Characteristics of sit-to-stand movement are associated with trunk and lower extremity selective control in children with cerebral palsy: a cross-sectional study

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Even though the effect of several factors on sit-to-stand (STS) performance of children with CP has been previously explored, the potential role of lower extremity selective control, trunk control and sitting function on the performance of STS has not been examined. This study aimed to investigate the association of trunk control and lower extremity selective motor control with STS performance in children with CP. We recruited 28 children with CP aged between 4 and 10 years whose Gross Motor Function Classification System levels were I and II and 32 age-matched typically developing (TP) children. Trunk control, sitting function, selective control of the lower extremities and STS were evaluated with Trunk Control Measurement Scale (TCMS), sitting section of Gross Motor Function Measure-88 (GMFM-88), Selective Control Assessment of the Lower Extremity (SCALE) and the STS outcomes of a force platform [weight transfer time, rising index, and center of gravity (COG) sway velocity], respectively. In all evaluations, children with CP demonstrated lower scores than TD children. A moderate correlation was found between total scores of TCMS, GMFM-88 sitting section scores and COG sway velocity during STS and a fair correlation between SCALE total scores and COG sway velocity in the CP group ($r = -0.51$, $r = -0.52$, $r = -0.39$, respectively). A fair correlation was found between SCALE total scores and the weight transfer time during STS in children with CP ($r = -0.39$). Based on these results, improving trunk and lower extremity selective control may enhance STS performance in children with CP. *International Journal of Rehabilitation Research* 45: 279–286 **Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.**

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Introduction

Children with cerebral palsy (CP) exhibit neuromuscular and musculoskeletal impairments such as spasticity, muscle contractures, loss of selective motor control, weakness [1], poor balance and impaired postural control [2]. These deficits significantly limit their functional performance, activity level and gross motor skills in daily routine tasks [3]. Among the neuromotor impairments encountered in CP, impaired postural control plays a central role, as postural control deficits in CP lead to significant limitations in daily functional activities because postural control and stability are essential requirements for voluntary movement [4].

Sit-to-stand (STS) movement is one of the motor skills frequently performed in the daily routine and requires sufficient postural control [5]. The STS task can be described as a transitional movement that involves the ability to move the body forward and upward from sitting to standing posture without losing balance [6]. It is a challenging functional task for children with CP, as it requires neuromuscular coordination, balance and postural control, which are affected negatively in those children, in addition to muscle strength [6]. Neuromuscular coordination to regulate the movement of the center of gravity (COG) into the horizontal and vertical direction and to control postural alignment both in a static position and during movement is necessary for STS task [7].

The capacity to perform STS task is an indicator of mobility level and a prerequisite for basic activities of daily living such as walking [8]. There are many studies in the literature that examine postural control during STS in children with CP and they have indicated that children with spastic CP present major postural oscillations during the STS movement and complete the task in a longer time compared with typically developing (TD) peers [2–4,9,10]. Sitting function is crucial for the child to accomplish the upright posture against gravity and also essential to provide the postural control required for the functional movements of upper extremity [11]. In two previous studies, lower extremity selective motor control has been found to be associated with Gross Motor Function Classification System (GMFCS) level and gait pattern abnormality in children with CP [12,13]. A recent study has revealed that trunk control as well as lower extremity impairments, both evaluated in sitting, are moderate to highly related to gait capacity in children with CP [14].

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Considering the functional relevance of STS and its impairments in children with CP, researchers have investigated many factors that may have an effect on STS performance, including seat height, armrests, chair type, movement speed, and body position (foot, trunk or arm) [15]. Even though the effect of several factors on STS performance of children with CP has been previously explored, the potential role of lower extremity selective motor control, trunk control and sitting function on the performance of this movement has not been explored. Therefore, the aim of this study was to investigate the relationship between trunk control, lower extremity selective motor control and sitting function with STS performance in children with CP, and also to characterize the range of impairments of the recruited CP children by comparison to TD children. We hypothesized that better trunk control, lower limb selective control and sitting function are connected to better STS performance in children with CP.

Methods

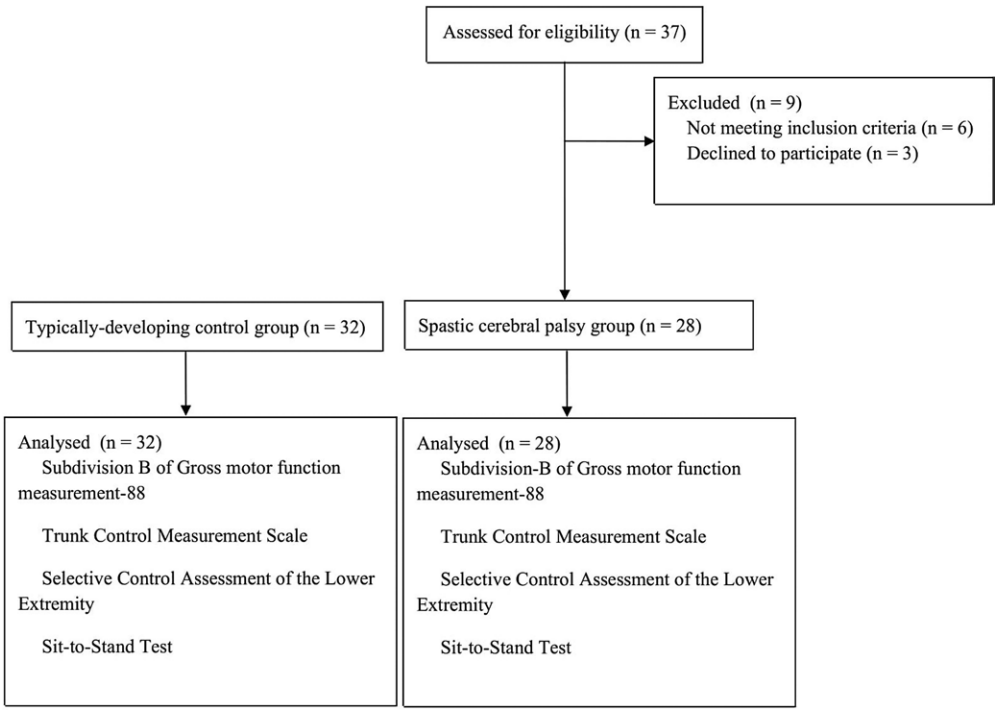
This cross-sectional, observational study was conducted between March 2019 and July 2019 at the Marmara University Medical School Pendik Education and Research Hospital. Twenty-eight children between the ages of 4 and 10 diagnosed with spastic CP (n = 12 diplegic; n = 16 hemiplegic) and 32 age-matched TD controls were included in the study. The inclusion criteria for children with CP were the following: being classified at GMFCS level I or II [16], are able to perform STS

Table 1 Characteristics of the participants

Variables	CP children (hemiplegic palsy, $n = 16$)	CP children (diplegic palsy, $n = 12$)	TD children ($n = 32$)
Sex			
Male, *n* (%)	8 (50)	8 (66.7)	12 (37.5)
Female, *n* (%)	8 (50)	4 (33.3)	20 (62.5)
Age (year) (mean ± SD)	7.2 ± 1.5	7 ± 1.5	6.8 ± 1.8
Weight (kg) (mean ± SD)	25.4 ± 6.9	25.1 ± 7.8	25.8 ± 8.4
Height (cm) (mean ± SD)	122.1 ± 8	119.3 ± 13.1	123.3 ± 11.5
GMFCS			
Level I	10	1	
Level II	6	11	

CP, cerebral palsy; TD, typically developing; GMFCS, gross motor function classification system.

Fig. 1



The study flow-chart in line with STROBE statement.

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without using lower extremity orthoses or an assistive device, able to understand the command given, and no history of orthopedic surgery or botulinum toxin injection within 6 months before the test. The exclusion criteria were as follows: children with any known accompanying systemic disorder, presence of uncontrolled epilepsy, having the lower extremity contracture, and presence of any additional neurological or orthopedic problems that may affect balance and trunk control. The characteristics of the participants are presented in Table 1.

The study was approved by the ethics committee of the Marmara University School of Medicine (approval number: 09.2019.261) and was conducted according to the Declaration of Helsinki principles. The study protocol was registered on the Clinical Trials Registry with registration number NCT04225546. Before the study, oral and written informed consents were obtained from all participants and their guardians.

Assessment

Before the evaluation, demographic data of all participants were collected through an interview. All participants were evaluated by the same experienced pediatric physiotherapist within a maximum period of 1 h and in accordance with the test instructions.

Trunk control was evaluated with Trunk Control Measurement Scale (TCMS) [17], sitting function was evaluated with sitting section of Gross Motor Function Measure-88 (GMFM-88) [18], selective control of the lower extremities function was evaluated with Selective Control Assessment of the Lower Extremity (SCALE) [19] and STS was evaluated with NeuroCom Balance Master device's STS subtest [20,21].

Table 2 Comparison of sit-to-stand parameters between cerebral palsy and typically developing children

STS parameters	CP children ($n = 28$)	TD Children ($n = 32$)	P
Weight transfer time (second)	0.34 (0.10–2.30)	0.20 (0.10–0.50)	**0.004**
Rising index (%)	25.50 (7.00–38.00)	24.00 (10.00–52.00)	0.96
COG sway velocity (degree/second)	5.10 (2.00–10.50)	3.45 (1.10–5.60)	**0.0001**

Median (minimum–maximum) values are reported.
Bold indicates statistically significant of *P* values.
COG, center of gravity; CP, cerebral palsy; max, maximum; min, minimum; STS, sit-to-stand; TD, typically developing.

TCMS is an assessment that examines sitting balance during functional activities. It measures the static and dynamic sitting balance, and dynamic sitting balance is divided into two parts as selective motion control and dynamic reach. The scale consists of 15 items in total and whose total score varies between 0 and 58, high score represents better performance. Each item was repeated three times and the best performance was recorded. Its reliability and validity have been established in children with spastic CP [17].

GMFM-88 is a measurement used to show gross motor functions in children aged 15 months to 13 years. The test contains five main sections and consists of 88 items. Scoring is done as follows according to Likert scale: 0 = can not initiate to movement, 1 = actively initiates some of the movement, 2 = partially completes the movement but can not finish it and 3 = completes the movement independently [18]. GMFM-88 is a valid and reliable test in children with CP [22]. In this study, the sitting section (20 items) of GMFM-88 was used to evaluate the sitting function.

SCALE is divided into five subscales: hip, knee, ankle, subtalar and toe joints, and evaluates the selective motor controls of the joints. To assess the score of SCALE, the child is asked to perform specific and timed isolated movements at each joint. Each joint movement is scored on a three-point ordinal scale ranging from 0 to 2 (unavailable, impaired and normal). The total score is obtained by summing the points attained from the joints. Its reliability and validity have been supported for children with spastic CP [12].

STS Test was performed via NeuroCom Balance Master (NeuroCom International, Clackamas, Oregon, USA). It is a computerized device used for the objective evaluation of postural stability. This device consists of an 18 × 60-inch force plate, which can detect the COG direction and movement speed, and a computer and software system connected to this platform. The STS is one of the tests assessing for dynamic stability. In order to ensure standardization during the evaluation, the children were positioned on a wooden block without back and arm support, with the knees flexed at 90° and the feet on the force platform. Children were asked to stand up as quickly as possible without using their hands for support and maintain an upright posture for 5 s. The test was repeated thrice, and the average weight transfer time (second), rising index (%), and COG sway velocity (degree/second) during the rising phase were calculated. The weight

Table 3 Comparison of sit-to-stand parameters between hemiplegic and diplegic cerebral palsy children

STS parameters	Hemiplegic palsy ($n = 16$)	Diplegic palsy ($n = 12$)	P
Weight transfer time (second)	0.26 (0.10–2.30)	0.57 (0.20–1.50)	**0.04**
Rising index (%)	25.06 ± 8.07	22.83 ± 7.79	0.47
COG sway velocity (degree/second)	4.35 (2.00–7.90)	5.40 (3.50–10.50)	0.16

Median (minimum–maximum) values are reported except for the Rising index (mean ± SD).
Bold indicates statistically significant of *P* values.
COG, center of gravity; CP, cerebral palsy; STS, sit-to-stand.

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transfer time calculates the time from the start of the test until the center of mass reaches the feet. The rising index calculates the amount of power exerted by the legs during the ascending phase (percent of body weight). The COG sway velocity reflects the sway of the center of mass during STS and within 5 s after standing up. STS test was performed three times. The test results were the average of the values of three trials. The NeuroCom Balance Master device has previously been shown to be a valid and reliable method of measuring postural control in children [23].

Sample size

An online calculator (https://sample-size.net/correlation-sample-size/) was used for sample size estimation. To obtain a 0.50 correlation, when assuming the type I error of 0.05 and the type II error of 0.80, the required sample size was calculated as 29.

Statistical analysis

IBM SPSS Statistics 25.0 (SPSS Inc., Chicago, Illinois, USA) was used for the statistical analysis of the findings obtained in the study. Descriptive statistics were used to describe the charecteristics of the objects. Shapiro–Wilk test was performed to assess whether numerical variables are normally distributed. For the comparison of two independent groups, independent sample *t*-test was used when normal distribution conditions were met, and Mann–Whitney U test was used when normal distribution conditions were not met. Similarly, Pearson correlation analysis was used for the normally distributed data, and Spearman correlation analysis was used for the nonnormally distributed data. A correlation coefficient was defined as little or none (0.00–0.24), fair (0.25–0.49), moderate (0.50–0.74), or good (≥0.75) [24]. Statistical significance level was accepted as $P < 0.05$.

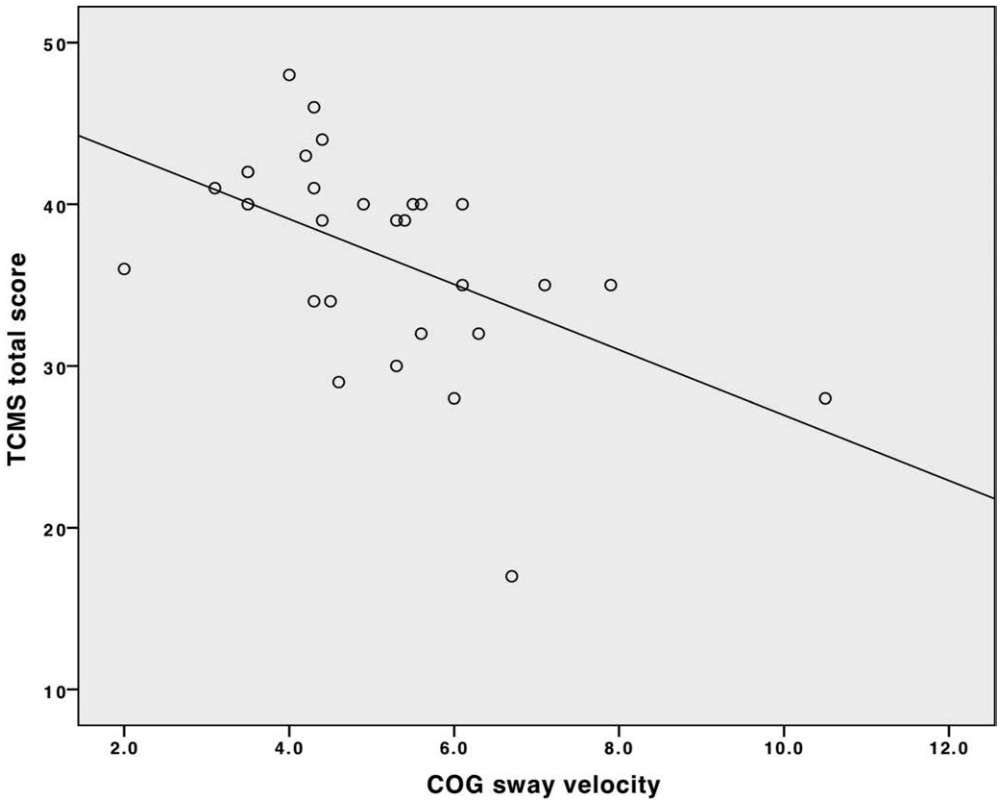
Results

Twenty-eight children with spastic CP and 32 age-matched TD children were included (Fig. 1). No significant differences were found among the groups in terms of age, sex, weight, height and BMI (Table 1).

The subscales and total TCMS scores were statistically significantly lower for the CP group than in the TD group ($P < 0.001$). Children with hemiplegic CP presented significantly better scores in all subscales of TCMS when compared with children with diplegic CP ($P < 0.05$).

For the CP group, SCALE scores were significantly lower than in the TD group ($P < 0.001$). When children with

Fig. 2



Correlation between TCMS total score and COG sway velocity. TCMS, trunk control measurement scale.

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hemiplegic and diplegic CP were compared, it was determined that the selective control of children with hemiplegic CP was better than children with diplegic CP and that there was a significant difference for SCALE's total score between the two groups ($P < 0.001$).

In the STS test, the weight transfer time of the CP group was slower compared with the TD group. The COG sway velocity of children with CP was higher than in the TD group. There was no significant difference in the rising index (Table 2). When the children with hemiplegic and diplegic CP were compared with STS test, the children with diplegic CP demonstrated slower weight transfer time than the children with hemiplegic CP. Thus, performing STS activity is more challenging for diplegic than hemiplegic CP children. There was no statistically significant difference between the children with hemiplegic and diplegic CP for other parameters of the STS ($P > 0.05$) (Table 3).

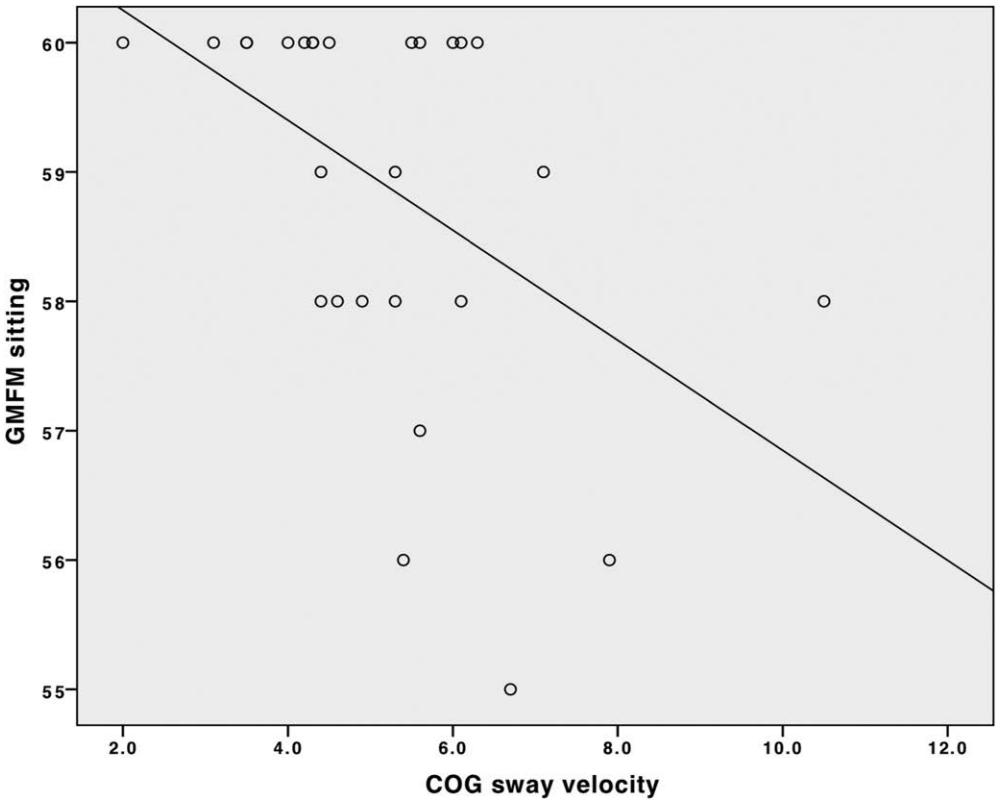
A negative moderate correlation was detected between total scores of TCMS, GMFM-88 sitting section scores and COG sway velocity ($r = -0.51$, $r = -0.52$, respectively) (Figs. 2 and 3), and a fair correlation was detected between SCALE total scores and COG sway velocity in the CP group ($r = -0.39$) (Fig. 4). A negative fair correlation was found between SCALE total scores and the weight transfer time in children with CP ($r = -0.39$). A correlation was not detected between rising index and TCMS, SCALE, and GMFM-88 sitting subscale scores (Table 4).

Discussion

The present study aimed to investigate the association between trunk control, sitting function, lower extremity selective motor control and STS performance in children with CP who could walk independently without support and to compare with TD children for descriptive purposes. In all evaluations, children with CP demonstrated lower scores than TD children. The results of this study have shown that impairments in trunk control, sitting function and selective control of the lower extremities were associated with STS performance.

The comparison between groups demonstrated that the children with CP showed poorer performance on TCMS. This indicates that even though children with CP in GMFCS levels I and II are able to perform all posture transfers, the quality and performance are questionable. This could be due to lower muscle strength, lower

Fig. 3



Correlation between GMFM sitting score and COG sway velocity. COG, center of gravity; GMFM, gross motor function measure.

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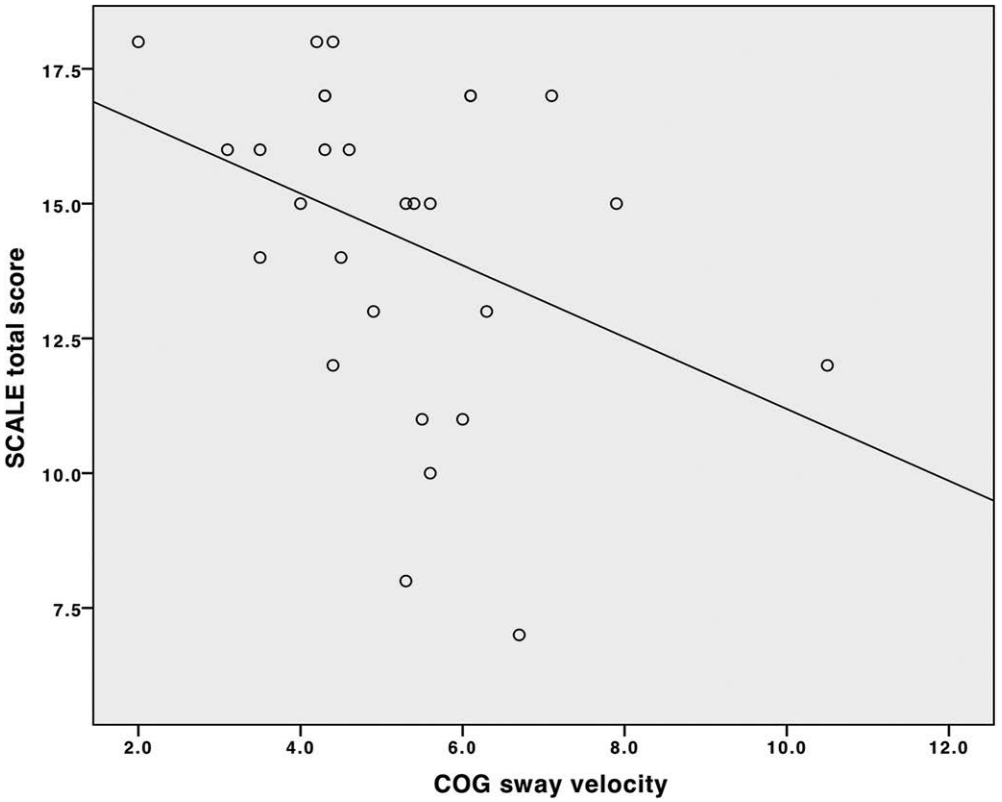
Fig. 4



Correlation between SCALE total score and COG sway velocity. COG, center of gravity; SCALE, selective control assesment of lower extremity.

Table 4 Correlations between sit-to-stand parameters and trunk control measurement scale subscales, gross motor function measure-88 sitting section and SCALE total score in children with cerebral palsy

	STS parameters		
	Weight transfer time (second)	Rising index (%)	COG sway velocity (degree/second)
TCMS subscales	*r* (*P*-value)	*r* (*P*-value)	*r* (*P*-value)
Static sitting balance	−0.09 (0.65)	−0.16 (0.41)	**−0.6** (0.001)
Dynamic sitting balance	−0.08 (0.69)	−0.03 (0.9)	−0.41 (0.03)
Dynamic reaching	−0.001 (0.1)	−0.11 (0.57)	−0.44 (0.02)
Selective motion control	−0.07 (0.73)	−0.001 (0.1)	−0.37 (0.05)
TCMS total score	−0.1 (0.63)	−0.03 (0.88)	**−0.51** (0.006)
SCALE total score	−0.39 (0.04)	−0.02 (0.91)	−0.39 (0.04)
GMFM-88 sitting section	−0.11 (0.56)	−0.26 (0.18)	**−0.52** (0.004)

The bold indicates moderate correlation.
COG, center of gravity; GMFM-88, gross motor function measure-88; SCALE, selective control assesment of lower extremity; STS, sit-to-stand; TCMS, trunk control measurement scale.

extremity motor control selectivity [14], and postural control deficits reported in this population [25]. The results of the current study indicate that selective motor control impairment of the lower limbs in children with CP (GMFCS levels I and II) was greater than in TD children, and also selective motor control of lower limbs in children with diplegic CP was poorer than in children with hemiplegic CP. Previously reported results were similar to ours [26,27].

In this study, in which we found similar results to the literature, the weight transfer time of children with CP during STS took longer than TD children, and the COG sway velocity during STS was higher in children with CP than in TD children [2,3,5,28]. The results of this study demonstrated that even though the participants with CP had mildly affected motor impairment, STS is a challenging activity that lasts longer and requires more postural control than TD children. When the children with

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hemiplegic and diplegic CP were compared in terms of the COG sway velocity during STS, there was no statistically significant difference between the two groups. This result may be due to the inclusion of only children with GMFCS levels I and II and relatively small number of participants in this study. We found that children with diplegic CP had longer weight transfer time during STS than hemiplegic children. In line with our results, it can be said that performing STS activity is more challenging in children with diplegic CP than in hemiplegic children. Similar results were present when we grouped children with CP according to their GMFCS level. Children with GMFCS level I had a shorter weight transfer time than children with GMFCS II.

The previous studies reported that lower Pediatric Balance Scale, Pediatric Evaluation of Disability Inventory scores were related to greater postural oscillations during sitting and standing balance [29] and STS execution [3,30]. A recent study concluded that the evaluation of trunk control can provide valuable information for the functional abilities of children with spastic CP [31]. The present study is the first to evaluate the relationship between trunk control in the sitting position and STS parameters. The COG sway velocity during STS is an indicator of dynamic postural stability. Therefore better trunk control may result in better dynamic stability. It was previously emphasized in the literature that loss of lower extremity selective control [2] and impaired muscle coordination [32] might affect STS activity, but no study has been conducted on this subject. The weight transfer time can be described as the time in seconds needed to shift the COG forward from a seated position to full weight bearing on both feet. Thus, it is reasonable to say that especially better ankle selective control can induce shorter times in weight transfer and lower sway velocity based on the results of this study. In line with the results of the present study, it can be suggested that therapeutic approaches to improve trunk control and lower extremity selective control might improve the performance of STS. This needs to be investigated in future interventional studies. Also, further studies should investigate the relationship between functional performance during daily life activities and trunk control, selective lower extremity control and STS performance.

To the best of our knowledge, this is the first study evaluating the relationship of trunk control and selective control of lower extremity with STS activity parameters in children with spastic CP. The objective data obtained by the computerized balance assessment provide confidence in the relationship of STS with other parameters. Another strength of the current study was the inclusion of a control group, which provided the opportunity to compare these children with TD peers. The relatively small sample size can be accounted for limitation of this study. Some of the correlations (Figs. 3 and 4) seem to be influenced by the extreme data points, the reported strength of the association should be interpreted with caution.

Conclusion

Children with mild CP have longer weight transfer time and higher COG sway velocity during STS compared with TD children. Therefore, although children with mild CP are able to walk independently, STS is still challenging for them. STS movement in children with CP is associated with trunk control, sitting function, and selective control of lower extremity. Based on the results of this study, increasing lower extremity selective control and trunk control may help to improve STS performance in children with CP.

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Clinical trials registration number: NCT04225546.

Conflicts of interest

There are no conflicts of interest.

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