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Effect of contralateral isokinetic training on strength and reaching skill in children with spastic hemiplegic cerebral palsy: randomized control trail

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ABSTRACT

Background: Hemiplegic cerebral palsy (CP) occurs as a result of injury to the sensorimotor cortex that controls one side of the body. It affects one side of the body, including the limbs, trunk, and potentially the neck. The ability of hemiplegic children to reach, hold, and manipulate objects with their hands is one of their biggest challenges. ***Purpose:*** The study aimed to identify how cross-education affected the activity and function of the affected upper limb in children with spastic hemiplegic cerebral palsy. Additionally, it aimed to determine the effect of contralateral isokinetic resistance training on strength in children with spastic hemiplegic cerebral palsy. ***Methodology:*** Thirty two spastic hemiplegic cerebral palsied children aged from 5 to 7 years participated in this study. They were assigned randomly into two equal groups: Control group (A) received a designed physical therapy program for 60 min / three sessions per week and study group (B) received the same designed physical therapy program given to control group (A) in addition to isokinetic resistance training for the shoulder abductors of the contralateral upper limb in concentric mode at the angular velocity of 180 degree/ second. The concentric isokinetic shoulder abductors peak torque in Newton- meters and average power were assessed by isokinetic dynamometer apparatus. The ability of the child to perform the reaching skills was assessed by the Modified Functional Scale for Reaching. All variables were assessed before and after two successive months of intervention.

Results: The results revealed significant improvement in the shoulder abductor torque, power average and reaching in both groups with favor of study group (B). ***Conclusion:*** Adding contralateral isokinetic training to the designed physical therapy program is effective for improvement of strength and reaching skill in children with spastic hemiplegic cerebral palsy.

Keywords: Contralateral isokinetic training, strength, reaching, hemiplegia, cerebral paly

1. Introduction

Hemiplegic cerebral palsy (CP), occurs as a result of injury to the sensorimotor cortex that controls one side of the body. It affects one side of the body, including the limbs, trunk, and potentially the neck. The upper limb is significantly more affected than the lower limb, and ambulation frequently makes the lower limb's involvement more obvious **(Hary et al., 2020)**. Spastic hemiplegia affects about 13% of all children with cerebral palsy **(Jonsson et al., 2019).**

The ability of hemiplegic children to reach, hold, and manipulate objects with their hands is one of their biggest challenges. Most of daily tasks as clothing, eating, grooming, and handwriting, are affected by these issues. The use of the upper extremities is crucial for performing large motor tasks as crawling and walking. It is also essential for regaining equilibrium and defending the body against falls **(Bax et al., 2014).**

Hand function is significantly compromised in children with hemiplegic CP. As a result, children with hemiplegic CP typically find it difficult to use the affected upper extremity. It is a must for CP children to learn how to do tasks using their non-involved upper extremity (developmental disuse). Because of the brain damage brought on by CP, this lack of use might lead to even more deficiencies **(Klingels et al., 2012).**

Skilled hand movements including reaching typically do not develop well in spastic hemiplegic CP children, which makes it difficult for them to do numerous everyday tasks like dressing and eating. Recent researches evaluated the reaching abilities of children with cerebral palsy (CP) revealed that these kids displayed longer reach durations and more segmented movement trajectories, both when reaching with the affected side and with the dominant arm, in comparison to children who were typically developing **(Arnould et al., 2014).**

Scripture et al., (1894) originally described the inter-limb phenomena known as "cross education" or the "cross-training effect". **Mastalerz and Sadowski., (2020)** described how unilateral resistance training causes the opposing, untrained limb's capacity to increase its generated force

Cross education is a phenomena where long-term unilateral motor actions influence both the strength of the trained muscle group and the strength of the unexercised contralateral muscle group. Exercise of the contralateral limb consistently elicited electromyographic (EMG) activity in the homologous muscles of the affected limb, according to research on hemiplegic patients, which improved the function of the affected muscles (**Paillard., 2020**).

Muscle performance can be evaluated objectively using isokinetic in a secure and accurate manner. Isokinetic testing is valid, dependable, and repeatable evaluation method (**Ellenbecker and Davies., 2000).** It is beneficial in boosting muscular strength with muscles contracting at a consistent rate over the full range of joint motion. Its workouts can be carried out concentrically (muscles shorten during contraction) or eccentrically (muscles extend during contraction) **(Richardson et al., 2007).**

The goal of the study was to identify the effect of cross-education on the activity and function of the affected upper limb in children with spastic hemiplegic cerebral palsy. Additionally, it aimed to determine the effect of contralateral isokinetic resistance training on strength of shoulder abductors in children with spastic hemiplegic cerebral palsy

2. Material and methods

2.1. Design ad sitting

A randomized controlled trial was carried out at the outpatient Physical Therapy clinics, Faculty of physical therapy, Cairo University, Egypt with an ethical code stated in Helsinki Declaration 1975. It was

conducted between May 2022 and January 2023. Our study had registration number: NCT05718388, which was found on Clinicaltrials.gov.

2.2. Procedures:

Ethical considerations

The procedures had ethically approved by ethical committee board approval of the Faculty of Physical Therapy, Cairo University before performing the study. A consent form was obtained from all parents of participated children. All parents received a brief explanation of the examination and treatment processes before signing an informed permission form. "In addition to reading the study myself, I've also had it read and explained to me. When I've had the possibility to inquire about it, I've always gotten good responses. I voluntarily agree to have my child participate in this study".

Sample size calculation

Sample size calculation: G*Power (version 3.1.9.2; Germany) was used to compute the sample size a priori, using these values and our assumption (alpha= 0.05, power= 0.8 and effect size =0.75). As a result, the total estimated sample size for hemiplegic cerebral palsied children was 29 children, increasing by almost 10% to 32 patients, when the dropout rate from the time of randomization to the end of the treatment protocol was taken into account.

Subjects

Thirty two spastic hemiplegic CP children were selected from the outpatient clinic of Faculty of Physical Therapy, Cairo University. They were referred from pediatric neurologist as having spastic hemiplegia. After screening, the selected children were from both genders, their age ranged from five to seven years, they had mild to moderate spasticity according to the Modified Ashworth Scale, they were able to follow verbal instructions and they were able to stand unassisted and walk with abnormal pattern. Children who had any visual or auditory problems, fixed deformities in the affected upper limb that interfere with fine motor functions, history of any surgical interference in upper limbs for less than one year, and un-cooperative children were excluded.

Randomization

Forty seven hemiplegic CP children were evaluated for eligibility; six children were excluded because they failed to fulfill the inclusion criteria and nine parents refused to participate in this study. As a result, 32 hemiplegic cerebral palsied children were included in this trial **Figure (1).** They were assigned randomly into two equal-sized groups using random allocation software to reduce selection bias **(Saghaei, 2004).** The group control group (A), received a designed physical therapy program and the study group (B) received the same designed physical therapy program as group (A) in addition to isokinetic resistance training for the contralateral upper limb.

2.3. Outcomes:

At the baseline evaluation and two months following the intervention, all children were evaluated for the following outcomes:

Primary outcome: Concentric isokinetic shoulder abductors peak torque in Newton- meters and average power.

Isokinetic dynamometer was used to measure the concentric isokinetic shoulder abductors peak torque in Newton- meters and average power. The device was calibrated before the test, and the test protocol's fundamental input parameters, movement speed and contraction mode, were established. The test was

conducted at an angular velocity of 180 degrees per second in concentric mode with gravity adjustment. Each child was seated with his back erect and supported at a 90-degree angle between the trunk and the hip joint. A large strap was placed diagonally across the trunk to reduce body movement during testing, the start angle was calculated by moving the lever arm and limb to an angle of 0 degrees of shoulder adduction before the test began. The range of motion (ROM) was then set up. As the lever arm and limb were moved to a 90-degree shoulder abduction angle, the stop angle was computed. During the testing processes, the rotating axis of the dynamometer was positioned to be coaxial with the shoulder axis by adjusting the lever arm attachment length, chair back, and arm pad height. The testing protocol included three maximum trails, followed by a one-minute break. The greatest peak torque value was measured during these three trails **Figure (2)**.

Secondary outcome: Modified functional scale for reaching.

It was used to measure the ability of the child to perform the reaching skills and to determine the level of performance and functional improvement in reaching skills. Each child was seated in chair with hips, knees and ankles were positioned at a 90-degree flexion and, with feet positioned flat on the floor. The test was performed with a leveled yardstick that was mounted on the wall at the height of the child's acromion level while sitting in a chair. The test measured the maximum distance the child can reach forward with from sitting position with the upper extremity flexed to 90 degrees, while maintaining a fixed base of support in the sitting position. **(Marchesi., 2022).**

2.4. Intervention:

The control group (A):

Children in this group underwent a designed physical therapy program for 60 min, three sessions per week for two consecutive months: This physical therapy program was based mainly on the neurodevelopment technique and directed toward strengthening of upper limb muscles and improvement of normal patterns of postural control (righting, equilibrium and protective reactions). These adaptable motor patterns were used as a basis for the development of skilled functional. They also received hand functions training program aiming to improve hand functions (reaching, grasping, manipulating objects in one hand, transfer objects between hands, and release)

The study group (B):

Children in this group received the same designed physical therapy program given to the control group (A) in addition to isokinetic resistance training of the contralateral upper limb for shoulder abductors in concentric mode at the angular velocity of 180 degree/ second applied three times per week for 8 weeks, making a total of 24 training sessions. Each session included three sets of eight maximal repetitions. Each child was trained in sitting position with the similar precaution of the testing protocol.

2.5. Statistical analysis:

Statistical Package for the Social Sciences (SPSS) software version 22 was used to analyze the data in this study. Descriptive statistics were used to calculate the mean and standard deviation of each variable. A Chi-square test was used for comparison between two groups in age and gender. Paired t-test was done to compare the pre and post treatment results for each group to determine the effect of each intervention. Independent t-test was used to compare the pre and post treatment results for the study group with the control group. All statistical results were significant when ($P < 0.05$).

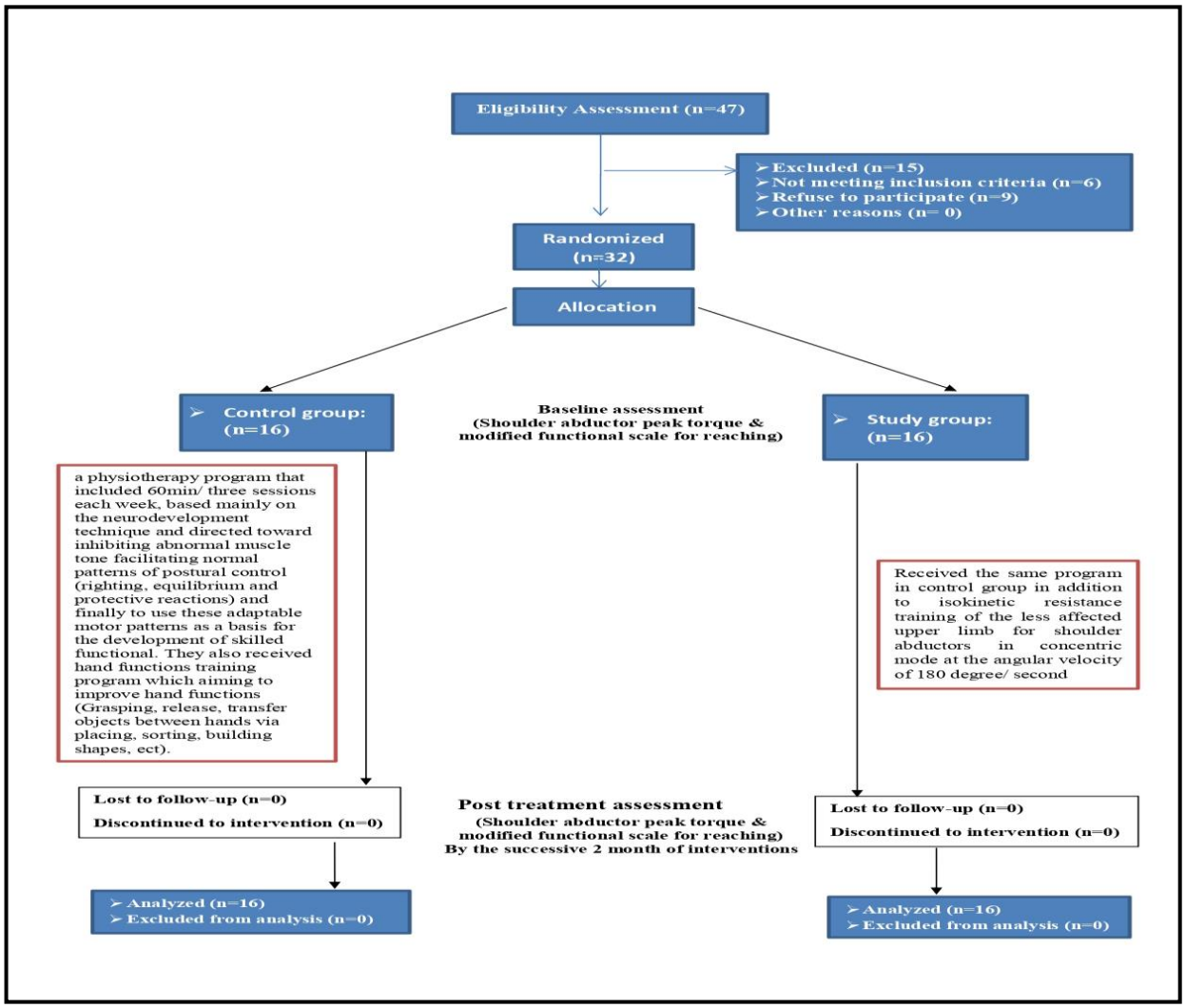

Figure (1): Flow chart

Figure (2): Biodex isokinetic dynamometer

Results

Children characteristics

Table (1) shows the characteristics of children, including age, gender, and degree of spasticity. Children characteristics between both groups did not differ significantly ($p > 0.05$).

Table (1): Comparison mean values of demographic data between two groups.			
Variables	Conrol Group (A) (n=16)	Study Group (B) (n=16)	P-value
Age (Year)	5.933 ± 0.729	5.867± 0.812	0.565
Gender (M/F)	8/8	9/7	0.786
Frequency distribution of affected side (RT/LT)	8/8	9/7	0.786
Degree of spasticity (1/1+)	7/9	8/8	0.875
Numerical Data are expressed as mean ± SD or number (%) P-value>0.05: non-significant			

Concentric isokinetic shoulder abductors peak torque and average power.

There was no statistically significant difference between the pre-treatment groups mean values of the concentric isokinetic shoulder abductors peak torque and average power ($P > 0.05$). There was a significant improvement in the concentric isokinetic shoulder abductors peak torque and average power in the study group after treatment compared with the control group after treatment ($P < 0.05$), **(Table 2)**.

Table (2): Comparison for concentric isokinetic shoulder abductors peak torque and average power within and between both groups.					
Variables		Groups (Mean ±SD)		t-value	P-value
		Control group (n=16)	Study group (n=16)		
Shoulder peak torque	Pre-treatment	5.92±0.972	5.807±2.857	0.145	0.885
	Post-treatment	6.58±0.787	13.173±1.808	12.95	0.0001*
	t-value	4.117	8.13		
	P-value	0.0001*	0.0001*		
	Effect Size (Cohen's d)	1.03	2.03		
Shoulder average power	Pre-treatment	1.11±0.489	1.54±1.14	1.328	0.1949
	Post-treatment	1.62±0.486	6.63±2.3	8.25	0.0001*
	t-value	6.68	7.53		
	P-value	0.0001*	0.0001*		
	Effect Size (Cohen's d)	1.67	1.88		
SD: standard deviation P-value: probability value * significant (P-value < 0.05)					

Modified functional scale for reaching.

There was no statistically significant difference in the pre-treatment mean values between the two groups in the modified functional scale for reaching ($P > 0.05$). There was a significant improvement in the concentric modified functional scale for reaching in the study group after treatment compared with the control group after treatment ($P < 0.05$), **(Table 3).**

Table (2): Comparison for modified functional scale for reaching within and between both groups.					
Variables		Groups (Mean ±SD)		u-value	P-value
		Control group (n=16)	Study group (n=16)		
Modified functional scale for reaching	Pre-treatment	1.667±0.488	1.60±0.507	105	0.766
	Post-treatment	1.80±0.56	2.733±0.457	29.5	0.0006*
	w-value	3.0	120		
	P-value	0.0001*	0.0001*		
SD: standard deviation P-value: probability value u-value: Mann-Whitney test value w-value Wilcoxon test value * significant (P-value < 0.05)					

Discussion

The study aimed to identify how cross-education affected the activity and function of the affected upper limb in children with spastic hemiplegic cerebral palsy. Additionally, it aimed to determine the effect of contralateral isokinetic resistance training on shoulder abductors' strength in children with spastic hemiplegic cerebral palsy. The present study included spastic hemiplegic CP children, which constitute a major type among spastic CP types. Spastic hemiplegia accounts about one third of all spastic CP cases as a result of unilateral brain lesion (**Chabrier et al., 2010).**

Hand skills are vital to the child's interaction with the environment. Engagement in most occupations requires object handling, almost all of which is accomplished with the hands. Usually greater impairment of hand use results in the need for increased adaptations if the child is to develop daily life skills. Children with a wide variety of disabilities are likely to have difficulty with hand function. These disabilities include cerebral palsy (**Fedrizzi et al., 2003 and Golding et al., 2014).**

The majority of children with spastic hemiplegia had a wide range of impairments in the function of the arm and hand. They may exhibit a delay in the development of a variety of motor abilities, such as the fine motor skills due to spasticity and motor weakness. Poor tactile discrimination and/or further muscular weakness have all been proposed as contributing factors to problems with force modulation in cerebral palsy patients **(Mutsaarts et al., 2005 and Bax et al., 2005).**

In the present study, the Biodex isokinetic dynamometer was used as an objective tool for evaluation of muscle performance and muscular activity. The isokinetic dynamometer is widely used to assess and improve muscle function for both rehabilitation and training purposes (**ZBM et al., (2020).** It has been used for strength testing and training in clinical settings. It is also safe to use with children because there is minimal risk of muscle and joint injuries (**Purkayastha et al., 2006).** The unique features of isokinetic dynamometry are optimal loading of the muscles in dynamic conditions and constant preselected velocity of movement. These features provide safety in the rehabilitation of patients with muscular and ligamentous injuries **(Findley et al., 2006)**.

The pre treatment measures of the strength and reaching skill using average power and peak torque parameters of shoulder abductors and Modified Functional Scale of Reaching obtained from both groups revealed non-significant difference between groups. The pre treatment mean values of strength for the control and study groups indicated weakness of shoulder abductors in children with spastic cerebral palsy.

Muscle weakness is a primary impairment in the children with CP **(Bartlett and Palisano 2002).** It is a significant impairment in the children with CP, which needs decreasing the amount of weakness through strengthening activities **(Damiano et al., 2002).** The impaired upper limb function in spastic hemiplegic children is considered the main factor contributing to decreased activity and participation in everyday activities of daily living (ADL) **(Sterr et al., 2002 and Fedrizzi et al., 2003).**

The results of the present study revealed significant increase in the peak torque and average power of shoulder abductors of both control and study groups, when comparing their pre and post treatment mean values. However, more increase in peak torque and average power of shoulder abductors with significant difference was noticed in the study group when comparing the post-treatment mean values of the study group with the control group.

The findings of this study came in agreement with **Carroll et al (2006)** who concluded that contralateral isokinetic training increased strength, by an average of 7% of initial strength, or about one-quarter of the increase in strength on the trained limb.

The improvements in strength can occur with training with high-force contralateral voluntary contractions or even with mental rehearsal of a contralateral task **(Evetovich et al., 2001**) and **(Munn et al., 2004)**. Choosing training at a fast velocity in this study, came in agreement with **Zhou., (2000**) who reported that training at high velocity is most beneficial for increasing torque of the trained and untrained arms.

The level of cross training may be related to the amount of change in strength of the trained limb. This also came in agreement with **Farthing and Chilibeck., (2003)** who confirmed that cross-education was greatest with the most unfamiliar type of training (fast-velocity training) which indicates that learning may play a large role in cross-education. This is also supported by the observation of **Munn et al., (2005)** who reported that training at higher speeds produce a greater contralateral effect than training at lower speeds. Increasing strength on the contralateral side may be related to the greater magnitude of strength gained in the trained arm when training at faster speeds.

The significant improvement in the peak torque and average power of shoulder abductors in spastic hemiplegic CP children may be attributed to the effect of cross education **(Teixeira and Caminha (2003).** A number of mechanisms at different levels of the nervous system have been proposed for causing the phenomenon of cross-education **(Hortobagyi et al., (2003).** Voluntary muscle contraction can acutely change the contralateral motor pathway. During unilateral voluntary contractions there is an activation in the contralateral hemisphere and ipsilateral sensory and motor cortical areas.

This also came in an agreement with **Zhou., (2000)** who reported that candidate's mechanisms include diffusion of impulses between cerebral hemispheres, co-activation of bilateral corticospinal pathways or learning in co-ordination during unilateral training. All of these possible mechanisms would involve recruitment of untrained musculature during training of the opposite limb.

The results of the study group at the end of treatment revealed a statistical significant improvement in reaching skill, which can be attributed to the improvement in muscular strength. These results agreed with **Oskoui et al., (2003)** who confirmed that strength training programs improve the functional level of both upper and lower extremities in children with cerebral palsy.

Also, these results came in agreement with **Cook and Woollacot., (2001),** who stated that normal upper extremity functions including the ability to reach for grasp and manipulate objects, are the basis for fine motor skills which are important to activities of daily living such as feeding, dressing, grooming and handwriting. They reported that the upper extremity control is intertwined with both fine and gross motor skills.

The significant improvement that was observed and continued by the statistical analysis of the mean values of the measuring variables of the control group may be attributed to the combined effects of the specially designed physical therapy program to strength shoulder abductors and the neurodevelopmental approach. This came in agreement with **Spearing et al., (2021),** who stated that the ultimate goal of neurodevelopmental treatment for the cerebral palsied child is to have the best possible function. Treatment sessions were directed toward a functional task. This could be achieved by conducting preparatory work to enable the child to perform the task. Initially, facilitated and guided movement were needed to decrease or prevent abnormal compensatory movement. Then, Feed forward was developed as the child actually practices the skill or task with the therapist’s guidance.

Also, the results came in agree with **Rameckers et al., (2015),** who concluded that strengthening exercises program is effective to influence the development and acquisition of functional skills in spastic hemiplegic cerebral palsied children.

Conclusion

From the previous results it can be concluded that adding isokinetic cross training to the designed physical therapy program can be an effective modality for improving strength and reaching function in spastic hemiplegic CP children. This helped the hemiplegic CP children to use their affected upper limb so increasing their opportunity to receive sensory information from the environment and improving their performance in their daily living activities.

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Disclosure

The authors declare that there is no financial conflict of interest with regard to the content addressed.

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