities [6].

Motor priming, using either unilateral or bilateral movements, is an important method of activating the motor cortex in neuro-paediatric rehabilitation and so providing more chances for neural plasticity. Unilateral motor priming has 2 forms: it can be applied through either the affected or the unaffected side [7].

Priming theory assumes that when the brain is activated through an intervention delivered before a motor learning intervention, it will become more responsive owing to increased neural activity. This may result from the modulation of long-term potentiation and help in the process of motor learning [8].

Priming of the motor cortex is associated with changes in neuroplasticity, associated with improvements in motor performance [7].

Movement-based priming involves any type of repetitive or continuous movement that is conducted to enhance the effect of the accompanying therapy. Movement-based priming typically includes bilateral or unilateral movements, mirror-symmetric active or passive movements, or any type of exercise, such as aerobic, isometric, and balance exercises. Repetitive movements can be single-joint movements, such as a repetitive unilateral wrist or elbow flexion and extension, or bilateral symmetrical movements of both limbs, such as bilateral wrist flexion-extension [9].

Although recent research has decreased the incidence of post-CP mortality, the disability persists and the most common one is upper limb functional limitation. It is not clear why a proportion of children with unilateral CP do not respond to evidence-based upper limb intervention [10].

Most studies focused on functional limitations, without a consideration of using abilities to counteract disabilities. The main objective of this study is to investigate the effect of unilateral movement-based priming in the form of cross-training applied to the less affected side on grasping at the affected side in children with unilateral spastic CP.

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Subjects and methods

Study design and sample size

A randomized controlled trial was performed in which the participants were randomly assigned into 2 groups.

The G*Power 3.1.9.4 software (Windows version) was used to determine the sample size and power by assuming a comparison of the difference between 2 independent means: 2 tails with an effect size of 1.1. Assuming $\alpha = 0.05$ and a power of 85%, a sample size of 32 participants turned out to be required, divided into 2 groups.

Inclusion and exclusion criteria

The participants were recruited from the outpatient clinic, Faculty of Physical Therapy, Cairo University. A total of 32 children of both sexes aged 5–7 years were selected. The patients included in this study were physically diagnosed with CP of spastic hemiparesis. The degree of spasticity ranged between 1 and 1+ in accordance with the modified Ashworth scale. Also, the children were cognitively competent and able to understand and follow instructions.

Patients with fixed deformities of upper or lower limbs were excluded, including one who had significant perceptual, cognitive, visual, and auditory disorders.

Randomization and intervention

With the consideration of equality in number, distribution of gender, and degree of spasticity (1:1) in both groups, randomization was allocated to avoid variation of the data obtained and also to avoid bias in the results. Stratification was performed through categorizing participants into categories following the initial assessment; then, each category took the same block number to ensure equal distribution of these numbers between both groups.

The children were randomly assigned into 2 groups, the control group (A) and the study group (B). Group A subjects engaged in a selected occupational therapy training program derived from fine motor development tasks. Those in group B implemented a unilateral priming protocol in a form of cross-training (strengthening exercises of the unaffected side) followed by the same program as received by the participants of group A, with a break of 5–10 minutes in between (cross-training + occupational therapy). The treatment sessions were conducted 3 times per week for 10 successive weeks.

Evaluation procedure

Handgrip strength (kg)

A Jamar Plus hand-held dynamometer (Patterson Medical Inc., China) was used for measuring handgrip strength. The readout displays isometric grip force of 0–90 kg and can be set to present kilograms or pounds. The dynamometer offers rapid exchange testing with audible signals and automatically calculates the average.

Each participant was seated on an adjustable height chair with back support. The head was maintained in the mid-position, trunk erected. The hips and knees were flexed 90°, with the feet fully supported on the ground. The shoulder joint was maintained beside the body in a neutral position, the elbow joint was kept at a right angle, the forearm remained in midway between supination and pronation, with the wrist joint in a slight extension position (15°). Then, the participant was asked to hold the handle of the dynamometer with the affected hand and squeeze it using maximum strength, then release. The procedure was repeated 3 times and the device calculated an average of the 3 trials.

Age equivalent for grasping

The Peabody Developmental Motor Scale – Fine Motor (PDMS-FM) was used to evaluate the age equivalent for grasping in the study participants. Each child was seated at a table on a chair that permitted them to comfortably place their feet on the floor. The table was large enough to allow the examiner and the child to sit opposite each other or side by side.

The examiner recorded relevant data about the tested participant, including their name, gender, and age. Age in months was used to determine scoring information. The examiner documented the child's raw score and age equivalent for grasping.

Treatment procedure

Selected occupational therapy program

This program was designed and applied to both groups. It usually started with stretching exercises as warming-up, aiming to relax the muscles of the affected upper extremity before task training. This included facilitation for wrist extensors, which was applied through using different facilitatory techniques, such as quick stretching, tapping, and active movements. Proprioceptive training with weight-bearing from different positions, such as the quadruped position, was applied. The wall push-up exercise with extended upper extremities was used to strengthen the shoulder girdles. The training also included exercises to facilitate hand skills based on the fine motor developmental sequence, involving reaching, grasping, release, and hand manipulative skills with repetitions. Encouragement was applied of arm/hand use during everyday activities, e.g. dressing, brushing teeth, combing hair, and washing face. These exercises were demonstrated in front of the child before performance.

Contralateral strengthening exercises

These were applied in the form of resisted exercises of the contralateral (unaffected) side before the selected occupational therapy program to the participants of group B. The design and implementation of exercises were based on an individual's repetition maximum for each muscle group. The maximum repetitions reached were 30 repetitions (3 sets of 10 repetitions) for each muscle group. It was applied to finger extensors, abductors and flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors and abductors. Rubber bands and different weights in the form of sand packs were used to apply strengthening exercises.

Statistical analysis

Data analyses were performed by using the Minitab-17 software for Windows. The collected demographic and other baseline characteristics were statistically treated to show the mean and standard deviation of the measured parameters. Chi-square test and independent *t*-test were used to compare baseline characteristics between both groups.

Parametric, as well as non-parametric statistical tests were performed to compare changes in handgrip strength, and age equivalent of grasping before and after the application of the rehabilitation programs. To compare the groups in each assessment, unpaired *t*-test and Mann-Whitney *U* test were used. The value of $p < 0.05$ was considered statistically significant.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (approval No.: P.T.REC/012/002735).

Informed consent

Informed consent has been obtained from the parents of all children included in this study after adequate explanation.

Results

A total of 32 participants were randomly assigned to groups A and B. Group A ($n = 18$) took part in occupational therapy, whereas group B ($n = 17$) received cross-training in addition to the treatment applied in group A. Of the 18 participants allocated to group A, 2 withdrew from the study (did not participate in > 2 consecutive sessions), compared with 1 participant from group B (Figure 1).

The baseline characteristics at entry including age, weight, and height are summarized in Table 1. No significant difference was observed between the groups concerning the baseline characteristics ($p > 0.05$).

The comparison of pre-treatment mean values between the groups showed no significant difference in the measured variables ($p > 0.05$).

Statistically significant differences were observed in handgrip strength and age equivalent for grasping when comparing pre- and post-treatment mean values of group A, as well as group B after the application of the rehabilitation programs ($p < 0.05$), as presented in Table 2.

Table 1. Baseline characteristics

Item	Group A (mean ± *SD*)	Group B (mean ± *SD*)
Age (years)	6.13 ± 0.74	6.0 ± 0.84*
Weight (kg)	18.6 ± 3.83	17.93 ± 2.89*
Height (m)	1.12 ± 0.09	1.09 ± 0.1*

* $p > 0.05$

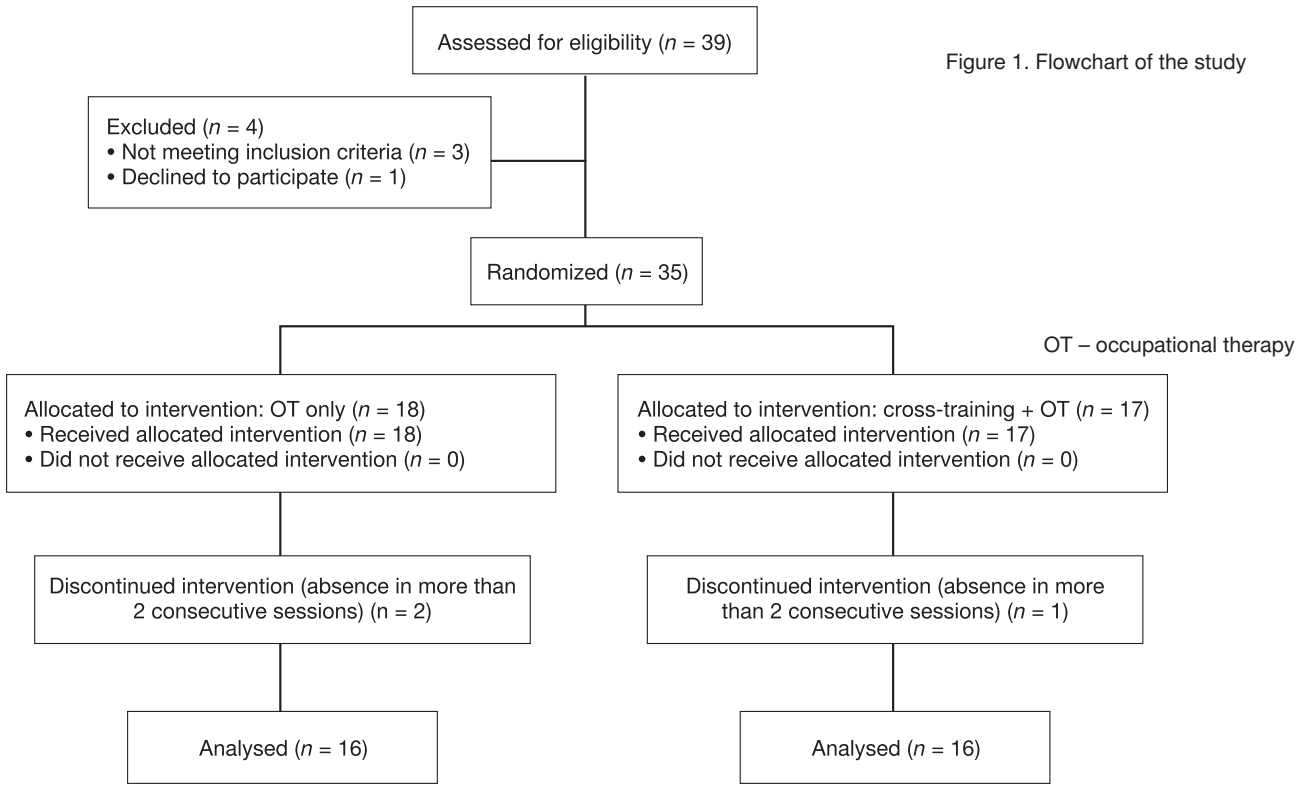

Figure 1. Flowchart of the study

Table 2. Comparison of mean outcomes concerning grasping

Outcomes	Group A		Group B		Post-post comparison
	Before	After	Before	After	
Handgrip strength (kg)	2.65 ± 0.51	3.91 ± 1.3	2.55 ± 0.54	5.09 ± 1.12	0.002
*p**	0.03		0.017		
Age equivalent (months)[a]	14.83 ± 3.42	25.47 ± 6.24	16.6 ± 4.17	33.57 ± 8.62	0.0226
*p***	0.002		0.002		

* $p < 0.05$ is statistically significant. Paired/unpaired *t*-test.
** $p < 0.05$ is statistically significant. Wilcoxon signed-rank test / Mann-Whitney *U* test.
[a] Age equivalent for grasping in accordance with the Peabody Developmental Motor Scale – Fine Motor

While comparing post-treatment mean values between the groups, a significant difference was noted in all measured variables in favour of group B ($p < 0.05$), as depicted in Table 2.

Discussion

The concept of treatment in chronic cases should be directed toward function as the chances for recovery are less. Neurodevelopmental disorders, especially CP, interfere mainly with motor function. Most of these deficits may affect the child's motor development.

CP patients do lack motor planning and execution of the motor task. Motor dysfunction in CP is usually associated with weak muscular contractions, disabilities in sensory consolidation and stability, and weak or absent motor planning, which is the prerequisite of a motor task execution [11].

With reference to the upper limbs, some evidence showed, by evaluating precision grip or complex reaching and grasping actions and motor dexterity, that also the hand considered not affected presented some deficits [12, 13].

The synergic hand is characterized by a stereotyped grasping that shows flexion and extension synergies and servomotor movements in the releasing action [14]. In addition to movement execution and sensory impairments, individuals with unilateral spastic CP have impairments in motor planning, which can also affect grasping [15, 16].

Priming can be categorized as a restorative intervention that reduces impairment by targeting underlying neural mechanisms in neurological disorders [17].

One of unilateral priming approaches is known as cross-training, a strength training paradigm in which one limb is trained to strengthen the opposite one. We have not found any literature that describes the impact of cross-training as a priming technique. However, strengthening and facilitation techniques to the less affected side during therapy with individuals with neurological impairment have been previously used in physical therapy and occupational therapy. Proprioceptive neuromuscular facilitation may start with manual facilitation and strengthening techniques (also termed irradiation) of the less affected side to prime the nervous system before training the affected side [18].

Neural mechanisms mediating motor priming vary across the priming methods. However, they may produce similar effects, including increased excitability or normalized inhibition, which concur with improvements in motor behaviour [19].

The mechanisms by which exercises enhance brain function are unclear. One potential mechanism is the increased expression of brain-derived neurotrophic factor, which supports the survival of existing neurons and promotes growth and differentiation of new neurons and synapses [20].

Resistance training with cross-training or cross-education techniques has been reported to strengthen homologous muscles [21] and increase cortical drive [22]. Carroll et al. [23] contended that cross-training techniques might be mediated by both spinal and supraspinal mechanisms.

Improper use of the upper extremity and physical inactivity are considered as main factors affecting its function owing to moderate to severe functional limitations and abnormal muscular activities in the form of abnormal patterns of co-contraction. As a result, functional limitations will increase in addition to developing irregularities in skeletal maturation, leading to propagation of deformities.

Motor control of hand has been quantified for more than 2 decades by examination of fingertip forces during precision grasping. Fingertip coordination in typically developing children generally approximates adult coordination by 6–8 years of age [16]. Therefore, choosing ages of 5–7 years seems appropriate to enhance the developmental process.

Currently, strengthening exercises have been added to physical therapy programs for children with CP as they focuses on improving sensory input through stimulation of deep sensation, as well as muscular outputs. Recently, motor-based priming has been studied in different ages as its mechanism depends on promoting the firing of neural circuits which will enhance motor performance. The present study aimed to investigate the effect of unilateral movement-based priming in the form of cross-training on grasping in children with unilateral spastic CP.

A hand-held dynamometer is indispensable in measuring handgrip strength in clinical practice, with many proofs of its validity and reliability. So, it was used in the current study; the tests were performed by a specialist blinded about the study.

Evaluation of any developmental outcome in paediatric physical therapy depends on its practice. So, PDMS-FM was used in the assessment as it concerns the development of grasping.

The results of the current study revealed changes in handgrip strength and age equivalent for grasping. Significance was apparent when comparing pre- and post-treatment results of groups A and B and when comparing post-treatment results of both groups in favour of group B, which involved cross-training in addition to an occupational therapy program.

The management of CP children, to optimize functional abilities, typically includes the input of many disciplines, e.g. occupational therapy. The main goals of occupational therapy are to increase functional abilities and to promote social participation and well-being [24]. Repetition of movements, visual integration, and short-term memory could be motivators for motor ability, regardless of whether the targeted side is the dominant or the non-dominant one [25].

There are 2 different mechanisms by which force-generating capacity could increase in the untrained, opposite limb. First, unilateral strength training could cause neuromuscular adaptations in the control system for the trained limb that can be accessed by the opposite limb. And second, unilateral strength training could cause a 'spillover' of neural drive to the untrained side that induces adaptations in the control system for the opposite limb. These alternatives may not be mutually exclusive, and adaptations from both mechanisms may be involved in the effect [23].

The current study results may also be attributed to the induced motor neuronal firing at a segmental level owing to the application of strengthening exercise before the intervention program received by the experimental group.

Limitations

This study had some limitations. It was restrained to one type of CP in addition to a limited range of age. This inclusion criterion, however, was aimed to avoid variation in results. Also, the study was limited to one fine motor developmental outcome, grasping.

Conclusions

On the basis of the previous discussion of the results, it could be demonstrated that unilateral motor priming through cross-training is effective in improving grasping outcomes of the affected upper extremity concerning strength, development, and quality in children with unilateral spastic CP.

Further investigations are required with different types of CP, different types of motor-based priming types, a larger sample, different follows-up, different age groups, as well as different assessment tools.

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Disclosure statement

The author does not have any financial interest and did not receive any financial benefit from this research.

Conflict of interest

The author states no conflict of interest.

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