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Effect of different levels of segmental trunk stability training on sitting and upper limbs functions in children with bilateral spastic cerebral palsy

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***Abstract*---**Background: Children with bilateral spastic cerebral palsy (BSCP) have insufficient trunk control and upper limbs (ULs) dysfunction. Purpose: to investigate the effect of segmental trunk stability training at different levels on sitting and ULs functions in children with BSCP. Subjects & Methods: Thirty-nine children with BSCP, with ages ranged from 2 to 4 years, their spasticity grade ranged from 1 to 1+ according to the Modified Ashworth Scale, their motor function was at level IV according to the Gross Motor Function Classification System – Expanded and Revised, their self-initiated ability to handle objects in daily activities with their hands was at level V according to the Mini-Manual Ability Classification System, all children's level of segmental trunk control score ranged from 3 to 5 according to the Segmental Assessment of Trunk Control were assigned randomly to 3 groups of equal numbers, 13 children for each group. Group (A) received a specially designed physical therapy (PT) program while wearing segmental trunk support from a level just below the child's inferior angle of the scapula to the level of his/her pelvis. Group (B) received the same PT program given to (group A)

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while wearing segmental trunk support from a level just below the child's rib cage to the level of his/her pelvis. Group (C) received the same program given to (groups A and B) while wearing segmental trunk support from the level of the child's inferior angle of the scapula to the level of his/her last rib. The PT program was conducted for 1 hour, 3 times per week for 6 successive months. The Gross Motor Function Measure (GMFM) - domain (B) was used to assess sitting and the Quality of Upper Extremity Skills Test was used to assess upper limbs function at baseline and after 6 months of intervention. Results: There was a statistically significant improvement in domain (B) of the GMFM in all groups. There was a statistically significant improvement in dissociated movement of ULs function in group (B). There was a non-significant improvement in all ULs functions in group (C). There was a statistically significant improvement in all ULs function except grasp in group (A). The improvement was in favor to group (A) ($p<0.05$). Conclusion: The segmental trunk stability training using external trunk support for the thoracic and lumbar regions in combination with the physical therapy session is effective in improving sitting and upper limb functions in children with BSCP.

***Keywords*---**Bilateral Spastic Cerebral Palsy, Segmental Trunk Stability Training, Sitting, Trunk Control, Upper Limbs Functions.

1- Introduction

Cerebral palsy (CP) is childhood's most common cause of physical disability. One of the most cited definitions of CP includes the phrase 'a group of permanent disorders of the development of movement and posture, causing activity limitation, that is attributed to non-progressive disturbances that occurred in the developing fetal or infant brain' (Rosenbaum, 2014; Rosenbaum et al., 2007).

According to the Surveillance for Cerebral Palsy in Europe (SCPE) classification, CP was classified into the following four subtype groups: spastic (bilateral and unilateral), dyskinetic (dystonic and choreoathetotic), ataxic, and non-classifiable. Bilateral spastic cerebral palsy term is used to describe the involvement of both sides of the body. By this classification, spastic quadriplegia and spastic diplegia are classified as BSCP (Cans, 2007).

Children with BSCP have a low tone in body muscles but a high tone in extremity muscles. The risk of deformities in the lower extremities and spine may be increased due to insufficient postural stabilization, and spinal malalignment (Seyhan and Kerem-Günel, 2019).

Trunk control is impaired in these children. This impairment is dependent on the topography and severity of the motor impairment (Heyrman et al., 2013). The sitting position allows efficient use of the upper extremities. Sitting can be severely impaired due to spasticity and poor trunk control (Strobl, 2013).

Children with spastic CP often have problems with their upper limbs (UL). Manual dexterity is a problem for children with CP. Motor control challenges, insufficient active range of motion, decreased grip strength, and persistent primitive grip reflexes can all contribute to it. In children with CP, there was a connection between trunk control and UL function. Individual motions are more difficult for children who have poor trunk control (Yildiz et al., 2018).

In the past, conventional thinking was that the whole trunk should be treated as a single entity. Recent researches proved that the segmental approach to trunk control at different levels of postural static support affects reaching and eye-hand coordination (Marcinowski et al., 2019). Still, no one knows what the best level of trunk support is for a child with spastic CP. So, instead of giving his/her a full support, it would be better to give them intermediate levels of trunk stabilization (Santamaria et al., 2016).

As there aren't any tools for precise trunk stabilization during training, more research is needed. Recently, segmental trunk control and its effects on improving both gross and fine motor skills have gotten more attention. Most earlier investigations employed segmental trunk fixation from a static sitting or standing posture. Therefore, the aim of the study was to examine the effect of external segmental stabilization of the trunk at different levels during the active training and participation of the child on sitting and upper limbs functions.

2- Material and methods

This experimental pretest-posttest study was approved by the Research Ethical Committee, Faculty of Physical Therapy, Cairo University on 1st December 2019 with approval no.: (**P.T.REC/012/002548**). Also, it was registered on https://www.clinicaltrials.gov/ with approval no. (**NCT04937439**).

2.1. Participants

Thirty-nine children with BSCP were recruited from Nour Alhayah Foundation for Rehabilitation of Children with CP, Cairo, Egypt between January 2020 and June 2022. All participants' legal guardians were informed about the aim and the methods of the study. Also, they signed the consent form.

2.2. Sample size:

The sample size was calculated considering the difference in dissociated movement among the 3 groups to be 0.57 (effect size), significance level= 0.05, and with 80% power. The sample size was calculated to be 11 children per group, 1:1:1 ratio. The presumed effect size was based on a pilot study of 5 individuals in each group. Assuming a 20% loss to follow-up, at least 13 children were needed for each group. Sample size calculation was conducted using G*POWER statistical software [version 3.1.9.2; Universität Kiel, Germany] and F tests- One way ANOVA.

2.3. Inclusion and exclusion criteria

The criteria considered for inclusion were: children with BSCP, their chronological age ranged from 2 to 4 years, the spasticity grade for these children ranged from 1 to 1+ according to the Modified Ashworth Scale (MAS), their motor function was at level IV according to the Gross Motor Function Classification System – Expanded and Revised (GMFCS-E&R), their self-initiated ability to handle objects in daily activities with their hands was at level V according to the Mini-Manual Ability Classification System (Mini-MACS), all children's level of segmental trunk control score ranged from 3 to 5 according to the Segmental Assessment of Trunk Control (SATCo).

Any child with the following criteria was directly excluded from the initial evaluation for the consistency of the sample if he/she had: surgical interference in upper limbs and/or spine, orthopedic problems, or fixed deformities in the vertebral column and/or upper extremities, uncontrolled seizures, visual or hearing impairment.

The selected children who met the criteria for the study were assigned randomly by sealed envelopes to three groups of equal numbers, thirteen children for each group. Each group was identified as study group (A), study group (B), and study group (C). Study group (A) received a specially designed PT program while wearing segmental trunk support from a level just below the child's inferior angle of the scapula to the level of his/her pelvis. Study group (B) received the same PT program given to (group A) while wearing segmental trunk support from a level just below the rib cage of the child to the level of his/her pelvis. Study group (C) received the same program given to (groups A and B) while wearing segmental trunk support from the level of the child's inferior angle of the scapula to the level of his/her last rib. The PT program was conducted for 1 hour, 3 times per week for 6 successive months. The flow of subjects was demonstrated through a flow chart based on Consolidated Standards of Reporting Trials (CONSORT), which was explained in Figure (1).

Instrumentation for sample selection:

- **Modified Ashworth Scale:**

The Modified Ashworth Scale (MAS) was created by Bohannon and Smith, (1987). MAS was easily and commonly used in clinical practice. It was used to measure the spasticity grade in pediatrics and adults who have upper motor neuron lesions. Its scores range from 0-4, with 6 choices (Mutlu et al., 2008).

Gross Motor Function Classification System - Expanded & Revised:

The Gross Motor Function Classification System - Expanded and Revised (GMFCS – E&R) is a valid and reliable method that is used to classify the patterns of motor disability in children with CP, on the basis of self-initiated movement with an emphasis on sitting, transfers, and mobility. It contains 5 age intervals (under 2 years, 2-4 years, 4-6 years, 6-12 years, and 12-18 years). It comprises five levels. Functional restrictions, the necessity for assistive mobility equipment, wheeled mobility, and quality of movement determine these levels (Palisano et al., 2008). The GMFCS - E&R age interval between 2nd and 4th birthday was used in this study.

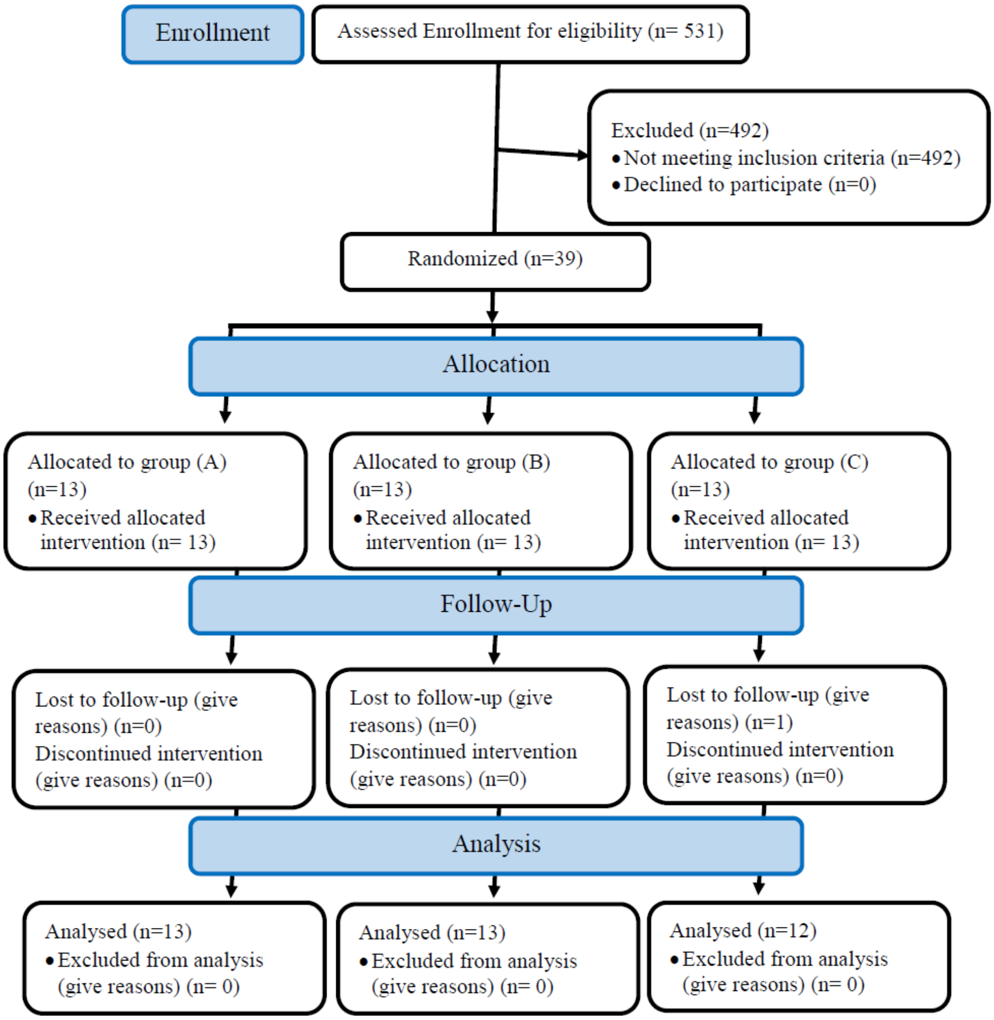

Fig. (1): Flow chart based on Consolidated Standards of Reporting Trials (CONSORT)

- **Mini-Manual Ability Classification System:**

The Mini-Manual Ability Classification System (Mini-MACS) is a classification system that describes how children with CP use their hands when handling objects in daily activities. It is valid for use with children with CP from 1 to 4 years of age. It assesses the child's general ability to handle everyday objects, not the function of each hand separately. The ability is ranked on five levels based on the children’s self-initiated ability and their need for assistance or adaptation when handling objects (Eliasson et al., 2016).

- **Segmental Assessment of Trunk Control:**

The Segmental Assessment of Trunk Control (SATCo) is a verified and internationally accepted measuring instrument. It assesses trunk control by considering many subunits that must be coordinated to achieve control when sitting. The evaluator progressively changes the level of trunk support from a high level of support at the shoulder girdle to assess head control, through support at the axillae, lower scapula, lower ribs, below ribs, pelvis, and finally, no support, in order to measure full trunk control. It includes tests of static, active, and reactive control. The SATCo needed a bench and strap for child support. The total score of SATCo is 20 (Butler et al., 2010). Children with BSCP with SATCo score ranged from 3 to 5 were selected for the current study.

Instrumentation for evaluation:

- **Gross Motor Function Measure:**

The Gross Motor Function Measure (GMFM-88) is a reliable and valid assessment tool for measuring changes in gross motor function over time in children with CP aged from 5 months to 16 years old. It consists of 88 items, and these items were organized into five dimensions. These dimensions are lying and rolling (A), sitting (B), crawling and kneeling (C), standing (D), walking, running, and jumping (E) (Russell et al., 2021). The sitting (B) dimension was assessed in the current study for all children in the three groups. It consists of only 20 items. The Gross Motor Ability Estimator (GMAE-2) was used in the current study for fast and accurate calculation of the dimension (B) score.

- **Quality of Upper Extremity Skills Test:**

The Quality of Upper Extremity Skills Test (QUEST) was designed to evaluate movement patterns and hand function in children with CP. It consists of four subsections: dissociated movement, grasp, weight bearing, and protective extension. It has a 34-item observational criterion-referenced test. Items are related to the movement quality, not to chronological age in children with CP, aged 18 months to 8 years (DeMatteo et at., 1993).

Instrumentation for intervention:

The segmental trunk stability training was done in the current study using a segmental trunk support during the traditional physical therapy session. The segmental trunk supports were padded and fabricated from leather. Their sizes were as the following:

- Dimensions of (50×13 cm) length and width, for group (A).
- Dimensions of (50×9 cm) length and width, for group (B).
- Dimensions of (50×5 cm) length and width, for group (C).

The following instruments were used in the implementation of the traditional physical therapy session: a mat, a medical ball with a diameter of 85 cm, different sizes of pediatric therapeutic wedges, and different sizes of rolls.

Procedures:

Spasticity grade, motor function level, hand functional ability level, and segmental trunk control were evaluated before starting the treatment for selecting the children with BSCP who participated in this study. Sitting milestone and ULs functions were evaluated for all children with BSCP who participated in this study before and after 6 months of treatment.

- **Evaluative procedures:**

The children were assessed by obtaining a detailed history and carrying out a physical examination. Children with BSCP were selected by using the classification tree for sub-types of CP according to Cans, (2007). Their mobility level was determined using GMFCS – E & R, which was level IV. Also, their ability to handle objects in everyday activities was determined was classified by using Mini-MACS, which was level V. Demographic data such as age and gender were also obtained from their case files.

- **Assessment of spasticity grade:**

Modified Ashworth Scale was adopted to quantify the grade of spasticity in elbow flexors in both ULs for all children in the three groups (A, B, and C) before treatment for the selection of children to be included in the study.

- **Assessment of motor function level:**

The Gross Motor Function Classification System – Expanded and Revised (GMFCS - E & R), with an age band from 2 to 4 years, was used to determine the level of self-initiated movements of the selected children. The GMFCS - E&R level of the subjects was determined according to its manual (McDowell, 2008). Children with BSCP at level IV on GMFCS were included in this study.

- **Assessment of hand functional ability level:**

The Mini-Manual Ability Classification System (Mini-MACS) was used to determine the level of the self-initiated ability to handle objects in the daily activities of the selected children. The Mini-MACS level of the subjects was determined according to its leaflet and MACS identification chart (Eliasson et al., 2016). Children with BSCP at level V on the Mini-MACS were included in this study.

- **Assessment of segmental trunk control:**

The exact level of segmental trunk control for the selected children was identified using the SATCo. The assessment procedures were done according to Butler et al. (2010) SATCo guidelines. The score of SATCo ranged from 3 to 5 for all participants.

Outcome measures:

- **Assessment of sitting:**

The gross motor function measure (GMFM-88) scale was used to assess the change in sitting for all children in the three groups. Dimension B (sitting), one of the five dimensions of the GMFM-88, was evaluated in this study before and after the 6 months of the segmental trunk stability training. This dimension included 20 items that deal with various aspects of sitting. The test was conducted according to instructions in the GMFM-88 user's manual (Russell et al., 2021). The percentage of dimension B (sitting) was calculated using the GMAE-2 software.

- **Assessment of upper limbs functions:**

Upper limbs functions were evaluated using the QUEST as one of the outcome measures in this study for all children in the three groups. It was assessed in this study before and after the 6 months of the segmental trunk stability training. The QUEST contained 34 items related to the quality of movement in four domains (dissociated movements, grasp, weight bearing, and protective extension). The total score of the QUEST was calculated for only the three subtests. The following procedures were done according to the QUEST manual (DeMatteo et at., 1992).

- **Treatment procedures:**

All children received the physical therapy program while wearing a trunk belt of a specific size according to the allocated group. The treatment program was conducted for the three study groups and lasted for one hour, three sessions per week for six months. The designed physical therapy program was carried out according to Martin and Kessler (2021) as follows:

a) Facilitation of head control in extension from prone lying position. Visual and/or auditory cues were added in front of the child for encouragement of active head extension. The exercise was repeated for 10 minutes.
b) Facilitation of head control in flexion from a supine lying position. This exercise was added instead of the previous exercise after the child gained head control in extension. The exercise was repeated for 10 minutes.
c) Facilitation of rolling from prone to supine position. The exercise was repeated for 10 minutes.
d) Facilitation of postural reactions from sitting on ball. The exercise was repeated for 20 minutes. After the child gained active response during righting reactions exercise, the equilibrium reaction exercise was done to the child using a faster speed. Then, after the equilibrium reaction developed by the child, the protective reaction exercise from sitting was done at first in forward direction then in side-to-side direction using a faster speed than equilibrium and righting exercises.
e) Stoops and recover exercise from sitting position on roll. A toy was placed on a spongy block beside the child on a level close to his trunk. The child was encouraged to move his/her right upper limb to grasp the toy and then the left upper limb. The exercise was repeated for 10 minutes.
f) Rising reaction (side lying to side sitting) on wedge. The exercise was repeated for 10 minutes.

2.4. Statistical analysis

Data management and statistical analysis were done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using the Shapiro-Wilk test and direct data visualization methods. According to normality testing, numerical data were summarized as means and standard deviations or medians and interquartile range. Quantitative data were compared between study groups using one-way ANOVA or Kruskal Wallis test for normally and non-normally distributed quantitative variables, respectively. Post-hoc analyses were done in the case of overall significance, and all post hoc analyses were adjusted for multiple comparisons using Bonferroni Correction. All statistical tests were two-sided. P values less than 0.05 were considered significant.

3- Results

3.1. Demographic Characteristics

Table (1) shows a non-significant difference was found in age among three study groups ($p>0.05$), as conducted by one-way ANOVA test. Additionally, the Chi-squared test has revealed the absence of variances in gender, subtype of BSCP, degree of spasticity, and SATCo score variables between groups.

Table (1): General characteristics of participated children.

	Group A (n=13)	Group B (n=13)	Group C (n=12)	F-Value	X^2-Value	P-Value
Age	2.84 ± 0.51[a]	3.16 ± 0.61	2.94 ± 0.78	0.859	-	0.432[NS]
Gender						
Boys	8 (61.5 %)[b]	11 (84.6 %)	9 (75 %)	-	1.80	0.406[NS]
Girls	5 (38.5 %)[b]	2 (15.4 %)	3 (25 %)			
Subtype of BSCP						
Quadriplegic CP	8 (61.5 %)[b]	8 (61.5 %)	6 (50 %)	-	0.488	0.799[NS]
Diplegic CP	5 (38.5 %)[b]	5 (38.5 %)	6 (50 %)			
Grade of Spasticity						
Grade (1)	10 (77 %)[b]	7 (53.8 %)	7 (58.3 %)	-	1.66	0.435[NS]
Grade (1^+)	3 (23 %)[b]	6 (46.2 %)	5 (41.7 %)			
SATCo score						
3	2 (15.4 %)[b]	5 (38.5 %)	3 (25 %)	-	2.92	0.571[NS]
4	5 (38.5 %)[b]	5 (38.5 %)	6 (50 %)			
5	6 (46.1 %)[b]	3 (23 %)	3 (25 %)			

*Data is presented as (a): Mean & standard deviation or (b): Numbers & percentages;
F-value: One-Way ANOVA test; P-Value: probability value; NS: non-significant; X^2: Chi-squared test

3.2. Statistical analysis of all outcome measures

- **Among group analysis**

According to Kruskal Wallis test results, there were no statistically significant differences in the dependent variables including (GMFM, dissociated movements, weight bearing, protective extension, and QUEST total score) at baseline measurements among the three groups, while there were statistically significant differences among groups in post-treatment comparison in all measured variables as shown in Table (2).

- **Within-group analysis**

Wilcoxon signed rank test has revealed statistically significant differences between pre-and post-treatment in all measured variables in group A. Also, there were statistically significant differences in dimension B of the GMFM, dissociated movements, and QUEST total score and non-significant differences were found in the remaining variables in group B. However, in group (C) there was a statistically significant difference were found in dimension B of the GMFM only and no statistically significant differences found in the remaining variables as shown in Table (2).

- **Multiple pairwise comparisons**

Post-hoc analysis using Bonferroni correction was used to perform multiple comparison between groups. The test revealed that there was statistically significant improvement in all measured variables in favor to group A as shown in Table (2).

4- Discussion

The objective of this study was to investigate the effect of the different levels of segmental trunk stability training on sitting and ULs functions in children with BSCP. Sitting (domain B of the GMFM) and dissociated movement, weight bearing, and protective extension (subtests of the QUEST) were specifically selected to be measured in this study.

The results of this study revealed there was a statistically significant improvement in all measured variables in favor to group A. This group had segmental trunk stability training using segmental trunk support from a level just below the child's inferior angle of the scapula to the level of his/her pelvis during the physical therapy session. The program was conducted for 1 hour, 3 times per week for 6 successive months. It has a statistically significant improvement in sitting and upper limb functions especially dissociated movements, weight bearing, and protective extension skills in children with BSCP.

Table (2): Statistical analysis of all outcome measures pre- and post-treatment between and among groups

Outcome Measure	Group A (n = 13)	Group B (n = 13)	Group C (n = 12)	X^2-value	P-value
GMFM B (%)					
Pre-treatment	0 (0 - 1.7)	0 (0 – 2.5)	1.7 (0 – 2.9)	0.399	0.819[NS]
Post-treatment	26.7 (17.5 - 30.8) [b&c]	6.7 (5.0 – 9.15) [a]	9.15 (5.42 – 11.7) [a]	23.972	**0.0001***
Z-Value	-3.180	-3.197	-3.072		
p-value	**0.001***	**0.001***	**0.002***		
Dissociated movements (%)					
Pre-treatment	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.923	0.382[NS]
Post-treatment	3.13 (3.13 - 3.13) [c]	3.13 (0 – 3.13)	0 (0 – 2.34) [a]	9.312	**0.01***
Z-Value	-3.207	-2.646	-1.730		
p-value	**0.001***	**0.008***	0.083[NS]		
Weight bearing (%)					
Pre-treatment	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0.0	1.0[NS]
Post-treatment	21.05 (10.53 - 31.58) [b&c]	0 (0 - 0) [a]	0 (0 – 0) [a]	33.564	**0.0001***
Z-Value	-3.196	0	-1.0		
p-value	**0.001***	1.0 [NS]	0.317[NS]		
Protective extension (%)					
Pre-treatment	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0.0	1.0[NS]
Post-treatment	5.56 (5.56 – 11.11) [b&c]	0 (0 - 0) [a]	0 (0 – 4.17) [a]	22.772	**0.0001***
Z-Value	-3.126	-1.0	-1.73		
p-value	**0.002***	0.317[NS]	0.083[NS]		
QUEST total score (%)					
Pre-treatment	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	1.923	0.382
Post-treatment	9.91 (7.28 – 14.34) [b&c]	1.04 (0 – 1.04) [a]	0 (0 – 2.17) [a]	26.645	**0.0001***
Z-Value	-3.181	-2.530	-1.630		
p-value	**0.001***	**0.011***	0.102[NS]		

Data were presented as median & Interquartile range; **X^2-value:** Kruskal–Wallis test; **Z-value:** Wilcoxon signed-rank test ***** Significant; **NS:** non-significant; **a:** significantly different from group a; **b:** significantly different from group b; **c:** significantly different from group c

We believed that in our study the trunk was divided into two regions: the region supported by the external trunk support and the region above and below the external support that received the targeted segmental training. We thought that children in group (A) received the targeted segmental trunk training at the trunk region from the inferior angle of both scapulae to the whole neck above the external trunk support. While children in group (B) received the targeted segmental trunk training at the trunk region from the end of thoracic cage to the whole neck above the external trunk support. Unlike, children in group (C) received the targeted segmental trunk training at the trunk region from the inferior angle of both scapulae to the whole neck above the external trunk support, and also, the region below it from the end of the thoracic cage to the pelvis.

It was observed that the segmental trunk stability training using different levels of external trunk support in the three groups had a significant effect on sitting in children with BSCP. These results came in concordance with Curtis et al. (2017) who concluded that targeted training may be an effective means of promoting movement control and functional ability in children with CP.

On the same line, Saavedra and Goodworth (2020) noted that children at GMFCS levels IV and V have undeveloped postural control and require contextual modifications to enable opportunities for basic acquisition and practice of head and trunk control. Also, this point of view is explained by Peeters et al. (2018) who discussed that when external trunk support is given to patients with a flaccid trunk, an optimal balance should be sought between providing stability and allowing movement of the trunk. The level of support can vary based on individual needs, ranging from pelvic support to complete thoraco-lumbosacral orthoses, and from rigid to flexible structures.

Moreover, the results of this study are consistent with the findings of Santamaria et al. (2016) who found that children with CP and trunk dysfunction demonstrate improved motor performance when the external assistance matches their intrinsic level of trunk control. Also, they reported that children in the severe group were unable to maintain posture with pelvic support and showed postural deficiencies with mid-ribs compared with axillae support.

The results of this study showed that the external trunk support used for children in group (A) has a significant effect in improvement of sitting more than the smaller sizes used in children in groups (B and C). The possible explanation of the significant improvement of sitting in group (A) is that the on supported upper part of the trunk received the targeted segmental trunk training at the region from the inferior angle of both scapulae to the whole neck above the external trunk support specified for this group. So, the external trunk support in group (A) left too little region for the center nervous system (CNS) to control. This is supported by Reeves et al. (2011) who reported that delays in feedback control can impair the control of the spine, particularly when the spine system is moving fast. The trunk segment is moving faster than the CNS can respond. The CNS must be able to track the spine to stabilize it.

There was a statistically significant improvement in domain (B) of the GMFM in favor to group (A). This may be attributed to the increased abdominal pressure done by the external segmental trunk support during the target training. The larger size belt used in group (A) gave the highest abdominal pressure. This explanation is supported by Cholewicki et al. (1999a) who found that the external support system to the trunk created increased abdominal pressure. This has been shown to increase stiffness and resist or stabilize the body against trunk flexion. This mechanism can increase spine stability without the additional coactivation of erector spinae muscles.

On the same line, Cholewicki et al. (1999b) reported that both wearing an abdominal belt and raising intra-abdominal pressure (IAP) can each individually, or in combination, increase lumbar spine stability. An increase in spine stability due to high IAP is likely obtained from the concomitant increase in muscle coactivation needed to generate this IAP. On the other hand, the stabilizing effect of the belt alone appears to be a passive mechanism.

Another explanation is that the antigravity muscles are needed to counteract the force of gravity. The longer the gravitational moment arm, the higher the demand on the antigravity muscles. We believed that the external support in group (A) decreased the gravitational moment arm, which lead to decrease the antigravity muscle force generated and became able to lift the upper part of the vertebral column easily.

On the same line, Saavedra et al. (2012) suggested that the critical constraint in achieving upright control was the infant's ability to anticipate and grade muscle responses to counteract gravitational torque. Normal infants learn to scale their motor responses to accommodate gravitational torque. Initial attempts by infants to achieve verticality were irregular, uncomfortable, and frequently failed motions that undershot or overshot the objective of upright posture, contributing to a significant degree of variability.

According to that previous belief, the external trunk support used for children in group (A) gave their trunk stability during the training and assisted the antigravity postural muscles. We thought that external trunk support decreased the demand for these muscles. As the external trunk support gave the spine a vertical alignment and the rest of upper part of the vertebral column is shorter than the region in other groups (B) and (C) which led to decrease the antigravity muscle force generated and became be able to lift the upper part of the vertebral column easily. That is why the children in group (A) had a high percentage of improvement in the GMFM – domain (B). This agrees with the opinion of Shumway-Cook and Woollacott (2016) who supported that an immature postural system is a limiting factor or a constraint on the emergence of coordinated arm and hand movements. It has also been suggested that delayed or abnormal development of the postural system may also constrain a child’s ability to develop independence in mobility and manipulatory skills.

Similarly, Harbourne and Stergiou (2003) revealed that when a skill level matures, the degrees of freedom are liberated enabling more flexible coordination of body parts within the environment. Infants and older children frequently employ the method of reducing the number of degrees of freedom while developing a new skill.

Children with CP have been shown to have improved motor performance when their sway is reduced. Moreover, Saavedra and Goodworth (2020) reported that children with CP that had severe impairments, posture is not automatic. Posture is regarded fundamentally unstable because even little deviations from upright cause gravitational forces to propel the body away from upright.

The results of the current study revealed that the external trunk support used for children in group (A) gave their trunk stability during the training and helped the upper limb function improvement as it allows more stability to the region below and more freedom to specific targeted training to both ULs. This explanation was supported by Shumway-Cook and Woollacott (2016) who noted that adding external trunk support to patient with postural muscles activation problems may lead to functional arm improvement.

Furthermore, these findings support the findings of Harbourne and Stergiou (2003), who observed that achieving independent sitting appears to be effortless and just a part of the regular maturation process. Once a newborn can sit and control his or her head and trunk, the arms are free for exploration and useful tasks.

Shumway-Cook and Woollacott (2016) explained that postural adjustments are also activated before voluntary movements to minimize potential disturbances to balance that the movement may cause. This is termed “anticipatory postural control.” That explains the improvement of ULs functions in group (A). As that group showed a higher significant improvement in sitting milestone.

In healthy infants aged between 4 and 6 months, the trunk control in the lumbar region encouraged positively the quality of reaching behavior than infants that had only thoracic region trunk control (Rachwani et al., 2013). The link between the improvements seen in sitting and ULs function improvement in group (A) indicated that the sitting milestone improvement is related with improvement in ULs functions especially weight bearing and protective extension skills. Children in group (A) has an external trunk support larger than group (B) and (C) and this may lead to decrease the trunk sway. The decrease of trunk sway and increase of the upper trunk stability may lead to better improvement of ULs functions. This explanation is supported by Bardsley (1993) who reported that sitting allows the child to use his/her ULs in an intensive and concentrated way.

The ability to plan and produce competent reaching and fine manipulation is supported by the musculoskeletal and neurological components of posture, according to Shumway-Cook and Woollacott (2016). Due to the numerous degrees of freedom in the upper body that must be coordinated during reaching activities, fine control gradually develops throughout development. Also, this comes in agreement with Martin and Kessler (2021) who concluded that functional use of the UL needed trunk control, whether that comes from postural muscle control or from a seating system.

This study had some limitations. Lack of measurement instruments adapted for Egyptian population. The participants’ recruitment was stopped from April 2020 to November 2020 due to the Coronavirus disease of 2019 pandemic in Egypt.

The participants' cognitive function delay might affect their understanding of the verbal commands and cooperation during the QUEST administration. The results of this study have indicated a need to consider the following recommendations: segmental trunk stability training at a level below the child's segmental trunk control is of clinical importance to be added to the regular physical therapy session and home program for children with BSCP. Additional studies are required to be done for discovering the effect of segmental trunk stability training on trunk muscles in children with BSCP using surface Electromyography (EMG). Similar studies are required to be done for exploring the effect of neuromuscular electrical stimulation (NEMS) in a descending segmental application on sitting milestone, and ULs functions in children with BSCP. Additional studies are required to be done for investigating the effect of segmental trunk stability training on head and trunk control in children with hypotonia e.g.: CP, spinal muscle atrophy, etc.

Conclusion

The segmental trunk stability training using external trunk support for the thoracic and lumbar regions in combination with the physical therapy session is effective in improving sitting and ULs functions in children with BSCP.

Conflict of authors

The authors declare that the research is conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Bohannon, R. W., and Smith, M. B. (1987). Interrater Reliability of a Modified Ashworth Scale of Muscle Spasticity. Physical Therapy, 67(2), 206–207. doi: 10.1093/ptj/67.2.206
2. Butler, P. B., Saavedra, S., Sofranac, M., Jarvis, S. E., and Woollacott, M. H. (2010). Refinement, Reliability, and Validity of the Segmental Assessment of Trunk Control. Pediatric Physical Therapy, 22(3), 246–257. doi:10.1097/pep.0b013e3181e69490
3. Cans, C. (2007). Surveillance of cerebral palsy in Europe: a collaboration of cerebral palsy surveys and registers. Developmental Medicine and Child Neurology, 42(12), 816–824. doi:10.1111/j.1469-8749.2000.tb00695.x

4. Cans, C. (2007). Surveillance of Cerebral Palsy in Europe: a collaboration of cerebral palsy surveys and registers. Developmental Medicine and Child Neurology, 42(12), 816–824. doi: 10.1111/j.1469-8749.2000.tb00695.x
5. Cholewicki, J., Juluru, K., and McGill, S. M. (1999a). Intra-abdominal pressure mechanism for stabilizing the lumbar spine. Journal of Biomechanics, 32(1), 13–17. doi: 10.1016/s0021-9290(98)00129-8
6. Cholewicki, J., Juluru, K., Radebold, A., Panjabi, M. M., and McGill, S. M. (1999b). Lumbar spine stability can be augmented with an abdominal belt and/or increased intra-abdominal pressure. European Spine Journal, 8(5), 388–395. doi: 10.1007/s005860050192
7. Curtis, D. J., Woollacott, M., Bencke, J., Lauridsen, H. B., Saavedra, S., Bandholm, T., and Sonne-Holm, S. (2017). The functional effect of segmental trunk and head control training in moderate-to-severe cerebral palsy: A randomized controlled trial. Developmental Neurorehabilitation, 21(2), 91–100. doi: 10.1080/17518423.2016.1265603
8. DeMatteo, C., Law, M., Russell, D., Pollock, N., Rosenbaum, P., and Walter, S. (1992). QUEST: Quality of Upper Extremity Skills Test. Hamilton, ON: McMaster University, Neurodevelopmental Clinical Research Unit.
9. DeMatteo, C., Law, M., Russell, D., Pollock, N., Rosenbaum, P., and Walter, S. (1993). The Reliability and Validity of the Quality of Upper Extremity Skills Test. Physical and Occupational Therapy in Pediatrics, 13(2), 1–18. doi: 10.1080/j006v13n02_01
10. Dwijaya, A., & Atmaja, M. H. S. (2022). Clinical and imaging findings of klippel-trenaunay syndrome: A case report. International Journal of Health & Medical Sciences, 5(1), 145-149. https://doi.org/10.21744/ijhms.v5n1.1860
11. Eliasson, A.-C., Ullenhag, A., Wahlström, U., and Krumlinde-Sundholm, L. (2016). Mini-MACS: development of the Manual Ability Classification System for children younger than 4 years of age with signs of cerebral palsy. Developmental Medicine and Child Neurology, 59(1), 72–78. doi:10.1111/dmcn.13162
12. Haga, N., van der Heijden-Maessen, H. C., van Hoorn, J. F., Boonstra, A. M., and Hadders-Algra, M. (2007). Test-Retest and Inter- and Intrareliability of the Quality of the Upper-Extremity Skills Test in Preschool-Age Children with Cerebral Palsy. Archives of Physical Medicine and Rehabilitation, 88(12), 1686–1689. doi: 10.1016/j.apmr.2007.07.030
13. Harbourne, R. T., and Stergiou, N. (2003). Nonlinear analysis of the development of sitting postural control. Developmental Psychobiology, 42(4), 368–377. doi: 10.1002/dev.10110
14. Heyrman, L., Desloovere, K., Molenaers, G., Verheyden, G., Klingels, K., Monbaliu, E., and Feys, H. (2013). Clinical characteristics of impaired trunk control in children with spastic cerebral palsy. Research in Developmental Disabilities, 34(1), 327–334. doi:10.1016/j.ridd.2012.08.015.
15. Levitt, S. and Addison, A. (2018). Treatment of Cerebral Palsy and Motor Delay. 6th ed. London: Wiley-Blackwell; p. 214–25.
16. Guerrero, J. A. A., Moreira, J. A. M., Zambrano, M. J. Z., Rivas, F. E. C., & Pilligua, M. L. B. (2021). Applied neuroscience in early childhood and high school education. International Journal of Social Sciences and Humanities, 5(3), 223–231. https://doi.org/10.53730/ijssh.v5n3.2027
17. Marcinowski, E., Tripathi, T., Hsu, L., Westcott McCoy, S., and Dusing, S. (2019). Sitting skill and the emergence of arms-free sitting affects the

frequency of object looking and exploration. Developmental Psychobiology, 61(7), 1035–1047. doi:10.1002/dev.21854

18. Martin, S. and Kessler, M. (2021). Neurologic Interventions for Physical Therapy. 4th ed. Elsevier Saunders; p. 103-184.
19. McDowell, B. (2008). The Gross Motor Function Classification System - Expanded and Revised. Developmental Medicine and Child Neurology, 50(10), 725–725. doi:10.1111/j.1469-8749.2008.03104.x.
20. Mutlu, A., Livanelioglu, A., and Gunel, M. K. (2008). Reliability of Ashworth and Modified Ashworth Scales in Children with Spastic Cerebral Palsy. BMC Musculoskeletal Disorders, 9(1). doi:10.1186/1471-2474-9-44.
21. Palisano, R. J., Rosenbaum, P., Bartlett, D., and Livingston, M. H. (2008). Content validity of the expanded and revised Gross Motor Function Classification System. Developmental Medicine and Child Neurology, 50(10), 744–750. doi:10.1111/j.1469-8749.2008.03089.x.
22. Peeters, L. H. C., de Groot, I. J. M., and Geurts, A. C. H. (2018). Trunk involvement in performing upper extremity activities while seated in neurological patients with a flaccid trunk – A review. Gait and Posture, 62(0), 46–55. doi: 10.1016/j.gaitpost.2018.02.028.
23. Rachwani, J., Santamaria, V., Saavedra, S. L., and Woollacott, M. H. (2015). The development of trunk control and its relation to reaching in infancy: A longitudinal study. Frontiers in Human Neuroscience, 9, 94. doi:10.3389/fnhum.2015.00094.
24. Reeves, N. P., Narendra, K. S., and Cholewicki, J. (2011). Spine stability: Lessons from balancing a stick. Clinical Biomechanics. 26(4), 325–330. doi: 10.1016/j.clinbiomech.2010.11.010.
25. Rosenbaum, P. (2014). Definition and Clinical Classification. In: Cerebral Palsy: Science and Clinical Practice, 1st ed.; Dan, B., Mayston, M., Paneth, N., Rosenbloom, L., Eds.; Mac Keith Press: London, UK, 17–26.
26. Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., Dan, B. and Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy. Developmental Medicine and Child Neurology Supplement, 109(49), 8–14. doi:10.1111/j.1469-8749.2007.tb12610.x.
27. Russell, D., Wright, M., Rosenbaum, P., and Avery, L. (2021). Gross Motor Function Measure (GMFM-66 and GMFM-88) User's Manual, London: Mac Keith Press, 3rd ed.
28. Saavedra, S.L., and Goodworth, A.D. (2020). Postural Control in Children and Youth with Cerebral Palsy. In: Miller, F., Bachrach, S., Lennon, N., O'Neil, M.E. (eds) Cerebral Palsy. Springer, Cham. p 2565–2586. doi: 10.1007/978-3-319-74558-9_161
29. Santamaria, V., Rachwani, J., Saavedra, S., and Woollacott, M. (2016). Effect of Segmental Trunk Support on Posture and Reaching in Children with Cerebral Palsy. Pediatric Physical Therapy, 28(3), 285–293. doi: 10.1097/pep.0000000000000273.
30. Seyhan, K. and Kerem-Günel, M. (2019): Does stable sitting influence upper limb function in children with cerebral palsy? The Turkish Journal of Pediatrics, 61: 79-84.
31. Shumway-Cook, A. and Woollacott, M. (2016). Development of postural control. Motor control: Translating research into clinical practice. 5th ed., Baltimore, MD: Lippincott Williams and Wilkins;. p. 180-250.

32. Strobl, W. (2013). Seating. Journal of Children's Orthopaedics, 7(5), 395–399. doi:10.1007/s11832-013-0513-8
33. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). Get vaccinated when it is your turn and follow the local guidelines. International Journal of Health Sciences, 5(3), x-xv. https://doi.org/10.53730/ijhs.v5n3.2938
34. Yildiz, A., Yildiz, R., and Elbasan, B. (2018). Trunk Control in Children with Cerebral Palsy and its Association with Upper Extremity Functions. Journal of Developmental and Physical Disabilities, 30(5), 669. doi: 10.1007/s10882-018-9611-3.