

Research Paper

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross- Sectional Analysis

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ABSTRACT

In addition to core behavioural symptoms, Attention Deficit Hyperactivity Disorder (ADHD) is associated with notable challenges in cognitive deficits, particularly in executive functions. These executive function impairments play a crucial role in determining a child's overall functioning, influencing academic achievement, social interactions, and the ability to manage everyday activities independently. Although a growing body of international literature highlights these cognitive challenges, research examining executive function deficits in children with ADHD within the Indian context remains limited. The present study aimed to compare executive function abilities between children diagnosed with ADHD and typically developing controls, with the goal of informing more targeted and effective intervention strategies. A total of 90 children aged 8–12 years participated, including 45 children with ADHD and 45 age-matched peers. The Connors' Abbreviated ADHD Rating Scale and standardized neuropsychological instruments including the Tower of London Test, Wisconsin Card Sorting Test, Stroop Colour and Word Test, and Phonemic Fluency Test were administered to assess various executive function domains. Data were analysed using non-parametric statistical methods in SPSS. Results indicated that children with ADHD showed significantly poorer performance in phonemic fluency, planning, and cognitive flexibility compared to the control group. Moreover, executive deficits increased in severity as ADHD symptoms intensified. The findings highlight the relevance of executive function assessment in clinical practice and support the development of intervention strategies targeting cognitive deficits to improve functional outcomes in children with ADHD.

Keywords: *ADHD, Executive function, Planning, Set shifting, Response inhibition, Cognitive Flexibility.*

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Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

Attention deficit hyperactivity disorder (ADHD) is a prevalent neurodevelopmental condition; which impacts several aspects of children's functioning. The global prevalence of ADHD is approximately to be between 5% and 7% (Salari et al., 2023). The ADHD prevalence rates in India are reported to vary by region; a systematic review and meta-analysis synthesizing reported point prevalence of ADHD among children and adolescents ranging from 1.3% to 28.9% and a pooled prevalence of 7.1% (Joseph & Devu, 2019). Socioeconomic factors also play a role, with a study by Venkata and Panicker (2013) Reporting a prevalence of 6.84% in middle-income groups and 16.33% in lower socioeconomic groups. Furthermore, a study by Jaisoorya et al. (2020) in Kerala found that 4.3% of school-age children had ADHD, with the highest prevalence shown in those between the ages of 9 years and 11 years.

Children with ADHD often experience significant challenges that adversely affect their academic, adaptive, and social functioning. Research indicates that these children may struggle with sustaining tasks, have difficulty concentrating, exhibit hyperactive behaviours, and lack inhibitory control, all of which impede their ability to regulate their actions effectively. For instance, children with ADHD are frequently reported to encounter academic difficulties that can lead to poor performance and increased risk of social rejection (Barkley & Poillion, 1994).

Beyond the hallmark behavioural manifestations, ADHD in children is frequently associated with impairments in cognitive functioning, particularly in higher-order processes that support goal-directed behaviour, such as planning, organization, inhibitory control, and cognitive flexibility. Evidence from recent large-sample investigations and experimental studies has consistently documented the presence of cognitive deficits in this population, with executive functions being especially affected (Miklós et al., 2019). Experimental paradigms that systematically increase working memory and inhibitory demands have revealed pronounced difficulties in these core control processes among children with ADHD (Kofler et al., 2024). Complementary findings from meta-analyses of randomized controlled trials and functional neuroimaging research further substantiate these impairments, demonstrating deficits in working memory and inhibitory control, alongside atypical activation patterns within frontal–striatal neural circuits (Wang et al., 2025).

Additionally, empirical studies indicate substantial associations among different executive function components, underscoring their interdependent nature of these cognitive processes (Karalunas et al., 2017; Sandberg & McAuley, 2022). Longitudinal findings indicate that executive dysfunction is a significant predictor of poorer academic outcomes in children with ADHD (Jensen et al., 2025). Executive deficits have also been linked to social difficulties in school contexts, with evidence indicating that working memory plays a mediating role in the relationship between ADHD symptoms and teacher-rated social functioning. Collectively, these findings demonstrate that deficits in executive functioning substantially reduce both academic underachievement and social challenges in children with ADHD (Betancourt et al., 2024; Español-Martín et al., 2023; Kofler et al., 2024).

Literature on ADHD indicates significant deficits in cognitive functions and prefrontal cortical functioning among affected children. Neuroimaging studies indicate delayed maturation in the prefrontal cortex and structural abnormalities in region critical for executive control, including cerebral cortex, cerebellum, and caudate regions (Norman et al., 2016). Functional MRI studies indicate that children with ADHD exhibit altered

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

connectivity patterns across multiple neural networks, including fronto parietal, cortico-striatal and higher order cognitive circuits which are associated with impairments in attention, inhibition, and working memory (Benjamin et al., 2022; Soman et al., 2023). while genetic and pharmacological research highlights the importance of dopaminergic pathways in ADHD, dopamine dysfunction in modulating prefrontal–striatal networks underlying executive control, consistent with altered functional communication within these circuits in ADHD (MacDonald et al., 2024; Parlatini et al., 2024).

The growing awareness of executive function impairments in children with ADHD, particularly those related to frontal lobe dysfunction. Despite extensive research in Western contexts, there is a lack of focused investigation into these neuropsychological aspects of ADHD within the Indian population. Understanding the specific cognitive mechanisms underlying ADHD in this demographic is essential for developing more targeted, culturally appropriate interventions. Furthermore, exploring alternative treatment approaches, such as cognitive retraining and neurofeedback training, could provide viable options that are less likely to cause the side effects or complications often associated with traditional pharmacological treatments. These executive function-focused interventions may enable children to manage tasks, maintain focus, and organize their work more effectively, improving their learning and academic performance. These improvements also foster better classroom behaviour and stronger social interactions, helping children thrive in a structured school environment.

Objectives

- a) To assess the difference in executive functions between children diagnosed with ADHD and typically developing children.
- b) To examine the relationship between the ADHD symptom severity and executive function deficits.

METHOD

Sample

The Participants comprised 90 children aged 8-12 years. The clinical group included 45 children diagnosed with ADHD, recruited from the child Outpatient Unit of the Institute of Mental Health and Neurosciences (IMHANS), Kozhikode, Kerala. Diagnosed was made by Psychiatrist based on standard clinical criteria. Written informed consent was obtained from parents or legal guardians, and confidentiality of all collected information was assured. For comparison group consisted of 45 typically developing children without ADHD or any other psychiatric conditions were selected from various schools in the district, representing a mixed population.

Tools

1. Socio-Demographic Data Sheet: A structured data sheet was prepared by researcher for used to collect information on age, gender, education, family background, and other relevant demographic variables.
2. Conner's Abbreviated Rating Scale (Conners, 1990): This scale was used to assess the presence and severity of inattentiveness, hyperactivity, and impulsivity. Parents rated their child's behaviour across 10 items on a 4-point Likert scale ranging from 0 (*not at all*) to 3 (*very much*).
3. Tower of London Test (Shallice & Burgess, 1991): To assess planning ability and goal-directed problem solving, reflecting executive planning and foresight.

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

4. Wisconsin Card Sorting Test (Heaton, 1981): Used to measure cognitive flexibility, abstract concept formation, set-shifting ability, and inhibitory control of interference.
5. FAS Phonemic Fluency Test (Lezak, 2004) Participants are given one minute to come up with as many words starting with the letters F, A, and S as they can to gauge verbal fluency.
6. Stroop Colour and Word Test (Golden et al., 1978): Assessed response inhibition, cognitive flexibility, and selective attention

Procedure

After obtaining ethical approval, parents or legal guardians were informed about the purpose and procedures of the study, and written informed consent was obtained. Participants were assured of confidentiality and their right to withdraw from the study at any time. Children in the clinical group were screened using the Conners' Abbreviated Rating Scale to confirm symptom severity.

A purposive sampling method was used to select a total of 90 children aged 8–12 years from Kozhikode district. Children in the control group were recruited from schools and screened to ensure the absence of ADHD or other psychiatric conditions. All assessments were conducted individually in a quiet and distraction-free environment. The executive function measures assessing planning, set-shifting, verbal fluency, and response inhibition were administered according to standardized procedures. Scoring was carried out as per the guidelines provided in the respective test manuals.

Ethical issues

The study adhered to established ethical guidelines for research. All participants and their caregivers were provided with detailed information about the study, and written informed consent was obtained. Confidentiality of participant data was strictly maintained, and feedback was provided upon completion of the assessment. Ethical clearance was obtained from the Institutional Ethics Committee of the hospital.

RESULTS

Descriptive statistics indicated that the total sample comprised 90 children, with 45 children in the ADHD group and 45 children in the non-ADHD group. In both groups, 42 participants (93.3%) were boys and 3 participants (6.7%) were girls. The mean age of participants in both groups was 10 years.

As the data did not meet assumptions of normality, The Mann-Whitney U test was used to compare the executive function variables among the ADHD and Non-ADHD groups.

Table 1. Mann-Whitney U tests for comparison of Phonemic Fluency test and Tower of London test by the children with and without ADHD.

Variable	Group	N	Mean rank	Sum of Rank	U	p-value
Phonemic fluency	ADHD	45	21.13	634.00	169.00	.000**
	NON-ADHD	45	39.87	1196.00		
TNMM in Tower of London Test	ADHD	45	23.27	698.00	233.000	.001**
	NON-ADHD	45	37.73	1132.00		

*Total number of Minimum Moves (TNMM)

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

Table 1 presents the Mann–Whitney U test results comparing phonemic fluency and planning ability (Tower of London Test) between the two groups. Children with ADHD showed significantly poorer performance than non-ADHD children on the Phonemic Fluency Test ($U = 169.00, p < .01$) and required a significantly higher total number of minimum moves on the Tower of London Test, indicating deficits in planning ability ($U = 233.00, p < .01$).

Table 2 Results of Mann Whitney U test obtained by the children with and without ADHD in set shifting.

Subdomain	Group	Mean Rank	Sum of Mean Rank	U	p- value
PR	ADHD	41.77	1253.00	112.000	.000**
	NON-ADHD	19.23	577.00		
PrE	ADHD	41.98	1259.50	105.500	.000**
	NON-ADHD	19.02	570.50		
NPE	ADHD	39.35	1180.50	184.500	.000**
	NON-ADHD	21.65	649.50		
CLR	ADHD	31.78	953.50	411.500	.562
	NON-ADHD	29.22	876.50		

"Perseverative Responses (PR)", "Perseverative Errors (PrE)", "Non-Perseverative Errors (NPE)", "Conceptual Level Responses (CLR)".

Table 2 displays the results of the Mann–Whitney U test for the Wisconsin Card Sorting Test (WCST). Significant group differences were observed for Perseverative Responses ($U = 112.00, p < .01$), Perseverative Errors ($U = 105.50, p < .01$), and Non-Perseverative Errors ($U = 184.50, p < .01$), with children in the ADHD group demonstrating higher error rates. However, no significant difference was found between the groups for Conceptual Level Responses ($U = 411.50, p > .05$).

Table 3 Mann- Whitney U tests for comparison of Stroop test by the children with and without ADHD

Subdomain	Group	Mean Rank	Sum of Rank	U	p- value
Interference score	ADHD	31.50	945.00	420.000	.657
	NON-ADHD	29.50	885.00		
Color Word score	ADHD	20.25	607.50	142.500	.000**
	NON-ADHD	40.75	1222.50		

Table 3 summarizes the Mann–Whitney U test results for the Stroop Colour and Word Test. No significant difference was observed between the ADHD and non-ADHD groups on the Stroop Interference Score ($U = 420.00, p > .05$). In contrast, a significant group difference was found for the Colour–Word score ($U = 142.50, p < .01$), indicating impaired response inhibition in children with ADHD.

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

Table 4 Result of Pearson moment correlation among the variables of Executive Functions and Severity of ADHD.

Variables	Severity of ADHD (Conners Abbreviated Rating Scale)
Phonemic Fluency	-.544**
TNMM*	-.453**
Preservative responses	.565**
Preservative errors	.581**
Non-Preservative errors	.441**
Conceptual level Response	.082
Stroop Interference Score	.096
Stroop Colour Word Score	-.602**

**significant at 0.01 level.

* "Total number of Minimum Moves in the Tower of London test" (TNMM)

Pearson product–moment correlation analysis was conducted to examine the relationship between executive function variables and ADHD symptom severity as measured by the Conners' Abbreviated Rating Scale (**Table 4**).

The results revealed a significant negative correlation between ADHD severity and phonemic fluency ($r = -.544, p < .01$), planning ability as measured by the total number of minimum moves on the Tower of London Test ($r = -.453, p < .01$), and response inhibition as assessed by the Stroop Colour–Word score ($r = -.602, p < .01$). In contrast, ADHD severity was significantly and positively correlated with perseverative responses ($r = .565, p < .01$), perseverative errors ($r = .581, p < .01$), and non-perseverative errors ($r = .441, p < .01$) on the WCST. No significant correlations were observed for conceptual level responses ($r = .082, p > .05$) or Stroop Interference scores ($r = .096, p > .05$).

Overall, the results indicate that children with ADHD exhibit significant impairments across multiple domains of executive functioning, including verbal fluency, planning, cognitive flexibility, and response inhibition. Furthermore, greater severity of ADHD symptoms was associated with poorer executive function performance, particularly in planning, inhibitory control, and error regulation.

DISCUSSION

The present study demonstrates that most of the sample consisted of boys rather than girls. Although the study aimed for equal representation of both genders, females with ADHD were less available, leading to a male-dominated sample. This discrepancy may be due to lower referral rates for girls. Research suggests that males receive a diagnosis of ADHD more frequently than females, potentially because their symptom presentations differ. In contrast to males, who more frequently display the mixed type with hyperactivity and impulsivity, which makes diagnosis more obvious, girls frequently demonstrate inattentive symptoms, which are less disruptive and more likely to be missed (Martin, 2024; Mowlem et al., 2019).

The finding shows the children with ADHD had demonstrate reduced performance in phonemic fluency tasks, producing fewer words within specific categories. These difficulties are often associated with executive functions issues, such as working memory, response

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

inhibition and cognitive flexibility. A lack of mental flexibility may impede their ability to generate ideas quickly and respond to prompts effectively. Research consistently shows that children with ADHD face significant obstacles in tasks that require sustained attention and suppression of irrelevant responses. Studies suggest that deficits in prefrontal brain functions related to executive control contribute to these challenges (Goh et al., 2020; Semeijn et al., 2015).

The performance of the children in the Tower of London Test (TOL) with ADHD was lower when compared to that of children without ADHD. Children with ADHD have trouble controlling goal-directed behavior, planning task stages, and modifying their tactics in response to feedback, according to studies. They often take more time, require additional attempts, and commit more errors when solving problems. These impairments are linked to reduced prefrontal cortex activity. These deficits in executive functioning are frequently linked to impulsivity, inattention, and impaired working memory. These findings are in line with recent research (Patros et al., 2019; Sadozai et al., 2024).

According to this study, children with ADHD typically score worse on the Wisconsin Card Sorting Test (WCST) than children without ADHD, especially when it comes to perseverative responses (PR) and perseverative errors (PrE). These results imply that cognitive flexibility - more especially, the capacity to switch tactics when needed- is a major problem for children with ADHD. Their tendency to repeat previously successful responses, even when inappropriate, points to difficulties with adapting and shifting their thinking, which are core aspects of executive functioning deficits commonly seen in ADHD (Martel et al., 2022).

According to the current study, the conceptual-level responses of children with and without ADHD did not differ significantly; several factors could explain this result. Conceptual-level responses require abstract reasoning and the ability to shift perspectives, skills that may not be as impaired in children with ADHD as other cognitive functions. Children with ADHD may face challenges with attention shifting and maintaining focus over long periods, but they could perform similarly to their non-ADHD peers on tasks that do not require sustained cognitive effort for abstract reasoning (Barkley & Poillion, 1994; Ramos-Galarza et al., 2024) It is also possible that the WCST's cognitive demands were not sufficient to challenge conceptual-level processing in either group, or both groups may have used similar strategies to complete the task.

In this study of the children with and without ADHD groups showed a significant difference in color-word scores on the Stroop test, but no significant difference in interference scores. This result reveals that the cognitive process of interference control may not be as impaired in children with ADHD. However, the lower color-word score in the ADHD group points to broader difficulties in executive functions such as attention regulation, processing speed, and response inhibition. The color-word score reflects these combined cognitive demands, which are frequently challenging for children with ADHD. In contrast, the interference score specifically measures conflict resolution between competing stimuli, which may be less affected or not captured effectively by the Stroop test in younger children.

The relationship between ADHD severity and executive functions among children with and without ADHD reveals a significant negative correlation between "phonemic fluency", "the total number of minimum moves" in the Tower of London (TOL) task, "Stroop color-word

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

scores", and "Conners' Abbreviated Rating Scale (CARS)" scores. A significant inverse relationship between phonemic fluency, the total number of minimum moves in the Tower of London (TOL) task, Stroop color-word test scores, and Conners' Abbreviated Rating Scale (CARS) scores is revealed by the examination of the relationship between executive functions and ADHD severity in children with and without ADHD. This suggests that higher ADHD symptom severity is linked to reduced phonemic fluency, greater executive function impairments, and increased moves needed to complete the TOL task, indicating difficulties with planning and problem-solving. Prior research supports these findings; it shows that children with ADHD often struggle with tasks requiring verbal fluency due to challenges in executive functions like cognitive flexibility and working memory (Barkley & Poillion, 1994). Additionally, the TOL task is a widely used test of executive functioning, with studies reporting that children with ADHD typically perform worse, needing more moves due to impaired planning abilities (Anderson et al., 2010). The notion that ADHD is linked to deficits in inhibitory control, a key component of executive functioning, is further supported by the negative correlation with Stroop color-word test scores (Nigg, 2000).

The study revealed a significant positive correlation between perseverative responses, perseverative errors, and ADHD severity scores (Conners' Abbreviated Rating scale). These findings are consistent suggesting that higher ADHD severity is linked to greater difficulties in cognitive flexibility and set shifting. However, no significant association was found with research showing that individuals with ADHD often experience executive function impairments, including difficulties adapting to changing tasks and increased perseverative errors (Martel et al., 2022). Tasks like the Wisconsin Card Sorting Test highlight these challenges, as individuals with ADHD struggle with shifting cognitive strategies when task demands change (Irwin Harper et al., 2023). The absence of a significant relationship with conceptual responses could be due to task-specific factors or adaptive strategies used by some children. Overall, the results reinforce the link between worsening ADHD symptoms and increased executive function deficits, particularly in set-shifting and cognitive flexibility (Toplak et al., 2008).

Limitations and Future Directions

Despite its strengths, the study has certain limitations. The use of a convenience sampling method and a relatively modest sample size may limit the generalizability of the findings. Additionally, reliance on a single parent-report measures for assessing ADHD severity may introduce informant bias. Future research should incorporate multi-informant assessments, longitudinal designs, and neurobiological measures to further elucidate the developmental trajectories and neural mechanisms underlying executive dysfunction in ADHD.

CONCLUSION

The current study investigates the difference in executive function between children with ADHD and those without, and examined the relationship between executive function skills and the severity of ADHD symptoms. Findings reveal notable differences in executive functions between the two groups, with greater symptom severity being strongly linked to poorer executive function performance. The study highlights the critical need for targeted interventions, particularly in academic and behavioral contexts, for children with ADHD. Executive dysfunction has been found to be a significant factor in children with ADHD's behavioral issues, academic underachievement, and career difficulties. Interventions should therefore prioritize improving executive functions, such as cognitive retraining and neurofeedback, to enhance academic performance and manage behavioural issues.

Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

Additionally, the study emphasizes the importance of raising awareness among parents, teachers, and caregivers about ADHD's impact on children's academic development and behavior. Creating a supportive, structured environment in schools can help manage ADHD-related academic and behavioral challenges effectively. The limited availability of behavioral therapies further calls for more accessible and school-based programs, ensuring that children with ADHD receive the necessary academic support and behavioral interventions. Lastly, early diagnosis and tailored interventions, particularly for children struggling academically or displaying disruptive behaviors, are crucial. Addressing executive function deficits early can reduce long-term academic struggles and behavioral problems, enabling children with ADHD to succeed both in school and beyond.

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Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

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Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

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Executive Function Deficits in Children with Attention Deficit Hyperactivity Disorder: A Cross-Sectional Analysis

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Conflict of Interest

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