Effect of core stability exercises program on walking performance in children with diplegic cerebral palsy: A randomized control study.

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Abstract

Background: Children with cerebral palsy have poor axial control which affects their walking capabilities. Although there are limited studies that demonstrate core stability training in cerebral palsy.

Purpose: This study was conducted to examine the Effect of core stability exercises program on walking performance in children with diplegic cerebral palsy.

Methods: Thirty children with spastic diplegia from both genders enrolled in the study; their ages ranged from seven to ten years, were able to ambulate (Level II or III GMFCS), had no convulsions and had no history of surgical interference in the last 6 months. Children who had any fixed contractures or convulsions were excluded from this study. They were assigned randomly into two groups of equal numbers. The control group A received the regular physical therapy program according to the neurodevelopmental approach. And the study group B received the regular physical therapy program according to the neurodevelopmental approach besides core stability exercises program. The clinical assessments performed in this study included a measure of endurance Energy Expenditure Index (EEI) and a functional gait measure (GMFM scores; walking, running and jumping item).

Results: There were significant improvements in the measured variables in the study group B and significant difference between post treatment mean values (P<0.05) in favor to group B.

Conclusion: Core stability exercises program can be used to improve walking performance and lower the energy expenditure in children with diplegic cerebral palsy.

Keywords: Core stability, Walking, Energy expenditure, Diplegia, Cerebral palsy.

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Introduction

Spastic diplegia is amongst the most widely recognized clinical subtypes of Cerebral Palsy (CP). It represents about 44% of the total occurrence of CP. It is used when the motor impairment is milder in the upper limbs than the lower limbs. Most children have major weakness in the trunk and hypertonic limbs [1]. Spastic diplegia is characterized by increased muscle tone with difficulty in relaxing. Active movements are slow and stiff with abnormal patterns. Lower limbs are more affected than upper limbs. Head and neck are unaffected but there is weakness and limited rotation of the trunk [2].

Different ways of locomotion have been accounted in walking diplegic children. These motor behaviors are characterized by limited mobility in their lumbar spine, pelvis, and hip joints and show limited asymmetric pelvic tilt or pelvic rotation during gait. Many of these children walk with flexed hips, knees and ankles this gait pattern, known as crouch gait. Crouch gait is due to increased activity or tightness of the hamstrings [3].

Walking even with assistance in children with CP is needed for contribution in daily living activities and for their physical development. Proportionate to children who use wheelchair, walking children with CP are more skilled in their daily living activities in addition to dealing with normal children. As well, muscle action and weight acceptance during walking augment bone mass and can decrease the possibility of hip subluxation or dislocation. Other gains from ambulation are increased cardiopulmonary fitness and obesity prevention [4].

The term of “core stability” explains the capacity to control the position and movement of the central portion of the body. Core stability training targets the muscles deep within the abdomen that attach to the spine, pelvis and shoulders, that help in the preservation of proper posture and provide the basis for movements of extremities in a coordinated manner. Spinal stability is essential for the production of movement and relies on the core muscles to acquire sufficient strength, power, and endurance [5].

The core has illustrated by researchers as a “power-house” for initiating limb movement or as a double-walled cylinder or box in which the abdominals act as the front of the house, the paraspinals serve as the back, the diaphragm serves as the roof, and the musculature of the hip girdle and pelvic floor create the 2 basement of the house [6,7]. The Energy Expenditure Index (EEI) represents a ratio of resting and walking heart rate to walking velocity and results in units of beats per meter [8] and has been used as an indicator of energy expenditure for children with cerebral palsy in past research [9,10].

Heart rate is an easily measured parameter. Although heart rate may be affected by factors other than oxygen uptake, it has been shown to be an accurate and convenient index of energy expenditure for children during a steady state of submaximal work. Heart rate has been suggested to estimate energy expenditure in normal and disabled children [11]. Walking energy consumption is a valid evaluation of walking performance in individuals. Gait disabilities, such as CP and stroke, increase the energy expenditure of walking and the intensity of physical effort with altered walking speeds [12].

A crucial element for assessing intervention effectiveness for children with CP is the capability of being able to reliably measure responsiveness to change in gross motor abilities [13]. The Gross Motor Function Measure (GMFM-88) and its subsequent revisions (GMFM-66) as standardized criterion referenced measurement tools designed to measure gross motor function over time for children with disabilities, ages 5 months to 16 years of age, has become the most common functional outcome measure used by rehabilitation specialists to measure gross motor functioning in children with CP and other neurologically based conditions, such as Down syndrome and traumatic brain injury [14-19].

The uniqueness of these tools lies in the fact that the tools provide outcome scores that reflect how much of an activity a child can accomplish (function) rather than how well the activity is performed [15,17]. The scores provide an enhanced understanding of activity outcomes; ultimately leading towards achievement of contextual participation goals specific to the individual child. Although specialist training is not required to administer the tool, the authors recommend that administrators need to be familiar with assessing motor skills in children and the GMFM administration guidelines [15,17].

Materials and Methods

This randomized controlled study was conducted to investigate the effect of core strengthening exercises in addition to the physical therapy program on walking performance in children with diplegic cerebral palsy. Thirty children with spastic diplegia from both genders were selected from outpatient clinic, faculty of physical therapy, Cairo university. Having the following criteria; their ages ranged from seven to ten years, were able to ambulate, they had gait problems (level II or III GMFCS), had no convulsions, had no history of surgical interference in the last 6 months. Their heights were 1 meter and more to be able to see the screen and they had abnormal gait kinematics which can be collected from assessment. Children who had any fixed contractures or convulsions were excluded from this study.

They were assigned randomly (using computer generated random numbers) into two groups. The control group A consisted of 15 children (10 boys and 5 girls) and received the regular physical therapy program according to the neurodevelopmental approach. And the study group B consisted of 15 children (11 boys and 4 girls) and received the regular physical therapy program according to the neurodevelopmental approach besides core stability exercises program.

The protocol of the study was approved from the ethics committee, faculty of physical therapy, Cairo University (PT REC/012/003022). Following an explanation of the experimental protocol and written consents were obtained from all participants and their parents. Also, this study was registered as a clinical trial on Pan African Clinical Trial Registry with identification number of registry (PACTR 202102915429305). Also the study followed the guidelines of the declaration of Helsinki on the conduct of human research.

The clinical assessments performed in this study included a measure of endurance Energy Expenditure Index (EEI) and a functional gait measure (GMFM scores; walking, running and jumping item). For the EEI measurement for diplegic children; the (EEI) in beats/meter is calculated as the ambulation heart rate (beats/min) minus the resting heart rate (beats/min) divided by the ambulation velocity (meters/min). Higher numbers indicate greater energy expenditure, while lower numbers reflect more energy efficiency [20]. The heart rate measured by using pulsometer (Japan model Tunturi TPN-400).

All children were evaluated prior and after two months of training. For evaluation of EEI, firstly, the child rested seated in silence for about ten minutes and the mean heart rate was taken at 2nd minute, fifth minute and eighth minute as the resting heart rate by using pulsometer. The walking heart rate was measured on the treadmill using pulsometer and the mean heart rate was taken at the last three minutes of work during the last session of second and third month of training to assess endurance. Treadmill walking was adjusted at the predetermined individual, self-selected speed, which was held constant throughout the test.

The GMFM is used by a variety of rehabilitation specialists for clinical and research purposes to measure change over time and the effectiveness of interventions to affect change [21]. The standardized measures provide objective information in an easy to understand format. As stated earlier, the GMFM has become the standard tool for measuring change in gross motor function over time for children with CP [22].

For evaluating the walking abilities for the children with CP; walking, running and jumping section or dimension E in GMFM was used; each child performed the test items (as appropriate) and video tapped. Testing done without shoes; shorts and T-shirt is ideal. The score of each item according to the following system: 0=child unable to initiate the task, 1=child initiates the task, 2=child partially completes the task, 3=child completes the task, NT=Not Tested. The test score was calculated according to the test manual as follow:

E: Walking, running and jumping=total dimension E/72 *100=%.

The children in the study group performed Jeffrey's core stability exercises three times per week for an 8-weeks period and each session lasted 45-60 minutes. The core stability exercises program included exercises of progressively increasing difficulty, focusing on strengthening the abdominal, low-back, and pelvic muscles [23].

Jeffreys proposed exercise protocol included 3 levels starting with level 1 and gradually progressed to level 3; Level 1 consisted of static contraction training which was done in a stable condition [24]. Level 2 consisted of dynamic training which was done in a stable condition and level 3 consisted of dynamic and resistance training which was done in an unstable condition. Swiss balls were used to create an unstable condition [25].

First and second week

- Contracting abdominal muscles while lying in a supine position (3 sets and 20 reps in each set).
- Contracting abdominal muscles while lying in a prone position (3 sets and 20 reps in each set).
- Contracting abdominal muscles while in a squat position (3 sets and 20 reps in each set).

Third week

- Contracting abdominal muscles while lying in a supine position with one leg stretched and the other bent at knee and pressed against the abdomen (3 sets and 20 reps in each set).
- Contracting abdominal muscles while lying in a prone position with one leg stretched and the body weight on the other leg which is bent at knee (3 sets and 20 reps in each set).
- Side lying bridge for each side of the body (6 reps, 10 seconds pause).

Fourth week

- Contracting abdominal muscles while lying in a supine position and pulling the limbs upward with arms and legs kept close together (3 sets and 20 reps in each set).
- In squat position, one leg is raised and pulled outward and backward (3 sets for each leg and 20 reps in each set).
- Trunk rotation while holding weights in each hand (3 sets each part of the body and 20 reps in each set).

Fifth week

- Sitting on a Swiss ball and holding the abdomen in (3 sets, 10 seconds).
- Squatting while the Swiss ball is on the shoulder (3 sets and 15 reps for each set).
- Bringing up the arms and legs simultaneously in the prone position (3 sets and 10 reps for each set).

Sixth week

- Bending 45 degrees to the left or right.
- Bridging while shoulders and hands are on the floor and one leg is raised (3 sets and 15 second pause for each set).
- Contracting abdominal muscles while lying in a supine position on the Swiss ball (3 sets and 20 reps for each set).

Seventh week

- Lying supine on the Swiss ball and rotating the trunk to the sides (3 sets and 15 reps for each set).
- Doing the above exercise with holding weights in the hands (3 sets and 15 reps for each set).
- Side lying bridge with bringing up the leg (6 repetitions for each side of the body and 10-second pause).

Eighth week

- Lying supine on the Swiss ball and holding the abdomen in and bringing one leg up (3 sets and 20 reps for each set).
- Raising the opposite arm and leg while squatting (3 sets and 20 reps for each set)
- Bridge so that the feet are placed on the Swiss ball and raise one leg (3 sets and 15 second pause for each set).

For data analysis, all statistical measures were performed through the Statistical Package for Social Studies (SPSS) version 17 for windows, (SPSS, Inc., Chicago, IL). Paired and unpaired T-test was performed to detect level of significance within and between groups respectively.

Results

The present study was conducted to detect the effect of core strengthening exercises in addition to the physical therapy program on walking performance in diplegic cerebral palsied children. There were two independent variables, the first one was the tested groups which had two groups, the control group A (received the regular therapeutic exercise program for such cases based on neurodevelopmental therapy) and the study group B (received the regular therapeutic exercise program for such cases along with core strengthening exercises).

The second one was the (training periods); within subject factor which had two levels (pre, post). In addition, this test involved two dependent variables; GMFM score; (walking, running and jumping item) and Energy Expenditure Index (EEI). Data were obtained from patients of the two groups (control and study), statistically analyzed and compared with measurable variables; (GMFM score; walking, running and jumping item). And EEI scores obtained before and after treatment; using paired and unpaired T-test to detect level of significance within and between groups respectively.

GMFM scores

Within groups: As presented in Table 1, within group's comparison; the mean ± SD values of GMFM score in the "pre" and "post" tests were 60.88 ± 9.1 and 62.73 ± 8.4 (%) respectively in the group A. which revealed no significant difference (P-value>0.05).

It's also presented in Table 1, within group's comparison; the mean ± SD values of GMFM score in the "pre" and "post" tests were 63.1 ± 9.7 and 71.82 ± 10.3 (%) respectively in the group B, which indicated a significant difference (P<0.05).

Between groups: Date presented in Table 1 and showed that, the pretreatment mean values ± SD of GMFM score for group A and B were 60.88 ± 9.1 and 63.1 ± 9.7 (%) respectively. The difference between pretreatment mean scores + SD of the Gross Motor Function Measure (GMFM) indicated no significant differences (P>0.05).

Also, date presented in Table 1 showed that, the post treatment mean values002BSD of GMFM score for group A and B were 62.73 ± 8.4 and 71.82 ± 10.3 (%) respectively. The difference between post treatment mean scores + SD of the Gross Motor Function Measure (GMFM) indicated a significant differences (P<0.05).

GMFM score	Means ± SD	Means ± SD	MD	% of change	P-value
	Pre test	Post test			
Group A	60.88 ± 9.1	62.73 ± 8.4	1.85	3.04	0.25
Group B	63.1 ± 9.7	71.82 ± 10.3	8.72	13.82	0.013*
T-value	0.53	2.16			
P-value	0.69	0.02*			

Table 1. Pre and post treatment mean values of GMFM scores both groups (A and B). *: Significant level is set at alpha level <0.05.

EEI scores

Within groups: As presented in Table 2, within group's comparison the mean ± SD values of EEI score in the "pre" and "post" tests were 1.91 ± 0.92 and 2.0 ± 0.95 (beats/meter) respectively in the group A. Which revealed no significant difference (P-value >0.05). It's also presented in Table 2, within group's comparison the mean ± SD values of EEI score in the "pre" and "post" tests were 2.08 ± 0.75 and 1.065 ± 0.35 (beats/meter) respectively in the group B, which indicated a significant difference (P<0.05).

Between groups: Date presented in Table 2 showed that, the pretreatment mean values + SD of EEI score for group A and B were 1.91 ± 0.92 and 2.08 ± 0.75 (beats/meter) respectively. The differences between pretreatment mean scores+SD of the Energy Expenditure Index (EEI) indicated no significant differences (P>0.05).

Also, date presented in Table 2 showed that, the post treatment mean values ± SD of EEI score for group A and B were 2.0 ± 0.954 and 1.065 ± 0.35 (beats/meter) respectively. The differences between post treatment mean scores+SD of the Energy Expenditure Index (EEI) indicated a significant differences (P<0.05).

EEI score (Beats/Meter)	Means ± SD	Means ± SD	
	Pre test	Post test	P- value
Group A	1.91 ± 0.72	2.0 ± 0.654	0.23
Group B	2.19 ± 0.75	1.065 ± 0.35	0.001*
P value	0.72	0.04*	

Table 2. Pre and post treatment mean values of EEI scores both groups (A and B). *: Significant level is set at alpha level <0.05.

Discussion

Recently, there is a great researchers concern about studying the impact of core stability exercises on improving balance and walking functions in children with disabilities. Core stabilityarea is like a box that abdominal muscles form its anterior section, muscles of the spine and gluteal muscles form its posterior section, diaphragm muscle forms its roof, and pelvic girdle muscles form its floor [26,27].

The stability of the lumbo-pelvic region is essential that provides a base for the upper and lower extremities movement, to support loads transmission, and to protect the spinal cord and nerve roots [28]. The core muscles stabilize the spine and trunk during movements such as walking, jumping, running, and throwing [29]. Previous studies revealed that trunk muscle fatigue led to decreased dynamic stability of the trunk and loss of balance control [30,31]. It is essential to measure energy consumption because of its role in the evaluation of functional ability as the quantification of energy expenditure; at the same time, walking provides objective data to assist in the evaluation of children with walking disabilities as well as effectiveness of therapeutic modalities, such as walking aids, orthoses, rehabilitation programs, and surgical treatments [32].

Observation of the pre-treatment mean values of measured variables regarding this study revealed that children with diplegic CP tend to walk with abnormal gait pattern caused by the neurological impairments associated with musculoskeletal and biomechanical problems resulting in elevated energy cost during walking as; posterior calf spasticity resulting in toe strike, or toe-heel strike, shortened step length, limited reciprocating gait due to abnormal arm swing, and abnormal co-contraction of agonist and antagonist muscle around ankles and knees, all of that leading to decreased walking performance with high energy expenditure.

This come in agreement with Levin, 2006 who found that energy expenditure among children with CP is very important as children with CP consume more energy during ambulation and they have lower physical activity levels and lower energy requirements than do typically developing children [33]. Also, our explanations are parallel with previous studies recommendations that there is a strong relation between the degree of motor disorders and energy cost of walking [34]. Children with CP often begin their walking later than normal children and walk with a higher energy cost and slower speed [35,36].

The main movement limitations in children with cerebral palsy especially spastic type are walking with abnormal pattern activating unneeded muscles to control walking and consuming excessive energy during walking which may explain getting easy fatigability. As suggested by previous studies that individuals with CP are less active and more sedentary than their able-bodied peers [37]. Children and adolescents with CP tend to participate in less structured and lower intensity physical activities [38].

The results of the current study were confirmed by Dahlback et al. [39] who stated that Gait abnormalities in children with cerebral palsy have been shown to increase submaximal walking energy expenditure almost three-fold compared with healthy children. One consequence of this increased energy cost is that children with CP complain of fatigue at low walking intensities. Children with CP at the age of 7 have already lowered VO2 peak values compared to typical developing peers. Therefore, early intervention for an active lifestyle might be beneficial for promoting physical fitness in CP patients [40].

The post treatment results of the current study revealed a significant improvement of walking abilities in the study group with significant difference in favor to study group. Also, there was a significant reduction of energy expenditure index in the study group with significant difference in favor to study group when comparing post treatment mean values. The post treatment results of the current study may be attributed to the effect of core strengthening exercises program through proper activation of the postural muscles around lumbar and pelvic regions that help to stabilize the axial component of the body during walking.

This is parallel with Marshall et al. [41], who found that, core stability exercises activate the optimal posture of the lumbar and pelvic regions and reinforce the muscles around the trunk and pelvic regions that help to stabilize the body and head during limb movements by utilizing tonic or postural muscles during the entire body exercises. The results of our study may be due to the strengthening effect of the core muscles that allows a stable base for force transmission from the axial part to the lower extremities during walking along with proper activation of the postural muscles resulting in more efficient walking with lowered energy expenditure and delayed fatigue in children with neuro-motor impairments.

This could evoke the optimal lumbar-pelvic-hip chain mobility, good acceleration and deceleration, proper muscle balance and proximal stability, and corrects the postural alignments [42]. Moreover, walking performance improved owing to the improved proximal trunk control which provoked the enhancement in the distal lower extremity control and assisted the achievement of better balance and gait [43]. This come in agreement with the Ozmen et al. [44] who found that the core muscles stabilize the spine and trunk during movements such as walking, jumping, running, and throwing.

Also, our results may be attributed to the gained core strength that improve postural stability and balance while moving that allows more lower limbs control during walking induced by lumo-pelvic stability while standing and walking in children with neuro-motor impairments. This is consistent with Golsefidi et al. [45] who found significant effects of 8-week core stability training on students' balance with high functioning autism. In the same context Sayadinezhad et al. [46] concluded that progressive resistance training increases balance capacity in children with Down syndrome.

The post treatment improvement of walking performance may be due to the conditioning effect of the core muscles strengthening besides the lower extremities involvement in the exercises program that allow proper activation of the postural and lower limbs muscles along with controlled breathing due to targeting diaphragm and abdominal muscles strengthening leading to improving physical fitness and walking efficiency. This is parallel with findings of Hu et al. and Mcnair et al. who reported that the core muscles provide various functions during walking including; breathing, control of the trunk orientation, and adjustment of the pelvis and spine.

Conclusion

From the obtained results it can be concluded that core stability exercises program improve walking performance and physical fitness in children with diplegic cerebral palsy.

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