Observational Study

Medicine

OPEN

Segmental trunk control and developmental parameters in children with cerebral palsy aged 24 to 42 months

A cross-sectional study

Zeynep Arıkan, PT, MSc[a,b,*], Bilge Nur Yardımcı-Lokmanoğlu, PT, PhD[c], Akmer Mutlu, PT, PhD[c], Ayşe Livanelioğlu, PT, PhD[c]

Abstract

This study aimed (1) to investigate the relationship between segmental trunk control and motor, cognitive, and language development parameters in children with cerebral palsy (CP) and (2) to compare segmental trunk control levels and motor, language, and cognitive development in children with CP and typically developing (TD) peers. A cross-sectional observational study was conducted with 63 children aged between 24 and 42 months, including those with typical and atypical development. The atypical development group included 30 children with CP ranged from Gross Motor Function Classification System levels I to V (70.0% males, median age: 29 months, interquartile range: 25–36 months), and 33 children in the TD group (69.7% males, median age: 29 months, interquartile range: 26–36 months) included age-matched. Motor, language, and cognitive development domains were evaluated using the Bayley Scales of Infant and Toddler Development, Third Edition, and the level of trunk control was evaluated using the Segmental Assessment of Trunk Control. In children with CP, segmental trunk control was found to be strongly correlated with motor, cognitive, and language development (all $P < .001$, Spearman r ranged from 0.767–0.927). Furthermore, children with CP had lower segmental trunk control levels and cognitive, language, and motor development results than their TD peers (all $P < .001$). The strong relationship between segmental trunk control levels and developmental parameters can guide clinicians and therapists in planning and implementing intervention programs designed for children with CP who have difficulties in trunk control.

Abbreviations: Bayley-III = Bayley Scales of Infant and Toddler Development-Third Edition, CP = cerebral palsy, GMFCS = Gross Motor Function Classification System, SATCo = Segmental Assessment of Trunk Control, TD = typically developing.

Keywords: cerebral palsy, cognition, language development, motor development, postural control, trunk control

1. Introduction

Cerebral palsy (CP) is a group of persistent neurodevelopmental disorders affecting mobility and posture, resulting from a lesion in the developing fetal or infant brain.[1] Although motor and postural disorders are observed in children with CP, other developmental problems, including cognitive or communicative disorders, are accompanied by some of these children.[1,2]

Postural control is the ability to control the position of the body in space to maintain balance and orientation.[3] Children with CP have poor or impaired postural control compared to their typically developing (TD) peers due to spasticity, secondary musculoskeletal disorders, reduced muscle strength, abnormal timing, sensory loss, and reduced pelvic mobility.[4,5] Postural control disorders also frequently lead to motor dysfunction in children with CP[6] and affect the development of upper limb function, the ability to maintain upright posture, hand–eye coordination, as well as cognitive, perceptual, communicative, and social competencies.[7,8]

Trunk control, which involves stabilizing and selectively moving the trunk, provides an initial framework for postural

Written informed consent forms were obtained from the parents of the children.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

The study was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Board (decision number 2020/20-43), and all procedures were performed in accordance with the Declaration of Helsinki.

[a] Graduate School of Health Sciences, Physical Therapy and Rehabilitation Division, Hacettepe University, Ankara, Türkiye, [b] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Karamanoğlu Mehmetbey University, Karaman, Türkiye, [c] Developmental and Early Physiotherapy Unit, Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Ankara, Türkiye.

** Correspondence: Zeynep Arıkan, Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Karamanoğlu Mehmetbey University, 70200 Karaman, Türkiye (e-mail: zeynepkelgokmen.1990@gmail.com).*

How to cite this article: Arıkan Z, Yardımcı-Lokmanoğlu BN, Mutlu A, Livanelioğlu A. Segmental trunk control and developmental parameters in children with cerebral palsy aged 24 to 42 months: A cross-sectional study. Medicine 2025;104:6(e41486).

Received: 6 October 2024 / Received in final form: 7 January 2025 / Accepted: 22 January 2025

http://dx.doi.org/10.1097/MD.0000000000041486

control.[3,9] In infants with TD, trunk control develops progressively in a craniocaudal direction.[10] Infants first develop control of the head against gravity, then control of the upper, middle, and lower thoracic regions, and finally the upper and lower lumbar regions.[10] Atypical development in children with CP often disrupts or delays incremental craniocaudal progression, leading to deficits in segmental trunk control that can cause severe impairments in motor function.[11–13]

Sufficient trunk control is required for infants to sit independently[2,14] and is an essential prerequisite for goal-oriented behavior and learning in the sitting position, such as visual exploration and reaching.[15] For instance, infants gain knowledge regarding the properties of an object, such as its size, weight, shape, and function, by reaching and exploring it while sitting independently.[16] This knowledge of object properties can support problem-solving skills in the cognitive domain.[16,17] A study[18] supports these findings by demonstrating that the distinctiveness of the individual in the postural control of infants during exploratory tasks is a significant determinant of subsequent attention and cognitive development. Additionally, trunk control in a seated position forms the basis of communication.[19] The first steps in being able to communicate are being able to point, look around, and explore one's environment.[20,21] Sitting provides new perceptual experiences by changing infants' perspectives and encouraging face-to-face interactions with parents.[20,22] Consequently, the acquisition of trunk control and the ability to sit independently are likely to result in new learning opportunities, which may facilitate development in other domains, such as cognition and language.[22,23] In the above-mentioned framework, poor or impaired trunk control in children with CP might have cascading effects on cognitive and language development.[24,25] Previous studies[11,13,26] in children with CP have reported that trunk control is associated with gross motor function, upper extremity function, reaching performance, and functionality in children with CP. There are studies that show relationship between motor function and segmental trunk control in children with CP and TD peers,[11,12,27] but none have specifically examined the relationship between segmental trunk control and cognitive and language development, which are different areas of development in children with CP besides motor development.

Given this background, the purposes of this study were (1) to explore the relationship between segmental trunk control and motor, language, and cognitive development parameters in children with CP and (2) to compare segmental trunk control levels and motor, language, and cognitive development in children with CP and TD peers.

2. Methods

2.1. Design and procedure

This observational cross-sectional study was performed at Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Developmental and Early Physiotherapy Unit between December 2020 and September 2022. The atypical development group included children diagnosed with CP, and the comparison group included age-matched children with typical development. The Hacettepe University Non-Interventional Clinical Research Ethics Board approved this study on January 9, 2020, with decision number 2020/20-43. The parents of all participants provided written informed consent. The study protocol adhered to the principles of the Declaration of Helsinki.

The demographic data of children with CP and TD children, including sex, age, height, weight, were obtained from the parents and records, and descriptive characteristics of children with CP, including Gross Motor Function Classification System (GMFCS) levels and type of CP were noted. The Bayley Scales of Infant and Toddler Development-Third Edition (Bayley-III) and Segmental Assessment of Trunk Control (SATCo) were used to evaluate all children aged between 24 and 42 months on the same day. All assessments lasted between 60 and 90 minutes, depending on the state of cooperation and motivation of children. The SATCo assessments were performed by an experienced physical therapist (B.N.Y.L.) with more than 10 years of experience. An experienced physical therapist (E.K.B.) assisted in the administration of the SATCo. The assistant therapist stood in front of the child and demonstrated toys (e.g., ball, sound toys) to encourage the child to stand upright and turn the head and also applied gentle nudges on the manubrium/sternum, the right and left acromion, and the seventh cervical vertebrae posteriorly. Bayley-III assessments were administered by a certified scorer with more than 5 years of experience (Z.A.). The Bayley-III was performed in a well-lit, quiet and large room to allow the child to show their abilities. The child was positioned in a chair or on the parent's lap facing a suitable table. Assessors who applied the SATCo and Bayley-III were blind to each other's scores.

2.2. Participants

This study included children aged between 24 and 42 months with typical and atypical development. The atypical development group included children diagnosed with CP and the comparison group included age-matched children with typical development. Exclusion criteria for the atypical development group were a history of recurrent seizures, use of antiepileptic or antispastic medication, and any surgical procedure in the previous 6 months to correct congenital spinal deformity. Exclusion criteria for the typical development group were children with any developmental, neurologic, or genetic problems.

2.3. Outcome measures

2.3.1. SATCo. The SATCo is a clinical tool used to evaluate a child's trunk control level.[27] This tool is an ordinal scale that evaluates trunk control in 7 segments in the cephalocaudal direction.[27,28] The child's static, active, and reactive trunk control was assessed at each segment, but not just the head segment, which was used to test the reactive control.[27]

Each child was seated on a customized bench with knees at 90° and feet supported.[27] The pelvis was maintained in a neutral alignment using a pelvic strapping technique.[27] At each designated level, the physical therapist used a horizontal manual support around the trunk to maintain an upright posture.[27] Trunk control level was represented by a score between 1 and 8. The score reflects the segment in which children lose trunk control: head = 1, upper thoracic = 2, mid-thoracic = 3, lower thoracic = 4, upper lumbar = 5, lower lumbar = 6, full trunk control = 7, and no loss of trunk control = 8.[27–29] That is, while there was a postural control response above the specified segmental level, there was no response at that level or below. A score of 7 indicated that the child had not yet achieved the full mastery of trunk control necessary for independent sitting without hand support. Conversely, a score of 8 signified complete trunk control, indicating the child's ability to sit independently. This format has been used in previous research on SATCo.[27–29] The SATCo is a valid and reliable assessment tool that can be utilized for TD infants and children with neuromotor disabilities.[27]

2.3.2. Bayley-III. The Bayley-III scale is an applied tool that evaluate the developmental parameters of infants and toddlers aged 1 to 42 months.[30] This scale includes 3 developmental domains: language (expressive and receptive), cognition, and motor (fine and gross).[30] A composite score was provided for each domain (mean = 100, SD = 15, range = 40–160).[30] The composite score was interpreted as follows: 85 and above (within 1 SD of the mean) as normal, 85 to 70 (1 SD below the mean) as mild impairment, 70 to 55 (2 SD below the mean) as moderate impairment, and below 55 (3 SD below the mean) as severe impairment.[30]

2.4. Statistical analysis

Statistical analysis was conducted using the SPSS software for Macintosh, version 25.0 (SPSS Inc., Chicago, IL). Analytical methods (Shapiro–Wilk test) and visual techniques (probability and histogram plots) were used to determine whether the data were normally distributed. Descriptive statistics were calculated as numbers and percentages for categorical variables and medians and associated interquartile ranges (25th and 75th percentiles) for ordinal and non-normally distributed variables. Statistical results were interpreted at a 95% confidence interval with a $P < .05$ (two-tailed) significance level. Spearman rank correlation (rho) was applied to analyze the correlations between the composite scores of Bayley-III's language, motor, and cognitive domains, and segmental trunk control in all conditions. The rho from 0.00 to 0.10 were insignificant correlation, from 0.10 to 0.39 as weak correlation, from 0.40 to 0.69 as moderate correlation, from 0.70 to 0.89 as strong correlation, and from 0.90 to1.00 as very strong correlation.[31] GraphPad Prism version 8.2.1 (GraphPad Software, San Diego, CA) was used to construct the correlation plots. The Mann–Whitney *U* test was used to analyze the differences between independent groups in the absence of parametric test assumptions. G*Power version 3.1 was utilized to calculate the post hoc power. The post hoc power (1-β) was over 95% with an error of 0.05, and the effect size of the current study was 1.71.

Table 1

Descriptive characteristics of all children.

Demographics	Children with CP (n = 30)	Children with TD (n = 33)
Age (months), median (IQR)	29.0 (25.0–36.0)	29.0 (26.0–36.0)
Height (cm), median (IQR)	87.5 (83.0–94.0)	90.0 (88.0–94.0)
Weight (kg), median (IQR)	13.0 (10.5–15.0)	13.0 (12.0–15.0)
Sex (male), n (%)	21 (70.0)	23 (69.7)
GMFCS levels, n (%)		
Level I	5 (16.7)	
Level II	5 (16.7)	
Level III	4 (13.3)	
Level IV	11 (36.7)	
Level V	5 (16.7)	
Type of CP, n (%)		
Spastic	27 (90.0)	
Dyskinetic	1 (3.3)	
Ataxic	0 (0)	
Mixed	2 (6.7)	
SATCo static scores, n (%)		
Head	7 (23.3)	0
Upper thoracic	1 (3.3)	0
Mid-thoracic	3 (10.0)	0
Lower thoracic	5 (16.7)	0
Upper lumbar	1 (3.3)	0
Lower lumbar	2 (6.7)	0
Full trunk control	2 (6.7)	0
No trunk control loss	9 (30.0)	33 (100.0)
SATCo active scores, n (%)		
Head	8 (26.7)	0
Upper thoracic	2 (6.7)	0
Mid-thoracic	2 (6.7)	0
Lower thoracic	5 (16.7)	0
Upper lumbar	1 (3.3)	0
Lower lumbar	1 (3.3)	0
Full trunk control	6 (20.0)	0
No trunk control loss	5 (16.7)	33 (100.0)
SATCo reactive scores, n (%)		
Upper thoracic	11 (36.7)	0
Mid-thoracic	6 (20.0)	0
Lower thoracic	1 (3.3)	0
Upper lumbar	1 (3.3)	0
Lower lumbar	4 (13.3)	0
Full trunk control	3 (10.0)	0
No trunk control loss	4 (13.3)	33 (100.0)

% = Percentage, CP = cerebral palsy, GMFCS = Gross Motor Function Classification System, IQR = interquartile range (25th and 75th percentile), n = number, SATCo = Segmental Assessment of Trunk Control, TD = typically developing.

3. Results

A total of 63 children were included in this study. This study included 30 children with CP (30.0% female, median age: 29.0 months), and 33 age-matched TD children (30.3% female, median age: 29.0 months). The distribution of children with CP according to GMFCS levels, type of CP (spastic, dyskinetic, ataxic, or mixed), and distribution of SATCo scores in the 3 different conditions of children with CP and TD are shown in Table 1. Each child in the TD group completed the SATCo with the highest possible score (full trunk control achieved).

The Spearman correlation coefficients between the Bayley-III and SATCo results in children with CP are summarized in Table 2 and Figure 1. There was a significant correlation between segmental trunk control in all 3 conditions and Bayley-III results. A very strong positive correlation was found between all static, active, and reactive controls of the SATCo and the motor domain of Bayley-III, and a positive, strong correlation was found between all conditions of the SATCo and the cognitive and language domains of Bayley-III ($P < .001$).

Comparisons of Bayley-III composite scores and SATCo scores for both groups are shown in Table 3. All Bayley-III composite scores in children with CP were significantly lower than those in their TD peers ($P < .001$). In all static, active, and reactive controls, children with CP segmental trunk control scores were significantly lower than those of their TD peers ($P < .001$). The reactive control group had the lowest median value compared to the static and active controls in children with CP, with a median value of 3.

According to the GMFCS levels of children with CP, the SATCo static, active, and reactive control scores are shown in Figure 2, and the Bayley-III motor, cognitive, and language domain composite scores are shown in Figure 3. Children with CP with high functional levels (GMFCS I and II) had the highest static, active, and reactive control scores of the SATCo (Fig. 2) and cognitive, language, and motor domain composite scores of the Bayley-III (Fig. 3), whereas children with low functional levels (GMFCS IV and V) had the lowest scores (Figs. 2 and 3).

Table 2

Spearman correlations between SATCo scores and Bayley-III composite scores in children with CP (n = 30).

Correlations coefficients (*r*)		SATCo		
		Static control	Active control	Reactive control
Bayley-III	Motor domain	0.920**	0.927**	0.926**
	Cognitive domain	0.800**	0.772**	0.767**
	Language domain	0.839**	0.803**	0.815**

Bayley-III = Bayley Scales of Infant-Toddler Development-3rd Edition, SATCo = Segmental Assessment of Trunk Control.

** All values are significant at $P < .001$.

4. Discussion

In our current study, segmental trunk control and developmental parameters of children with CP and TD children aged between 24 and 42 months were examined. In addition to the strong correlation between SATCo (static, active, and reactive control) and motor development, our study demonstrated a strong correlation between SATCo and domains of cognitive and language development in children with CP. Furthermore, children with CP had lower segmental trunk control levels and cognitive, language, and motor development results than their TD peers, consistent with our clinical observations.

Any problem in the neuromotor system may affect postural control, which is a significant element of motor development.[32] Trunk postural control is linked to the acquisition of upright gross motor abilities, including independent sitting and standing.[33] Butler et al[27] found a strong relationship between the sitting component of the Gross Motor Function Measure (GMFM) and SATCo (R = 0.731–0.833) in 24 children with neuromotor disorders with an average age of 10 years and 4 months, 21 of whom had CP. Our present study showed a stronger correlation (R = 0.920–0.927) between motor development and trunk control in children with CP than that a previous study by Butler et al.[27] A possible explanation for this stronger correlation could be that this study included younger children with narrower age ranges. Montero-Mendoza et al conducted a study evaluating sitting skills requiring trunk control with the Level of Sitting Scale and gross motor functions with the GMFCS level in 139 children with CP and found a strong correlation between the findings of the 2 assessments.[34] In another study, Curtis et al[11] reported that a one-level increase in SATCo can have an effect of approximately 0.5 to 11 points on the GMFM in children with CP between the ages of 1 and 14 years. As a different population, in a study[35] conducted on infants and toddlers with Down syndrome, the authors found a high relationship between SATCo and GMFM and stated that the trunk control is important in determining gross motor function. The significant correlation we found between motor development and segmental trunk control in the current study aligns with the findings of previous studies[11,27,35] that evaluated only the gross motor function of developmental parameters. In contrast to these studies,[11,27,35] our study used the Bayley-III assessment tool, which assesses both gross and fine motor parameters. Therefore, our study showed that segmental trunk control might be related not only to gross motor development but also to fine motor development in children with CP.

A stable trunk helps the child develop language and cognitive skills, while also supporting adaptation to the environment.[3] Children with CP may not always be able to explore and interact with their environment like their TD peers because of impaired trunk control,[23] which may lead to delays in cognition and language later in life.[25,36,37] An important finding of our study is that children with CP who have impaired or poor trunk control also have poor cognitive and language development, which confirms the information mentioned above.[3,23,25,36,37] One possible explanation for this may be that within the framework of the embodied cognition approach,[38] children's poor trunk control while sitting may not allow them to receive and produce sensory information that forms the basis of cognitive and language development.[36,39]

The development of independent sitting, which requires segmental trunk control, changes learning opportunities and may have cascading effects on cognitive and language development.[25] Previous studies have reported a positive relationship between sitting skills and attention-cognitive abilities in

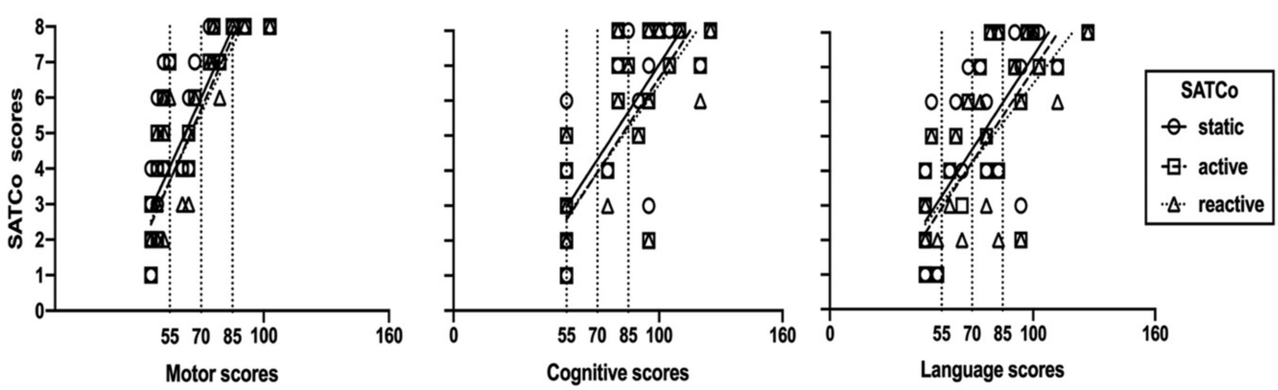

Figure 1. Correlation graphs of SATCo (static, active, reactive condition) scores and Bayley-III (motor, cognitive, language development) scores. The numbers on the y-axis are the SATCo trunk segmental levels in which children lose trunk control: 1 = head, 2 = upper thoracic, 3 = mid-thoracic, 4 = lower thoracic, 5 = upper lumbar, 6 = lower lumbar, 7 = full trunk control, and 8 = no loss of trunk control. Bayley-III = Bayley Scales of Infant-Toddler Development-3rd Edition; SATCo = Segmental Assessment of Trunk Control.

Table 3

Comparison of Bayley-III composite scores and SATCo scores of both groups.

		Children with CP (n = 30) Median (IQR)	Children with TD (n = 33) Median (IQR)	*Z*	*P*
Bayley-III	Cognitive domain	55.0 (55.0–95.0)	110.0 (105.0–120.0)	–5.623	<.001
	Language domain	66.5 (47.0–91.0)	106.0 (97.0–115.0)	–5.590	<.001
	Motor domain	52.0 (46.0–74.0)	100.0 (94.0–107.0)	–6.353	<.001
SATCo	Static control	4.0 (1.75–8.0)	8.0 (8.0–8.0)	–5.692	<.001
	Active control	4.0 (1.0–7.0)	8.0 (8.0–8.0)	–6.439	<.001
	Reactive control	3.0 (2.0–6.25)	8.0 (8.0–8.0)	–6.638	<.001

Bayley-III = Bayley Scales of Infant-Toddler Development-3rd Edition, CP = cerebral palsy, IQR = interquartile range (25th and 75th percentile), n = number, *P* = statistical significance, SATCo = Segmental Assessment of Trunk Control, TD = typically developing.

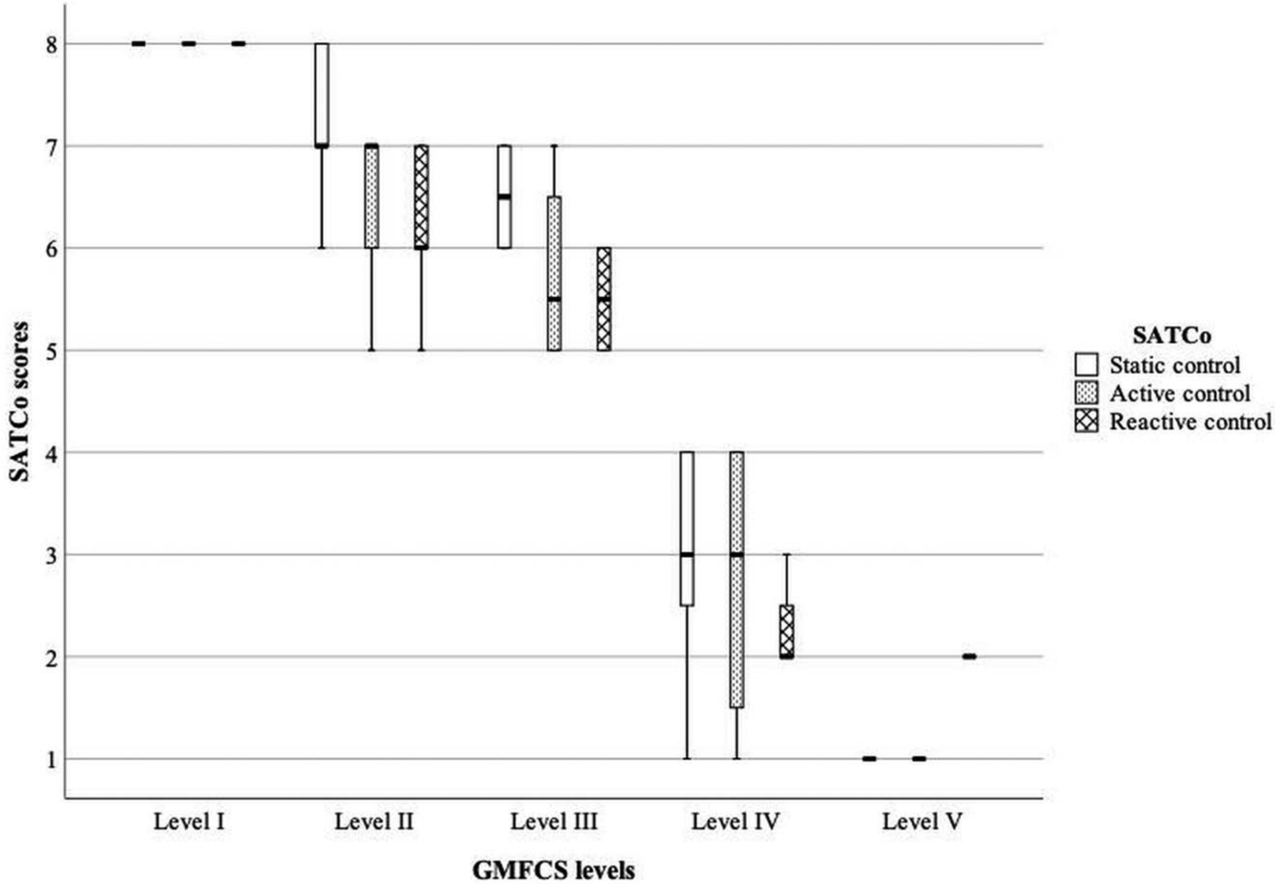

Figure 2. SATCo scores (static, active, reactive) of children with CP according to the GMFCS levels. The solid line represents the medians of the group at each level. CP = cerebral palsy, GMFCS = Gross Motor Function Classification System, SATCo = Segmental Assessment of Trunk Control.

children with CP[24] and motor delay.[40] To our knowledge, there has been no research, apart from the results of our study, that explores the relationship between language development and segmental trunk control in children with CP. In contrast, Oudgenoeg-Paz et al[41] found a positive association between the age at which independent sitting skills were acquired and productive language skills from 16 to 28 months, and Libertus and Violi[22] found a positive correlation between increased sitting time and receptive language skills at 10 and 14 months in children with TD. The current study did not directly investigate the relationship between developmental parameters and sitting skills, but it revealed an association between segmental trunk control, which affects sitting skills, and cognitive and language development. Impaired or poor trunk control in children with CP may lead to difficulties in cognitive and language development, and this information may be valuable for clinicians and future studies.

Consistent with previous studies,[12,42] our study found that the level of segmental trunk control in children with CP varied according to the severity of involvement, and these children had poor trunk control, as expected, compared to children with TD. A possible explanation for this may be that craniocaudal progression of trunk control during normal development[29] is impaired or delayed during atypical development in children with CP.[2]

Development is a multidimensional and dynamic process that includes cognitive, language, and motor development.[43] In this dynamic process, children with severe motor impairments have different experiential backgrounds than those whose movements are not restricted.[44] It is likely that there is an interaction between brain lesions and inadequacy of experience.[44,45] In addition, more than 1 developmental domain may be affected in children with CP due to general brain impairment.[37,46] Factors such as functional mobility and general brain impairment may result in children with CP performing lower in motor, language, and cognitive developmental domains than their TD peers. Rich et al[47] reported that children with hemiparetic CP had lower performance in fine motor skills of the less affected hand than their TD peers, and Nyman et al[48] reported that a group with neurodevelopmental disabilities, 6 of whom had CP, had a significantly lower prevalence of canonical babbling than children with TD. A recent systematic review and meta-analysis[49] revealed that children with CP showed deficits in executive functioning, a component of the cognitive domain, compared to their TD peers. As expected, in line with the results of these studies,[47–49] we showed that children with CP showed lower performance in motor, cognitive, and language development domains than their TD peers.

4.1. Limitations

The present study had several limitations. First, the distribution according to the GMFCS levels was not homogeneous; therefore, we cannot generalize this relationship to all children with CP. Another limitation is that 90% of the children with CP included in our study had spastic-type CP; therefore, it may not be correct to generalize these results to dyskinetic, ataxic, and mixed clinical types. Therefore, future studies should be conducted with a larger sample size to provide an even distribution across GMFCS levels and types of CP to support the current findings.

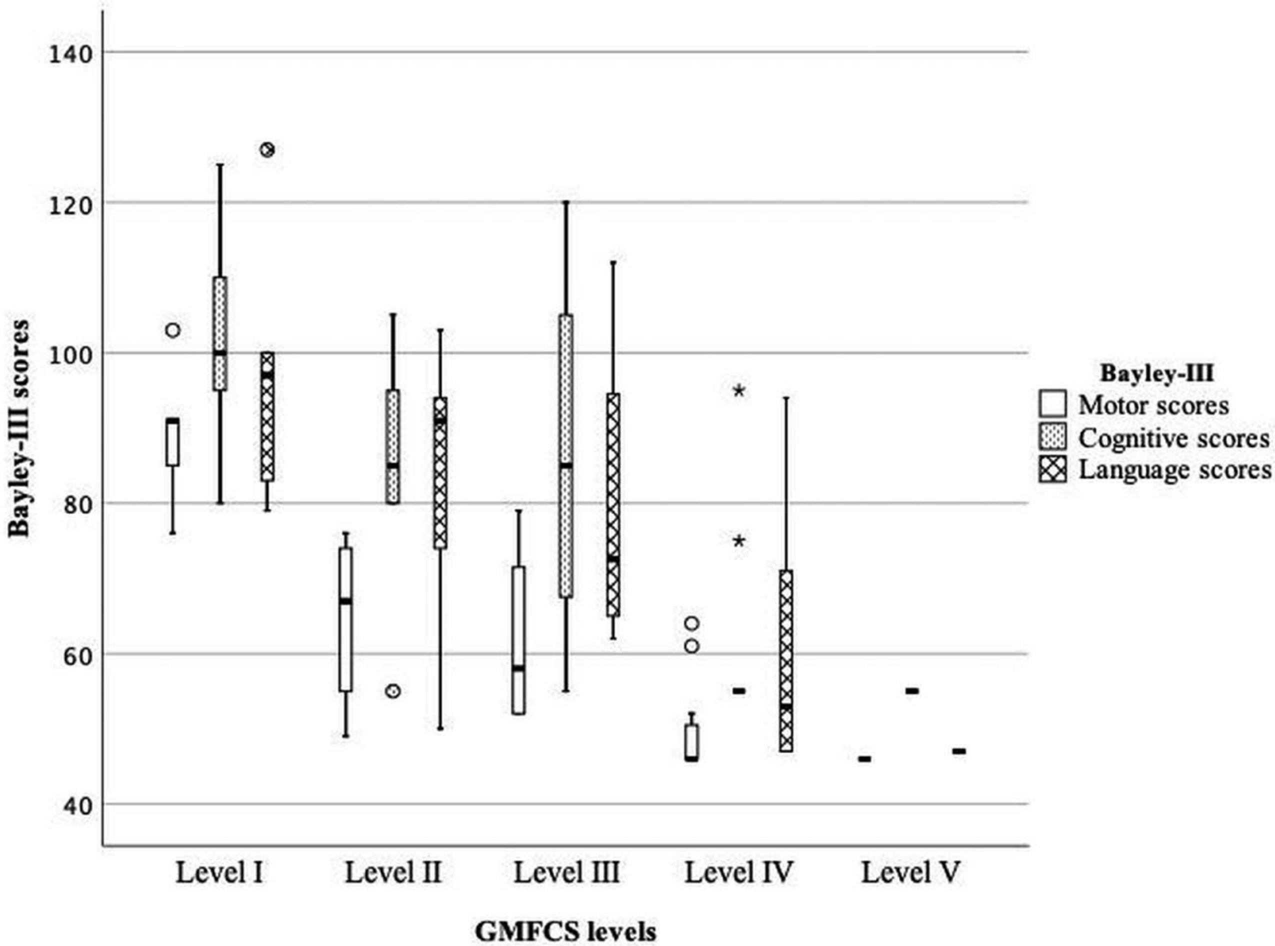

Figure 3. Bayley-III scores (motor, cognitive, language) of children with CP according to the GMFCS levels. The solid line represents the median for each group at each level. The boxes and whiskers represent the spread of data within the GMFCS levels. Asterisks represent outliers in the GMFCS levels. Bayley-III = Bayley Scales of Infant-Toddler Development-3rd Edition, CP = cerebral palsy, GMFCS = Gross Motor Function Classification System.

5. Conclusion

In conclusion, this study revealed that segmental trunk control is strongly related to motor development as well as cognitive and language development in children with CP. In addition, segmental trunk control levels and cognitive, language, and motor development results of children with CP were lower than those of their TD peers. We believe that this strong relationship will guide clinicians and therapists in planning and implementing intervention programs for children with CP who have difficulties in trunk control.

Acknowledgments

We would like to thank our colleague Esra Kınacı-Biber, PT, MSc for her support during the study.

Author contributions

Conceptualization: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu, Akmer Mutlu, Ayşe Livanelioğlu.
Formal analysis: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu, Akmer Mutlu.
Investigation: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu.
Methodology: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu, Akmer Mutlu, Ayşe Livanelioğlu.
Project administration: Ayşe Livanelioğlu.
Resources: Zeynep Arıkan.
Supervision: Akmer Mutlu.
Visualization: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu, Akmer Mutlu, Ayşe Livanelioğlu.
Writing – original draft: Zeynep Arıkan.
Writing – review & editing: Zeynep Arıkan, Bilge Nur Yardımcı-Lokmanoğlu, Akmer Mutlu, Ayşe Livanelioğlu.

References

[1] Goldsmith S, McIntyre S, Blair E, Smithers-Sheedy H, Badawi N, Hansen M. Cerebral Palsy: Epidemiology. In: Eisenstat DD, Goldowitz D, Oberlander TF, Yager JY, eds. Neurodevelopmental Pediatrics: Genetic and Environmental Influences. Springer; 2023:479–495.
[2] Hadders-Algra M, Carlberg EB. Postural control: a key issue in developmental disorders. Clinics in Developmental Medicine No. 179. London: Mac Keith Press; 2008:22–73.
[3] Massion J. Postural control systems in developmental perspective. Neurosci Biobehav Rev. 1998;22:465–72.
[4] van der Heide JC, Fock JM, Otten B, Stremmelaar E, Hadders-Algra M. Kinematic characteristics of postural control during reaching in preterm children with cerebral palsy. Pediatr Res. 2005;58:586–93.
[5] Dewar R, Love S, Johnston LM. Exercise interventions improve postural control in children with cerebral palsy: a systematic review. Dev Med Child Neurol. 2015;57:504–20.
[6] Pierret J, Beyaert C, Vasa R, Rumilly E, Paysant J, Caudron S. Rehabilitation of postural control and gait in children with cerebral palsy: the beneficial effects of trunk-focused postural activities. Dev Neurorehabil. 2023;26:180–92.
[7] Ju Y-H, You J-Y, Cherng R-J. Effect of task constraint on reaching performance in children with spastic diplegic cerebral palsy. Res Dev Disabil. 2010;31:1076–82.

[8] Redstone F, West JF. The importance of postural control for feeding. Pediatr Nurs. 2004;30:97–100.
[9] Verheyden G, Vereeck L, Truijen S, et al. Trunk performance after stroke and the relationship with balance, gait and functional ability. Clin Rehabil. 2006;20:451–8.
[10] Rachwani J, Santamaria V, Saavedra SL, Wood S, Porter F, Woollacott MH. Segmental trunk control acquisition and reaching in typically developing infants. Exp Brain Res. 2013;228:131–9.
[11] Curtis DJ, Butler P, Saavedra S, et al. The central role of trunk control in the gross motor function of children with cerebral palsy: a retrospective cross-sectional study. Dev Med Child Neurol. 2015;57:351–7.
[12] Saavedra SL, Woollacott MH. Segmental contributions to trunk control in children with moderate-to-severe cerebral palsy. Arch Phys Med Rehabil. 2015;96:1088–97.
[13] Santamaria V, Rachwani J, Saavedra SL, Woollacott MH. The impact of segmental trunk support on posture and reaching in children with cerebral palsy. Pediatr Phys Ther. 2016;28:285.
[14] Pin TW, Butler PB, Cheung H-M, Shum SL-F. Relationship between segmental trunk control and gross motor development in typically developing infants aged from 4 to 12 months: a pilot study. BMC Pediatr. 2019;19:1–9.
[15] Rochat P, Bullinger A. Posture and functional action in infancy. In: Vyt A, Bloch H, Bornstein MH, eds. Early child development in the French tradition: Contributions from current research. Lawrence Erlbaum Associates; 1994:15–34.
[16] Gibson EJ. Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge. Ann Rev Psychol. 1988;39:1–42.
[17] Lawson KR, Ruff HA. Early focused attention predicts outcome for children born prematurely. J Dev Behav Pediatr. 2004;25:399–406.
[18] Wijnroks L, van Veldhoven N. Individual differences in postural control and cognitive development in preterm infants. Infant Behav Dev. 2003;26:14–26.
[19] Bhat A, Galloway J, Landa R. Relation between early motor delay and later communication delay in infants at risk for autism. Infant Behav Dev. 2012;35:838–46.
[20] Iverson JM. Developing language in a developing body: The relationship between motor development and language development. J Child Lang. 2010;37:229–61.
[21] LeBarton ES, Iverson JM. Associations between gross motor and communicative development in at-risk infants. Infant Behav Dev. 2016;44:59–67.
[22] Libertus K, Violi DA. Sit to talk: relation between motor skills and language development in infancy. Front Psychol. 2016;7:475.
[23] Kretch KS, Koziol NA, Marcinowski EC, et al. Infant posture and caregiver-provided cognitive opportunities in typically developing infants and infants with motor delay. Dev Psychobiol. 2022;64:e22233.
[24] Surkar SM, Edelbrock C, Stergiou N, Berger S, Harbourne R. Sitting postural control affects the development of focused attention in children with cerebral palsy. Pediatr Phys Ther. 2015;27:16–22.
[25] Kretch KS, Marcinowski EC, Hsu LY, et al. Opportunities for learning and social interaction in infant sitting: effects of sitting support, sitting skill, and gross motor delay. Dev Sci. 2023;26:e13318.
[26] Kim DH, An D-H, Yoo W-G. The relationship between trunk control and upper limb function in children with cerebral palsy. Technol Health Care. 2018;26:421–7.
[27] Butler P, Saavedra MS, Sofranac MM, Jarvis MS, Woollacott M. Refinement, reliability and validity of the segmental assessment of trunk control (SATCo). Pediatr Phys Ther. 2010;22:246.
[28] Pin TW, Butler PB, Cheung H-M, Shum SL-F. Segmental assessment of trunk control in infants from 4 to 9 months of age-a psychometric study. BMC Pediatr. 2018;18:1–8.
[29] Pin TW, Butler PB, Cheung H-M, Shum SL-F. Longitudinal development of segmental trunk control in full term and preterm infants-a pilot study: part I. Dev Neurorehabil. 2020;23:185–92.
[30] Del Rosario C, Slevin M, Molloy EJ, Quigley J, Nixon E. How to use the Bayley scales of infant and toddler development. Arch Dis Child Educ Pract Ed. 2021;106:108–12.
[31] Schober P, Boer C, Schwarte LA. Correlation coefficients: appropriate use and interpretation. Anesth Analg. 2018;126:1763–8.
[32] da Silva KM, Pádua RF, de Sá CDSC, de Paula Carvalho R. Relationship between trunk control and gross motor development of infants in the first year of life: a systematic review. Early Hum Dev. 2024;189:105929.
[33] Westcott SL, Burtner P. Postural control in children: implications for pediatric practice. Phys Occup Ther Pediatr. 2004;24:5–55.
[34] Montero Mendoza S, Gómez-Conesa A, Hidalgo Montesinos MD. Association between gross motor function and postural control in sitting in children with Cerebral Palsy: a correlational study in Spain. BMC Pediatr. 2015;15:1–7.
[35] Flores M, Mitchell K, Bickley C, Da Silva CP. Psychometric properties of segmental assessment of trunk control in infants and toddlers with Down Syndrome. Pediatr Phys Ther. 2020;32:250–6.
[36] Oudgenoeg-Paz O, Leseman PP, Volman M. Exploration as a mediator of the relation between the attainment of motor milestones and the development of spatial cognition and spatial language. Dev Psychol. 2015;51:1241.
[37] Oudgenoeg-Paz O, Mulder H, Jongmans MJ, van der Ham IJ, Van der Stigchel S. The link between motor and cognitive development in children born preterm and/or with low birth weight: a review of current evidence. Neurosci Biobehav Rev. 2017;80:382–93.
[38] Adolph KE, Hoch JE. Motor development: embodied, embedded, enculturated, and enabling. Annu Rev Psychol. 2019;70:141–64.
[39] Smith L, Gasser M. The development of embodied cognition: six lessons from babies. Artif Life. 2005;11:13–29.
[40] Harbourne RT, Ryalls B, Stergiou N. Sitting and looking: a comparison of stability and visual exploration in infants with typical development and infants with motor delay. Phys Occup Ther Pediatr. 2014;34:197–212.
[41] Oudgenoeg-Paz O, Volman MCJ, Leseman PP. Attainment of sitting and walking predicts development of productive vocabulary between ages 16 and 28 months. Infant Behav Dev. 2012;35:733–6.
[42] Hansen L, Erhardsen KT, Bencke J, Magnusson SP, Curtis DJ. The reliability of the Segmental Assessment of Trunk Control (SATCo) in children with cerebral palsy. Phys Occup Ther Pediatr. 2018;38: 291–304.
[43] Arıkan Z, Şahan AK, Mutlu A. Examination of developmental parameters and oral motor development in infancy (Bebeklik döneminde gelişim parametreleri ve oral motor gelişimin incelenmesi). Turkiye Klinikleri J Pediatr. 2020;29:27–38.
[44] Stadskleiv K. Cognitive functioning in children with cerebral palsy. Dev Med Child Neurol. 2020;62:283–9.
[45] Bottcher L. Children with spastic cerebral palsy, their cognitive functioning, and social participation: a review. Child Neuropsychol. 2010;16:209–28.
[46] Bottcher L, Flachs EM, Uldall P. Attentional and executive impairments in children with spastic cerebral palsy. Dev Med Child Neurol. 2010;52:e42–7.
[47] Rich TL, Menk JS, Rudser KD, Feyma T, Gillick BT. Less-affected hand function in children with hemiparetic unilateral cerebral palsy: a comparison study with typically developing peers. Neurorehabil Neural Repair. 2017;31:965–76.
[48] Nyman A, Lohmander A. Babbling in children with neurodevelopmental disability and validity of a simplified way of measuring canonical babbling ratio. Clin Linguist Phon. 2018;32:114–27.
[49] Zimonyi N, Kói T, Dombrádi V, et al. Comparison of executive function skills between patients with cerebral palsy and typically developing populations: a systematic review and meta-analysis. J Clin Med. 2024;13:1867.