



Effect of Core Stability Exercises on Hand Functions in Children With Hemiplegic Cerebral Palsy

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Objective To investigate the effectiveness of core stability exercises on hand functions in children with hemiplegic cerebral palsy.

Methods Fifty-two children with hemiplegic cerebral palsy ranging in age from 6 years to 8 years were enrolled in this study. They were randomly assigned to two (control and study) groups. The control group received the selected physiotherapy exercises, and the study group received the same selected physiotherapy exercise program and core stability exercises. Time motor performance, gross manual dexterity, and upper extremity skills assessed using the Jebsen Taylor Hand Function Test, Box and Block Test, and Quality Upper Extremity Skill Test, respectively, were measured before and after 12 weeks of the treatment program.

Results There were significant improvements in both groups by comparing the mean values of all measured variables before and after treatment ($p < 0.05$). There were significant differences between the control and study groups with respect to all measured variables when comparing the post-treatment outcomes ($p < 0.05$).

Conclusion This study suggests that core stability exercises can be an effective intervention that may improve hand functions in children with hemiplegic cerebral palsy.

Keywords Hemiplegia, Cerebral palsy, Children, Hand, Core stability

INTRODUCTION

Children with hemiplegic cerebral palsy (CP) have an upper limb impairment, which can influence the capacity to perform and participate in activities of daily living (ADLs). This impairment results from spasticity, im-

paired sensation, and reduced strength. Consequently, the functional ability of the upper limb is often compromised [1]. Lesions in the sensorimotor cortex and corticospinal tract result in unilateral prehensile dysfunction. These children regularly have unpredictable patterns of prehension, weakness, spasticity, incomplete fraction-

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ation of fingers, and sensory disturbance. Children with hemiplegic CP have impaired fingertip force control and timing during object manipulation [2].

The manipulative actions and fine motor skills in typically developing children improve rapidly during the first years of life, with subsequent refinement occurring throughout childhood [3].

Children with hemiplegia may have debilitating symptoms affecting play, education, and self-care. In addition, children with hemiplegic CP barely use the affected hand to perform unimanual activities. The affected hand is typically used when bimanual task performance is required [4]. There are several traditional approaches, such as the use of modalities, splinting, casting, passive stretching, and promoting posture and mobility of the upper limbs of children with hemiplegic CP, with the goal of decreasing muscle tone and spasticity, enhancing the range of movement of the affected limb, and improving the functional use of the limb [5].

“Core stability” describes the ability to control the position and movement of the central portion of the body. Core exercise is directed to the deep muscles inside the abdomen that connect with the spine, pelvis, and shoulders to maintain good posture, thus providing a foundation for extremity movement. Spinal stability is important for movement development and depends on the core muscles to achieve adequate strength, power, and endurance [6].

Components of core stability include strength, endurance, balance, and related back, abdominal, and pelvic muscle activities [7,8].

The effectiveness of postural control and body center on fine manual dexterity is a common assumption. The neuromuscular system is closely linked to almost all centers of the central nervous system that regulate muscle tension (tone), process sensory information, and organize motor responses. The pyramidal system transmits “action plans” originated from the cortical motor areas and controlled the complexity of voluntary movements and versatile maneuvers of upper extremities [9].

It is essential to incorporate methods that can maximize the use of the affected extremity. Thus, the aim of this study was to investigate the influence of core stability exercises on hand functions in children with hemiplegic CP.

MATERIALS AND METHODS

Study design

A randomized, single-blind, controlled clinical trial was conducted at the Faculty of Physical Therapy outpatient clinic, Badr University in Cairo.

Participants

Sixty children with hemiplegic CP were recruited for

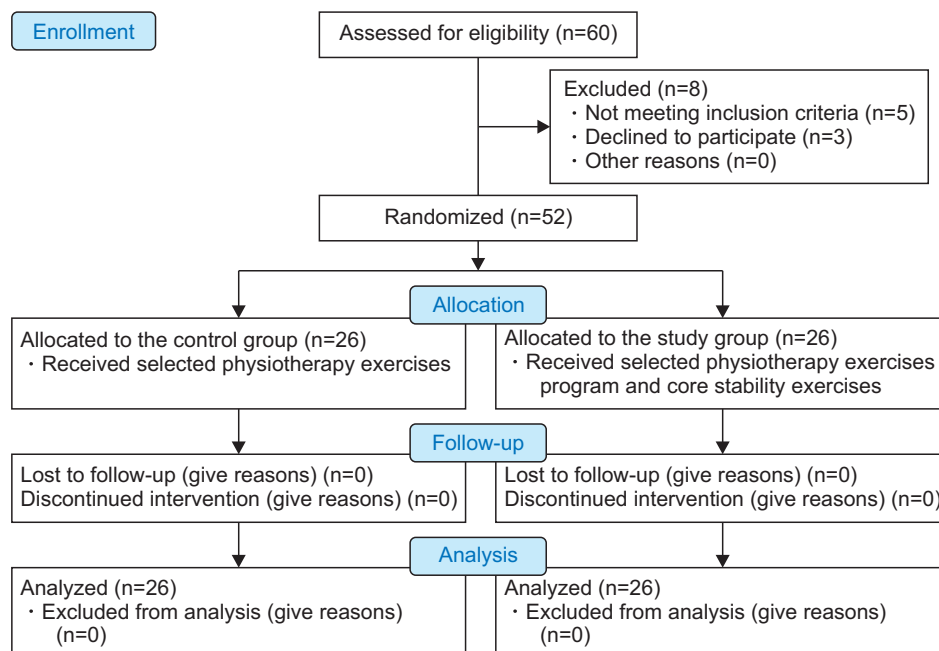


Fig. 1. Participant's flow diagram.

this study; five children did not meet the inclusion criteria, and the parents of three children refused to participate in the study. Following the baseline measurements, children were assigned randomly into two equivalent groups using closed envelopes. The therapist prepared sealed envelopes, which contained a piece of paper indicating whether each child was allocated to the control group or the study group. The experimental design is shown in the flow diagram in Fig. 1.

Fifty-two children with hemiplegic CP (35 boys, 17 girls) participated in this randomized controlled study. Children were included in this study based on the following criteria: age ranging from 6 years to 8 years, diagnosed with hemiplegic CP verified by magnetic resonance images obtained from medical documents, and mild spasticity of the upper limb (Modified Ashworth Scale grade 1 to 1+) [10]. The children were categorized as level I to II, according to the Gross Motor Function Classification System [11]. Also, these children were cognitively competent and able to understand and follow instructions. Some children were excluded from this study in the case of fixed contracture or deformities in the spine or extremities, visual or respiratory disorders, a history of orthopedic surgery on the affected limb, dorsal rhizotomy, botulinum toxin injection in the upper limb within the last 6 months, or planning to have one during the study period. Prior to data collection, the purposes, procedures, and benefits were fully explained to the parents of the participating children. This study was conducted in accordance with declaration of Helsinki guidelines for studies involving humans. This study was approved by the Ethics Review Committee of the Faculty of Physical Therapy, Cairo University (No. P.T.REC/012/002582). Prior to data collection, the purpose, procedures and benefits were fully explained to the parents of the participating children and the consent form was obtained.

Outcome measures

All procedures were performed at baseline (pre-treatment) and the end of 3 successive months of treatment (post-treatment) in a warm lighted and quiet room.

Jebsen Taylor Hand Function Test

The child sat in front of a table to conduct the Jebsen Taylor Hand Function Test (JTHFT), where the evaluation was carried out [12]. The test includes seven items.

All items except writing were tested: writing depends on the level of education and hand dominance and has low reliability [13,14]. Each trial was separated by 60 seconds to 90 seconds of break to minimize any potential fatigue. It took a maximum of 2 minutes (120 seconds) for each item to be completed. The shorter the time taken for the JTHFT, the more efficient the performance is [15].

Box and Block Test (BBT)

The child was sitting on an adjusted chair in front of a two-compartment box placed on a table containing 150 blocks. The child should place his/her hands on the sides of the box as preparation before the test begins. Following the instructions, the child was given a 15-second trial. The test includes grasping, moving, and releasing wooden blocks from one side to the other. During the test, the child should pick up only one block and transport it over the partition before he/she can place the block in the other compartment. The score was recorded for 1 minute as the number of blocks passed over the wooden partition [16].

Quality Upper Extremity Skill Test

The Quality Upper Extremity Skill Test (QUEST) was developed to specifically overcome the limitations of currently available measures of hand function. This measurement evaluates the quality of upper extremity skill function through 33 activity items of 4 domains: dissociated movement consists of 19 items, grasp consists of 6 items, weight-bearing consists of 5 items, and protective extension consists of 3 items.

It is designed for children who exhibit neuromotor impairment with spasticity and validated for children aged 18 months to 8 years. The test takes 30–40 minutes, and its scores range from 0 to 100 [17].

Intervention

All participants received the same selected physiotherapy program for the affected upper extremity, which consists of facilitation of postural mechanism; proprioceptive training, including weight-bearing activities for the upper and lower limbs; strengthening exercises for the back, abdominal muscles, ankle dorsiflexors, knee (flexors and extensors), and hip (flexors, extensors, abductors, internal and external rotators); standing exercises (standing holding on, standing alone with arms

free, standing holding on and asking the child to lift one foot, standing on one leg, standing on balance board); gait training in different directions at a different speed; and up and downstairs and jumping in place and broad jumping. This program was given for 1 hour with a rest period of 2 minutes between each group of exercises, 3 days a week for 12 weeks. The study group received additional core stability exercises, which consist of three levels. Each level took 4 weeks. The difficulty of each level varies in proprioception, balance, and stability as it started from exercising on a stable surface “mat” and ended with unstable surface “physioball”. The first simple level involves supine abdominal draw (3 sets per 20 repetitions), abdominal draw-in with a double knee to chest (3 sets/20 repetitions), and supine twist (3 sets per 20 repetitions). The second medium level involves pelvic bridging (3 sets per 3-5 repetitions) and twists with a medicine ball (3 sets per 10-20 repetitions). The third difficult level involves bridging with head-on physioball holding this position for 3-5 seconds, then slowly relaxing (3 sets per 10-20 repetitions), and prone bridging (3 sets per 3-5 repetitions). There was a 30-second rest between sets [18].

All participants were cooperative during treatment sessions, and the adherence rate was approximately 97%.

Sample size

The pre-study sample size calculation was performed based on a pilot study using G*Power statistical software (version 3.1.9.2; Franz Faul, University of Kiel, Germany) (F tests-MANOVA: repeated measures, within-between interaction measurements, $\alpha=0.05$, $\beta=0.2$, and large effect size) and revealed that $n=52$ was the appropriate sample size for this study.

Data analysis

A t-test was used to analyze subject characteristics between groups. Sex and affected side distribution were compared between groups using the chi-square test. The Shapiro-Wilk test was used to check the normal distribution of data, and Levene’s test for homogeneity was conducted to test the homogeneity between groups. Within and between groups, effects on subtests of JTHFT, QUEST, and BBT were investigated by mixed MANOVA. Multiple post-hoc tests were conducted using Bonferroni correction. A $p<0.05$ was the level of significance. SPSS software version 25 (IBM SPSS, Armonk, NY, USA) was

used for all statistical tests.

RESULTS

Subject characteristics

There was no significant difference between both groups in the subject characteristics ($p<0.05$) (Table 1).

Effect of treatment on subtests of JTHFT, QUEST, and BBT

There was a significant interaction between treatment and time (Wilks’ $\lambda=0.02$; $F_{(11, 40)}=159.86$, $p=0.001$, $\eta^2=0.97$). There was a significant main effect of time (Wilks’ $\lambda=0.003$; $F_{(11, 40)}=1234.97$, $p=0.001$, $\eta^2=0.99$). There was a significant main effect of treatment (Wilks’ $\lambda=0.02$; $F_{(11, 40)}=138.09$, $p=0.001$, $\eta^2=0.97$).

Within-group comparison

After treatment, there were significant improvements in the JTHFT subtest time and QUEST and BBT subtest scores in both groups compared to the pre-treatment results. There was a significant increase in the score of subtests of QUEST and BBT in the control and study groups post-treatment compared with the pre-treatment score ($p<0.001$) (Table 2).

Between-group comparison

Before treatment, there was no significant difference between groups in all parameters ($p>0.05$). After treatment, there was a significant decrease in the time of subtests of JTHFT of the study group compared with that

Table 1. Basic characteristics of participants

| | Control group | Study group | p-value |
|---------------|---------------|-------------|--------------------|
| Age (yr) | 6.89±0.75 | 7.00±0.67 | 0.60 ^{a)} |
| Weight (kg) | 25.84±1.07 | 26.15±1.63 | 0.42 ^{a)} |
| Height (cm) | 120.40±8.66 | 119.46±9.46 | 0.71 ^{a)} |
| Gender | | | 0.76 ^{b)} |
| Girl | 9 (34.61) | 8 (30.76) | |
| Boy | 17 (65.38) | 18 (69.23) | |
| Affected hand | | | 0.74 ^{b)} |
| Right | 19 (73.07) | 20 (76.92) | |
| Left | 7 (26.92) | 6 (23.07) | |

Values are presented as mean±standard deviation or number (%).

^{a)}Using a t-test, ^{b)}chi-square test.

Table 2. Subtests of JTHFT, subtests of QUEST, and Box and Block Test pre- and post-treatment of control and study groups

| | Pre-treatment | | | Post-treatment | | | p-value ^{b)} (pre vs. post) | |
|------------------------------------|---------------|-------------|-----------------------|----------------|-------------|-----------------------|---|-------------|
| | Control group | Study group | p-value ^{a)} | Control group | Study group | p-value ^{a)} | Control group | Study group |
| Subtests of JTHFT (s) | | | | | | | | |
| Turning cards over | 15.28±1.18 | 15.51±1.96 | 0.61 | 12.18±1.46 | 9.51±1.81 | 0.001 | 0.001 | 0.001 |
| Picking up small object | 22.36±1.24 | 21.81±1.77 | 0.19 | 18.69±1.11 | 11.44±1.59 | 0.001 | 0.001 | 0.001 |
| Simulated eating | 33.07±2.28 | 33.76±1.88 | 0.24 | 27.88±2.89 | 21.47±3.54 | 0.001 | 0.001 | 0.001 |
| Stacking checker | 16.73±1.06 | 16.32±1.19 | 0.20 | 13.49±1.91 | 9.25±1.45 | 0.001 | 0.001 | 0.001 |
| Moving light cans | 8.40±0.74 | 8.57±0.85 | 0.44 | 5.98±1.06 | 3.79±0.94 | 0.001 | 0.001 | 0.001 |
| Moving heavy cans | 9.21±0.76 | 9.09±0.83 | 0.59 | 6.23±0.66 | 4.27±0.88 | 0.001 | 0.001 | 0.001 |
| Subtests of QUEST | | | | | | | | |
| Dissociated movement | 75.89±1.16 | 75.65±1.82 | 0.56 | 84.41±1.82 | 87.21±1.33 | 0.001 | 0.001 | 0.001 |
| Grasp | 70.78±1.09 | 71.00±1.99 | 0.76 | 80.52±1.69 | 84.11±3.72 | 0.001 | 0.001 | 0.001 |
| Weight bearing | 80.44±0.79 | 80.49±0.83 | 0.83 | 91.06±1.61 | 93.41±1.96 | 0.001 | 0.001 | 0.001 |
| Protective extension | 50.94±2.32 | 51.58±1.89 | 0.28 | 85.37±3.29 | 66.04±2.64 | 0.001 | 0.001 | 0.001 |
| Box and Block Test (blocks/min) | 35.34±1.32 | 35.77±1.14 | 0.22 | 41.84±0.96 | 50.34±1.05 | 0.001 | 0.001 | 0.001 |

Values are presented as mean±standard deviation.

JTHFT, Jebsen Taylor Hand Function Test; QUEST, Quality Upper Extremity Skill Test.

^{a)}Between-group comparison, ^{b)}within group comparison.

of the control group ($p < 0.001$) and a significant increase in the score of subtests of QUEST and BBT in the study group compared with that in the control group ($p < 0.001$) (Table 2).

DISCUSSION

The current research has been carried out to investigate the effectiveness of core stability exercises on hand function in children with hemiplegic CP.

There was a significant impairment in motor function of the upper extremity performance in children with hemiplegic CP. The upper extremities of children with CP are commonly impaired to reach, grasp, move, release, and manipulate objects, which are crucial for the quality and performance of ADLs [19]. The limited ability in children with hemiplegic CP to interact with people and the environment restricts involvement and participation. Motor dysfunction in children with CP induces the impairment of physical activity and lack of general experience [20,21].

This study highlights the potential influence of core stability in relation to hand skills in children with hemiple-

gic CP.

The results of the current study revealed that there was significant improvement in control and study groups regarding JTHFT, BBT and QUEST compared with the pre-treatment results. These findings support that integration of core exercises in hemiplegic patients along with traditional exercises can enhance the upper extremities functions [22].

This comes in accordance with the study that found a significant correlation between the movement of the upper limb and trunk control as the improved upper limb movement was associated with improved trunk control and stability [23].

The study group after the 3 months of treatment showed significant improvement in JTHFT, BBT and QUEST which could have been attributed by the effect of core exercise in improving the upper limbs functions. These findings support that posture maintenance and trunk stability is needed in children with CP in order to perform hand motions in playing and eating [24].

Physiological activations of the core muscles result in several biomechanical effects allowing efficient lo-

cal and distal function. Core muscle exercises result in anticipatory postural adjustments, which position the body to withstand balance disturbance created by the kicking, throwing, or running forces [25]. Core stability is a dynamic process in which optimum muscle capacity is required and neuromuscular control that can quickly integrate sensory input and adjust motor responses relative to internal and external input [26]. Moreover, training the core musculature on an unstable surface (e.g., physio-ball) improves the balance, stability, and proprioceptive capabilities. This gives a consistent feedback about the interactions between the body and the environment and permitting the precision of movement [27].

Significant improvement of hand functions reported in this study may be attributed to the internal and external sensory input which plays a crucial role in motor rehabilitation. Also, it can be attributed to anticipatory postural adjustments that developed with core stability exercises that create the proximal stability for distal mobility.

Core muscles play an important role in the stability as well as mobility of the body parts in preserving balance, improving the upper and lower limb's mobility against gravity; thereby facilitate the functioning of the arms and legs [28-30].

Core exercises improve trunk stability to enhance upper limb efficiency as improving proximal stability will improve distal mobility. Core exercises improved upper limb function in relation to skilled motor behavior and postural sway [31]. This comes in agreement with a previous study, which reported that proximal activation of the core muscles provides either maximum force at the distal end, similar to whip cracking, or provide precision and stability to the distal end. For instance, maximum internal rotation force of the shoulder to rotate the arm is generated by the interactive moment of trunk rotation [32].

On the other hand, the results of this study come in disagreement with another study that reported that the core muscle exercise had no obvious effect on enhancing upper limb function as compared to conventional physical therapy. This difference in results may be due to insufficient duration of exercise. Six weeks of core stability exercises may not be enough to produce significant improvement in muscle strength that appears in comparison between groups and not enough to produce a change in upper limb function, as the rate of gain from exercises may not be evident [33].

This study was limited by the lack of direct measurement of core and hand muscle strength. There was no follow-up of the children to ensure the long-term maintenance of the improvement.

Future studies should investigate the long-term effects of core stability programs for children with CP.

In conclusion, the obtained results demonstrate that core exercises help to improve hand functions in children with hemiplegic CP.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Abd-Elfattah HM, Aly SM. Methodology: Abd-Elfattah HM. Formal analysis: Aly SM. Writing – original draft: Abd-Elfattah HM. Writing – review and editing: Abd-Elfattah HM, Aly SM. Approval of final manuscript: all authors.

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