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Cerebral palsy and executive functions: Inhibitory control and cognitive flexibility skills

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Abstract

Executive functions (EFs) are an umbrella term that includes various cognitive abilities (such as inhibition, planning, goal-setting, monitoring, and shifting). There is common agreement that there are three main EFs: inhibitory control, cognitive flexibility, and working memory. Further studies have reported that compared to typically developing peers, children with cerebral palsy (CP) show deficits in EF skills. This study aims to evaluate children with CP's inhibitory control and cognitive flexibility skills. Forty children with CP between the ages of 7–13 were included in the present study. EF scores of the CP group were compared with scores of typically developing peers matched one-to-one by age and sex. The EF skills were evaluated with Wisconsin card sorting test (WCST), Stroop color–word test (SCWT) TBAG Form, and executive function behavior rating scale parent form (BRIEF-P). It was determined that there was a significant difference in the WCST total trials, total errors, categories completed, and percent conceptual level responses scores ($p < .05$); SCWT-TBAG scores ($p < .05$), and BRIEF-P all scores ($p \leq .01$) of children with CP. The results of this study suggest that children with CP are disadvantaged with EF skills in terms of inhibitory control and cognitive flexibility.

KEYWORDS

cerebral palsy, children, cognitive flexibility, executive functions, inhibitory control

1 | INTRODUCTION

Cerebral palsy (CP) is a group of disorders that result from nonprogressive damage to the developing fetal or infant brain, leading to movement and posture impairments and causing activity limitations (Rosenbaum et al., 2007). Although brain damage is nonprogressive, the clinical manifestations may change as a result of age, growth, and central nervous system development (Weierink et al., 2013). According to The Surveillance of CP in Europe, CP is separated into spastic, dyskinetic, ataxic subtypes. It has been observed that approximately 70%–80% of individuals with CP exhibit clinical features consistent with the spastic subtype (Krigger, 2006). CP is typically characterized as a motor development disorder, but it encompasses a wide range of impairments beyond movement disorders. Individuals with CP often experience challenges related to sensory perception, cognitive, communicative, and behavioral problems (Bax et al., 2007; Fluss & Lidzba, 2020). Disability and functional limitations are often determined by comorbidities such as epilepsy, scoliosis, auditory and visual deficits, mental disability, and behavioral challenges (Shevell et al., 2013). These nonneuromotor comorbidities can be the primary reason for the burden of care and healthcare usage for individuals with CP and their families (Shevell, 2009).

CP has long been considered from a medical perspective, almost special priority is given to motor pathology (Cabezas & Carriedo, 2020). Recently studies are increasingly highlighting cognitive disorders in children with CP. Recent reviews have reported that children with spastic CP frequently experience challenges with attention and executive function (EF) skills (Fluss & Lidzba, 2020; Laporta-Hoyos et al., 2019; Stadskleiv, 2020; Stadskleiv et al., 2018). EF skills have been defined as an umbrella term that includes high-level cognitive processes involved in goal-directed, flexible, and adaptive behavior and the top-down regulation of cognition and behavior that are especially actuated in difficult and complex situations (Anderson, 2001; Bodimeade et al., 2013; Diamond, 2013; Freire & Osório, 2020; Goldstein et al., 2014; Roebers, 2017; Zelazo, 2020). EFs enable individuals to manage and change their actions at their sole discretion considering the consequences of each behavior (e.g., “I can't watch TV more because I need to study for next week's exam”) (Botvinick et al., 2001; Pereira et al., 2018). And play important roles in purposeful action, emotion regulation, social participation, functional independence, quality of life, and success in school (Bottcher, 2010; Dawson & Guare, 2014; Federica & Mellone, 2022; Mousavi et al., 2022; Sakash et al., 2018; Voyer et al., 2018; Zelazo, 2020). EFs, which have many different definitions or features, are mainly examined under three main headings: working memory, inhibitory control, and cognitive flexibility (Diamond, 2013).

Working memory is defined as an interface between perception, short-term memory, long-term memory, and target-specific actions (Diamond, 2013). It plays a vital role in oral communication, listening and reading comprehension, written expression, and correct long-term learning (Meltzer, 2014). Working memory begins to develop in infancy and continues to develop throughout in mid-late childhood (Anderson et al., 2010). Inhibitory control is defined as the central component of EFs (Barkley, 1997). Generally, it focuses on the ability to actively inhibit or delay a dominant response to achieve a goal (Morasch & Bell, 2011). It involves controlling attention, behavior, thoughts, or emotions and doing what is more appropriate or necessary to override a strong inner predisposition or an attractive external stimulus (e.g., suppressing an impulsive utterance) (Diamond, 2013; Zelazo, 2020). Inhibitory control begins to develop from the end of the first year of age and continues to develop rapidly across the toddler period and into the preschool years (Anderson et al., 2010; Diamond, 2006; Morasch & Bell, 2011). Cognitive flexibility is closely related to creativity and changing set up. It represents the ability to adapt to changing conditions. The ability to change plans in the face of obstacles, setbacks, new information, or faults (Dawson & Guare, 2014). Cognitive flexibility develops rapidly in the preschool period in parallel with the development of neural networks of the prefrontal cortex, and this development continuously increases well into adolescence. (Buttelman & Karbach, 2017).

Studies show that children with spastic CP have deficits in inhibitory control (Bottcher et al., 2010; Cabezas & Carriedo, 2020; Caillies et al., 2012; Christ et al., 2003; Li et al., 2014), cognitive flexibility (Bodimeade et al., 2013; Crichton et al., 2020), planning (Bodimeade et al., 2013; Stadskleiv et al., 2014), working memory (Di Lieto et al., 2017; Løhaugen et al., 2014; Van Rooijen et al., 2016), and information processing (Bottcher et al., 2010;

Laporta-Hoyos et al., 2019). On the other hand, children with dyskinetic CP tend to have mild EF deficits (Fluss & Lidzba, 2020) and normal comprehension and visual perception (Stadskleiv, 2020). Some of these studies have evaluated the EF skills in children with CP using clinical measures and compared them to typically developing peers (Bodimeade et al., 2013; Crichton et al., 2020; Freire & Osório, 2020; Laporta-Hoyos et al., 2019). Some of them have evaluated EF skills using behavior rating scales (in daily life skills) (Sørensen et al., 2016; Laporta-Hoyos et al., 2022; Muriel Molano et al., 2015). Only a few studies have used both clinical measures and behavioral ratings of EF together (Bottcher et al., 2010; Mousavi et al., 2022; Whittingham et al., 2014). Additionally, several studies have investigated the effectiveness of various interventions including computer-based cognitive training and physical exercise in improving the EF performance of children with CP (Piovesana et al., 2017; Lakes et al., 2019; García-Galant, et al. 2020; Di Lieto et al., 2021). While the studies have reported improvements in EF skills following these interventions, further research is needed to determine the most effective interventions and to better understand the underlying mechanisms of EF deficits in CP.

Poor inhibitory control and mental flexibility skills can be impacts individuals with CP in all aspects of daily life. For example, Roostaei et al. (2021) highlight the challenges that people with CP face when engaging in dual-tasking activities. Dual-task refers to the ability to perform two or more tasks simultaneously, which is a common occurrence in our daily lives (McIsaac et al., 2015; Okur et al., 2022). The tasks could be either motor or cognitive tasks (Huang & Mercer, 2001). Inhibitory control enables individuals to suppress automatic or prepotent responses, which is important for successful dual-task performance (Verbruggen & Logan, 2008). The sensory-motor disorders as a result of early brain damage may often expose children with CP to dual tasks (Reilly et al., 2008). The systematic review and meta-analysis of observational studies show that verbal fluency tasks are more likely to lead to a decline in walking speed compared to discrimination/decision-making tasks and mental tracking tasks (Such as maintaining a straight posture while reading) (Roostaei et al., 2021). The study concluded that the effects of dual-task conditions were more pronounced in children with CP, and that walking and balance performance deteriorated under these conditions. This makes it necessary to look at CP from a multifaceted perspective.

The International Classification of Functioning, Disability, and Health (ICF) (World Health Organization, 2007) recommends considering personal and environmental factors as well as body structure and functions for activity and participation. In the traditional CP rehabilitation model, poor attention is paid to the cognitive characteristics of individuals (Cabezas & Carriedo, 2020). Extending patient outcomes beyond sensory-motor disorders to include activity and participation is a valuable and patient-centered approach to CP treatment (Eslinger, 2022), as it is recommended by ICF. Evaluation of EFs in CP will allow the individual's rehabilitation plan to be formulated in a way that will affect all aspects of life as recommended in the ICF. Therefore, clinicians working with CP should consistently ask about nonmotor disabilities for appropriate assessment, rehabilitation, and guidance (Fluss & Lidzba, 2020).

In summary, individuals with CP are at risk for EF deficits, which can have a significant impact on their daily functioning. Early identification and intervention can help to improve EF skills and mitigate the impact of CP on cognitive functioning. In the narrative review of cognitive and academic profiles in children with CP, Fluss and Lidzba (2020) suggest that in high-risk infants or those diagnosed with early CP, regular general evaluation from early childhood to late childhood, when cognitive impairment may occur. They also suggest that elements of attention and executive deficit should be sought with the neuropsychological assessment tools to offer early guidance to parents and teachers who are often unprepared and confused by children with CP. It is also important to note that EF deficits in CP are not a homogeneous group. Different types of CP and different levels of impairment can result in varying degrees and patterns of EF deficits. Therefore, personalized assessment and intervention strategies are needed to address the specific needs of each individual with CP. Further research is needed to better understand the underlying mechanisms of EF deficits in CP and to identify the most effective interventions for this population (Cabezas & Carriedo, 2020; Mousavi et al., 2022; Sakash et al., 2018).

In this context, the main aim of our study is to determine whether the neuropsychological assessment (Inhibitory control and mental flexibility) and daily life skills of EFs of children with spastic CP are different from the reference group. Additionally, the aim is to establish whether the correlation findings between these two measurements provide clinical insight for evaluating EF in children with CP.

2 | METHOD

2.1 | Participants

A total of 130 children and adolescents with CP who had received a rehabilitation program at the Physical Medicine and Rehabilitation clinic of Kocaeli University Medical Faculty were evaluated. Children diagnosed with spastic CP between the age of 7–13, who volunteered with the permission of their parents, were included. Children who could not read, did not know primary colors, had severe dystonia or epileptic seizures, and had mental retardations or other neurodevelopmental disorders were excluded. The EFs scores of the children with spastic CP (CP group) were compared with those of reference group. The CP group was matched one-to-one by age and sex with their typically developing peers in the normative data. The reference group was established using the EF normative data scores of Turkish children. Table 1 presents the demographic characteristics of the CP group.

To evaluate the EF skills, Wisconsin card sorting test (WCST), Stroop color–word test (SCWT) TBAG Version, and executive function behavior rating scale parent form (BRIEF-P) were used. The study protocol was approved by the Kocaeli University Faculty of Medicine Ethics Committee with the project number KÜ GOKAEK 2017/155 and dated 07/06/2017.

2.2 | Materials

The study involves EFs evaluating measurement tools in the BİLNOT-Children neuropsychological test battery (Karakaş & Doğutepe-Dinçer, 2011), which was standardized for a sample of children in Turkey to provide standardized neuropsychological tests. The tests were conducted by a researcher certified in administering and scoring the tests.

2.2.1 | WCST

WCST consist of four stimulus cards containing three stimulus parameters (color, shape, and number). Participants are required to sort the numbered answer cards according to different principles and change their approach during

TABLE 1 Demographic data.

	Age (Mean ± SD)	Gender *n* (%)	CP type *n* (%)	GMFCS[a] *n* (%)
CP Group	9.4 ± 1.9	18 (45%) F	7 hemiplegic(17.5%)	I, *n* = 9 (22.5%)
			23 diplegic (57.5%)	II, *n* = 11 (27.5%)
		22 (55%) M	10 quadriplegic (25%)	III, *n* = 8 (20%)
				IV, *n* = 12 (30%)
Total		*n* = 40	*n* = 40	*n* = 40

Abbreviations: CP, cerebral palsy; GMFCS, Gross Motor Function Classification System; SD, standard deviation.
[a]GMFCS: I, Walks without Limitations; II, Walks with Limitations; III, Walks Using a Hand-Held Mobility Device; IV, Self-Mobility with Limitations; May Use Powered Mobility.

test administration (Grant & Berg, 1948). Responses were classified as correct errors, persistent responses, and nonperseverative errors. The WCST is primarily used to assess perseveration and abstract thinking (Grant & Berg, 1948). According to Greve et al. (2005), WCST is a high-level measurement tool that measures EFs. The WCST Turkish Form is associated with property such as attention, feature determination, perseveration, working memory, EFs, conceptualization, and abstract thinking (Karakaş & Doğutepe-Dinçer, 2011). WCST contains 4 stimulus cards and 128 response cards (Figure 1). The cases are required to find the correct category by the given feedback that the response is true or false (without mentioning the category name) while taking WCST (Erdoğan-Bakar et al., 2011).

Within the scope of this study, total trials (W1), total errors (W2), perseverative responses (W5), perseverative errors (W6), percent perseverative errors (W8), trials to complete first category (W9), which measure inhibition, and the number of correct responses (W4), conceptual level responses (W10), and percent conceptual level responses (W11) scores that measure set-up maintaining were calculated. The scores calculated from the responses to WCST are as in Figure 2.

2.2.2 | SCWT TBAG version

The SCWT TBAG Form, which is a neuropsychological measurement tool, is basically an EF test (Karakaş, 2011). It measures the ability to change the perceptual set up in line with changing demands and, under a "disruptive effect," suppress a habitual behavioral pattern and perform an unusual behavior, as well as focused attention

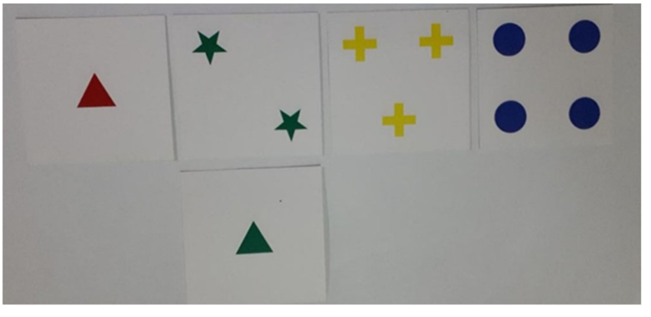

FIGURE 1 Wisconsin card sorting test (WCST).

WCST Scores	
W1	Total trials
W2	Total errors
W3	Total number of correct responses
W4	Number of categories completed
W5	Perseverative responses
W6	Perseverative errors
W7	Total number of non- perseverative errors
W8	Per cent perseverative errors
W9	Trials to complete the first category
W10	Conceptual level responses
W11	Percent conceptual level responses

FIGURE 2 Scores of Wisconsin card sorting test (WCST).

(Anderson, 2001; Scarpina & Tagini, 2017). The SCWT-TBAG version was formed by combining the original SCWT and the Victoria Form (Karakaş & Doğutepe-Dinçer, 2011).

In the SCWT-TBAG Form, subjects are required to read/say five task as fast as possible (Figure 3.). First, participants are required to read the names of colors printed in black ink (1. card in Figure 4). Second, participants are required to read the names of colors printed in an inconsistent color ink (2. card in Figure 4). The third table represents colored dots. Third, participants are required to say the color of circles (shape-color: SC). The fourth table represents inconsistent words which printed in an inconsistent color ink (e.g., the word "weak" in red ink). In the fourth table, participants are required to say the ink colors of the words. The fifth table is the same as the second table (the word "yellow" is printed in blue ink). Fifth, participants are required to say the color of the ink instead of reading the word (named color-word: NCW).

The SCWT has various scoring systems. In this study, we used NCW fifth section scores (time, number of errors, and corrections) to measure the inhibition. In addition, the difference 3 (Dif. 3) score was also used in the study to exclude the speaking speed factor. Dif.3 score was calculated by subtracting the time score of named SC from the time score of NCW (Difference between NCW and SC).

2.2.3 | Behavior rating inventory for executive functions (BRIEF)

BRIEF (Gioia et al., 2000) can be applied to children between the ages of 5–18. The validity of the scale in Turkish culture was carried out by Erdoğan-Bakar and friends (2011). There are two forms of BRIEF, teacher and parent. Both forms consist of 86 items and 8 subscales that include EF behaviors. Because the assessment is made in

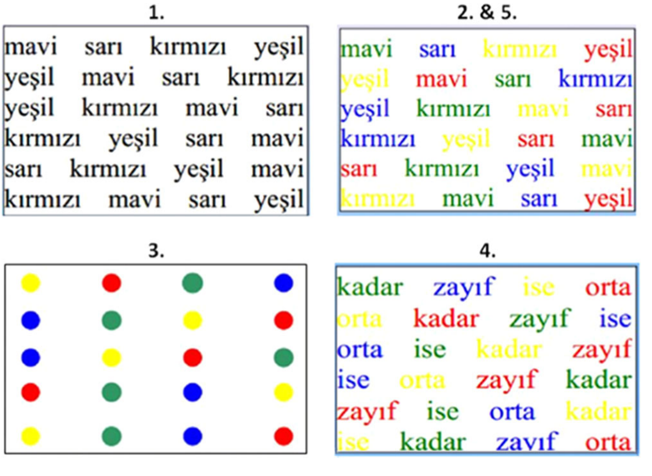

FIGURE 3 Stroop color–word test (TBAG Form).

Sections	Stimulus	Scope of the stimulus card	Task
1.Section	1.Card	Color names printed in black ink	Read color name
2.Section	2.Card	Color names printed in an inconsistent color ink	Read color name
3.Section	3.Card	Colored dots	Say dot color
4.Section	4.Card	Neutral words printed in color ink	Say ink color of word
5.Section	2.Card	Colors printed in an inconsistent color ink	Say ink color of word

FIGURE 4 Stroop color–word test (TBAG Form).

different environments, 18 items of the teacher and parent forms are different from each other. Three indicator scores are calculated from these subscales. The first is the "Behavior Regulation Index (Inhibit, Emotional Control, and Shift)," the second is the "Metacognition Index (Initiate, Working Memory, Plan/Organize, Organization of Materials, Monitor)," and the third is the "Global Executive Composite (GEC)" obtained from the sum of these two indicator scores (Figure 5). The parent form of BRIEF (BRIEF-P) has been used for this study. Parents indicate if the child shows difficulties concerning the behavior which given the test item with "1 (never)," "2 (sometimes)," or "3 (often)." High scores on BRIEF suggest poor EF skills (Erdoğan Bakar et al., 2011; Gioia et al., 2000).

2.3 | Statistical evaluation

Statistical evaluation was made with IBM SPSS 20.0 (IBM Corp.) package program. The normal distribution of the scores of the sample was evaluated by the Kolmogorov–Smirnov test. Since the samples did not show a normal distribution, the difference between the groups was evaluated with the Mann–Whitney U test. Correlation analyzes were evaluated by Spearman. For the testing of two-way hypotheses, $p < .05$ was considered sufficient for statistical significance.

3 | RESULTS

The scores on WCST total trials ($p = .00$), total errors ($p = .04$), categories completed ($p = .00$), and percent conceptual level responses ($p = .03$) scores were statistically significant. There was no significant difference in the scores of perseverative responses, perseverative errors, percent perseverative errors, trials to complete first category, and conceptual level responses ($p > .05$) (Table 2.).

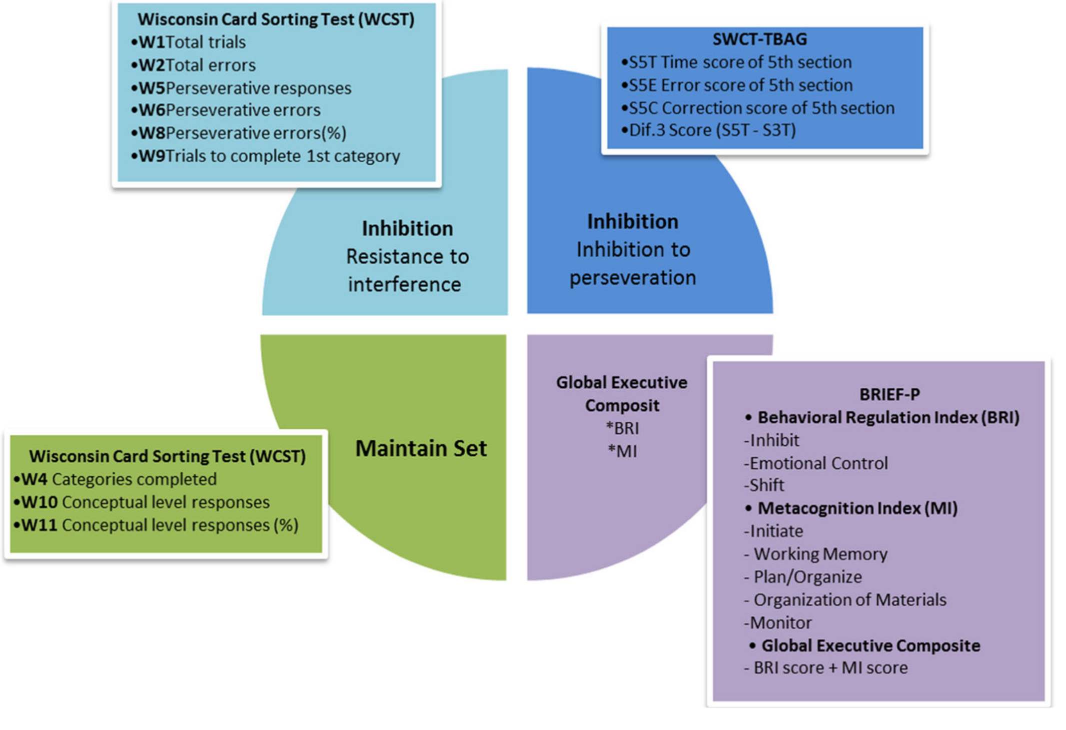

FIGURE 5 The test scores of executive functioning.

TABLE 2 WCST scores.

	CP group (Mean ± SD)	Reference group (Mean ± SD)	*p* Value
Total trials	123.5 ± 12.28	113.82 ± 14.28	**.000**
Total errors	55.6 ± 22.42	45.55 ± 14.17	**.040**
Categories completed	3 ± 1.94	4.21 ± 0.94	**.001**
Perseverative responses	37.9 ± 32.68	31.18 ± 10.84	.729
Perseverative errors	32.35 ± 24.09	26.98 ± 8.93	.893
Percent perseverative errors	25.59 ± 18.65	22.21 ± 5.91	.350
Trials to complete first category	31.4 ± 34	15.72 ± 4.56	.996
Conceptual level responses	50.95 ± 21.75	55.01 ± 5.94	.544
Percent conceptual level responses	42.51 ± 20.7	51.54 ± 12.7	**.038**

Abbreviations: CP, cerebral palsy; SD, standard deviation; WCST, Wisconsin card sorting test.

TABLE 3 SCWT–TBAG version scores.

	CP group (Mean ± SD)	Reference group (Mean ± SD)	*p* Value
S5Time (S5T) (s)	73.97 ± 37.17	40.63 ± 6.86	**.000**
S5Error (S5E)	1.9 ± 2.25	0.73 ± 0.12	**.020**
S5Correction (S5C)	3.25 ± 2.32	2.04 ± 0.45	**.004**
Difference 3 (S5T-S3T)	38.6 ± 24.46	22.54 ± 4.32	**.002**

Abbreviations: CP, cerebral palsy; SCWT, Stroop color–word test; SD, standard deviation.

TABLE 4 BRIEF-P scores.

Indicator	CP group (Mean ± SD)	Reference group (Mean ± SD)	*p* Value
BRI	48.72 ± 7.98	43.6 ± 2.44	**.010**
MI	83.67 ± 17.87	70.97 ± 2.63	**.000**
GEC	132.4 ± 24.03	114.61 ± 3.9	**.000**

Abbreviations: BRI, behavioral regulation index; BRIEF-P, executive function behavior rating scale parent form; CP, cerebral palsy; GEC, global executive composite; MI, metacognition index; SD, standard deviation.

The SCWT-TBAG and BRIEF-P test scores of the children with CP significantly differed ($p < .05$) from the reference group (Tables 3 and 4).

There was a positive correlation between SCWT-TBAG scores with BRIEF-P behavioral regulation index (BRI) ($p < .05$), metacognition index (MI) ($p < .01$), and GEC ($p < .01$) and WCST W2 ($p < .01$) scores (Table 5.).

There was a negative correlation between SCWT-TBAG scores with WCST Conceptual level responses (S5T $p = .01$; Difference 3 $p < .05$) and percent conceptual level responses (S5T $p < .01$; Difference 3 $p < .05$) scores. It

TABLE 5 Correlation between SCWT–TBAG scores with BRIEF-P and WCST scores.

		SCWT-TBAG	
		S5Time r[a]/*p*	Dif. 3 r[a]/*p*
BRIEF-P	BRI	.346/**.029**	.381/**.015**
	MI	.428/**.006**	.406/**.009**
	GEC	.434/**.005**	.428/**.006**
WCST	Total trials	.318/**.045**	.308/.053
	Total errors	.464/**.003**	.405/**.009**
	Categories completed	−.366/**.020**	−.305/.056
	Perseverative responses	.236/.138	.248/.122
	Perseverative errors	.267/.095	.266/.095
	Percent perseverative errors	.266/.097	.257/.109
	Trials to complete first category	.261/.103	.224/.164
	Conceptual level responses	−.401/**.010**	−.335/**.035**
	Percent conceptual level responses	−.448/**.004**	−.389/**.013**

Abbreviations: BRI, behavioral regulation index; BRIEF-P, executive function behavior rating scale parent form; GEC, global executive composite; MI, metacognition index; SCWT, Stroop color–word test; WCST, Wisconsin card sorting test.

[a]Spearman's correlation.

TABLE 6 Correlation between BRIEF-P and WCST scores.

		BRIEF-P		
		BRI r[a]/*p*	MI r[a]/*p*	GEC r[a]/*p*
WCST	Total trials	,339/**.002**	,470/**.000**	,448/**.000**
	Total errors	,231/**.039**	,417/**.000**	,301/**.007**
	Categories completed	−,331/**.003**	−,396/**.000**	−,409/**.000**
	Perseverative responses	,202/.073	,254/**.023**	,201/.074
	Perseverative errors	,203/.071	,268/**.016**	,214/.057
	Percent perseverative errors	,168/.136	,180/.111	,254/.172
	Trials to complete first category	,067/.557	,224/**.046**	,195/.083
	Conceptual level responses	−,079/.485	−,131/.247	−,048/.673
	Percent conceptual level responses	−,210/.062	−,415/**.000**	−,282/**.011**

Abbreviations: BRI, behavioral regulation index; BRIEF-P, executive function behavior rating scale parent form; GEC, global executive composite; MI, metacognition index; WCST, Wisconsin card sorting test.

[a]Spearman's correlation.

was observed that there was no correlation ($p > .05$) between perseverative responses, perseverative errors, and percent perseverative errors, trials to complete first category scores. While there was a positive correlation between SCWT-TBAG S5T score with WCST total errors ($p < .05$) score, a negative correlation between SCWT-TBAG S5T score with WCST categories completed ($p < .05$) score, and there was no correlation between SCWT-TBAG Difference 3 score and WCST categories completed score (Table 5.).

Table 6 presents correlations between the WCST and BRIEF-P scores. The WCST total trials and total errors scores correlated with the BRIEF-P BRI ($p < .05$), MI ($p < .01$), and GEC ($p < .01$) scores positively. The WCST categories completed score and BRIEF-P BRI ($p < .05$), MI ($p < .01$), and GEC ($p < .01$) scores negatively correlated. The WCST perseverative responses and perseverative errors correlated with BRIEF-P MI score positively ($p < .05$). The WCST percent conceptual level responses correlated with BRIEF-P MI ($p < .01$) and GEC ($p < .05$) scores negatively.

4 | DISCUSSION AND CONCLUSION

The results of this study suggest that children with spastic CP have problems with EF skills in terms of inhibitory control and cognitive flexibility. The significant difference in "completed categories" and "percent conceptual level responses" scores of WCST show that children with spastic CP have problems in maintaining the setting. Nadeau et al. (2008) reported similar results in the study that compared the WCST performance of children with spastic CP aged 9–12 with typical development peers (control group, $n = 50$). Unlike our findings, they reported "trials to complete 1st category" score of children with spastic CP was higher than the control group.

Inhibitory control enables individuals to regulate and adapt their behavior and conform to established social norms (Federica & Mellone, 2022). The lower performance of children with spastic CP in SCWT-TBAG and WCST "total trials, total errors, categories completed" scores reflected the difficulties with inhibitory control. Freire and Osório (2020) have also reported differences in inhibitory control between preschool children with CP and typically developing peers.

As far as the findings obtained from BRIEF-P, in which EF skills are evaluated by parents through daily life activities, children with spastic CP experience more difficulties than their peers with typical development in terms of behavior regulation (Inhibit, emotional control, and shift); metacognition indicators (Initiate, working memory, plan/organize, organization of materials, monitor); and GEC. These findings are similar to past research showing that children with spastic CP have EF difficulties (Nadeau et al., 2008; Sakash et al., 2018; Sørensen et al., 2016; Whittingham et al., 2014). Dissimilar to the other studies, we examined the correlation between BRIEF-P scores with WCST and SCWT-TBAG scores. The results of correlations reflected that fewer problems with inhibition and impulsivity are associated with lesser executive problems in daily life.

According to the constructivist models that have emerged with the rapid developments in neuroscience in recent years, maturation is a matter of self-structuring mental development through the interaction between innate structures and environmental configuration (Arsalidou & Pascual-Leone, 2016). Researchers describe the immature nervous system as a highly moldable system that hosts innate biological constraints and also through processing the active, ongoing environmental input and environmental input of the child (Bottcher, 2010). Early brain lesions are not the only reason for the difficulties that children with CP experience in their EF skills. Motor dysfunctions resulting from this damage limit children's learning environment and social environment during their developmental period. Some deficiencies will inevitably arise due to limited learning environments during the construction of mental processes when no intervention is made for children with CP for EF skills, which are thought to mature with age.

A systematic review of interventions for preventing and treating children with CP (Novak et al., 2020) has reflected that cognitive interventions are useful in a rehabilitation program and the tendency is to include those cognitive interventions to the rehabilitation programs. EFs play an important role in behavior regulation, social skills, and performance of daily living activities, as well as in the regulation of other cognitive skills (Garcia-Galant et al., 2020). Zelazo et al. (2016) reported that research clearly show that EF skills can be developed with relatively short interventions, such as increasing the difficulty levels of the tasks. Therefore, children with CP should be supported with various intervention programs regarding EF skills. Considering all these and the EF disorders in our study, for an effective rehabilitation program, it might be beneficial to evaluate all cognitive-linguistic, academic, social, and emotional characteristics of children with CP to determine the situations that create activity limitations

(Defined in ICF): "Difficulties an individual may have in executing activities."] and make treatment arrangements accordingly.

Children with CP are unique, just like every child. Besides the location, effect, and size of the lesions, which compose different combinations of activity limitations and participation in daily living skills of children with CP, the personality and context of the children also form another combination. The critical point here should be the use of neuropsychological tests in a way that allows for recognition of the individual's neuropsychological profile for the design of intervention programs that have functional goals for activities and participation.

5 | LIMITATIONS

In this study, the inhibitory control and cognitive flexibility skills of children with spastic CP were evaluated with neuropsychological tests. Functions such as learning, visio-spatial perception, decision-making, and working memory that can be measured by different neuropsychological tests were not evaluated.

The other limitation of this study was the lack of the IQ scores of the children with CP. Fluency reading ability was assumed to be the indicator of standard intelligence for this study. According to previous research, standard intelligence tests have limitations in measuring IQ scores of children with CP because some subtests depend on motor skills (Coceski et al., 2021; Sherwell et al., 2014; Yin Foo et al., 2013). More studies are needed to measure the intelligence of children with motor impairment.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

KÜ GOKAEK 2017/155

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