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Original Article

# A Comparison of Executive Function in Children with Developmental Coordination Disorder with Typically Developing Peers: A Comparative Study

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**ABSTRACT**

**Background:** Developmental Coordination Disorder (DCD) is a neurodevelopmental condition that impairs motor skills and can negatively affect attention and executive function. Additionally, the presence of comorbid neurodevelopmental disorders may further influence cognitive performance in children with DCD. This comparative study aimed to examine differences in two components of executive function between children with DCD and their typically developing (TD) peers.

**Methods:** In this causal-comparative study, 250 primary school students in Sepidan (mean age = 8.86 ± 0.44 years) were screened using the Movement Assessment Battery for Children–Second Edition (MABC-2) to identify children with DCD and TD children. Twenty children diagnosed with DCD were compared with their TD peers on two executive function tasks: working memory, assessed with the N-Back test, and cognitive flexibility, assessed with the Simple Stroop test. Multivariate and univariate analyses of variance were conducted to examine group differences in executive functions.

**Results:** Children with DCD demonstrated significantly lower accuracy on the working memory task (correct responses: 56.60 ± 21.43) compared with TD children (97.90 ± 13.42, P = 0.001). Additionally, their response times were significantly longer (910.35 ± 174.92 ms vs. 745.4 ± 164.35 ms, P = 0.004). In terms of cognitive flexibility, the interference score was significantly higher in DCD children (11.2 ± 6.32) than in TD children (5.4 ± 2.99, P = 0.001), indicating poorer performance.

**Conclusion:** The findings indicate that TD children outperform children with DCD in both working memory and cognitive flexibility. These deficits in multiple executive function components among children with DCD underscore the importance of early motor and cognitive interventions to support cognitive development in this population.



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## Introduction

Developmental Coordination Disorder (DCD) is characterized by impairments in acquiring and performing motor skills in the absence of any underlying medical or neurological condition, resulting in motor abilities below the level expected for a child's age. Children with DCD often experience low self-esteem, emotional and behavioral difficulties, and exhibit slowness or carelessness in performing daily activities that require motor coordination. These activities may include tasks such as grasping, hand-eye coordination, writing, riding a bicycle, and participating in physical exercise [1].

Motor difficulties in both fine and gross motor tasks, along with an inability to acquire more complex motor skills due to poor planning and impaired movement perception, are hallmark features of children with DCD [2, 3]. Additionally, children with DCD often demonstrate weaker academic performance compared to typically developing (TD) peers, and these difficulties persist, affecting the learning and execution of motor skills in daily life [4, 5]. A TD child intending to perform a movement first relies on perceptual input to formulate a plan, then creates a mental representation of the motion by encoding spatiotemporal parameters, and finally adjusts and executes the movement based on sensory-motor feedback [6].

In contrast, children with DCD struggle to analyze sensory information from their environment and to use this information to select appropriate actions. Due to sensory-motor deficits, they often have insufficient awareness of their physical surroundings and require support to enhance brain processing and organize sensory inputs for adaptive responses. Consequently, impairments in sensory integration and processing are major contributors to the motor coordination difficulties observed in children with DCD [7, 8]. Motor coordination, defined as the ability to produce rapid, precise, and balanced motor responses, depends on the integrated functioning of the nervous and musculoskeletal systems [9].

Complex motor coordination is closely linked with executive functioning (EF) [10]. Executive functions encompass higher-order control processes that guide and regulate cognitive, emotional, and behavioral responses during problem-solving tasks [11]. These functions include, among others, inhibition, working memory, cognitive flexibility/shifting, organization, goal-setting, planning, self-regulation, and fluency [12]. Research indicates a connection between motor impairments and cognitive deficits. Dewey and Bernier [13] suggested that atypical brain development in children with DCD contributes to both motor and cognitive difficulties. Other studies have shown that children with DCD face challenges in tasks requiring organization, decision-making, planning, working memory, visualization, and goal-directed behavior. These deficits in executive function can disrupt planning and daily life activities [14].

Conversely, some studies have reported that, despite notable motor deficits, children with DCD may exhibit cognitive abilities comparable to those of their TD peers [15]. Nevertheless, motor delays in children with DCD appear to reflect, at least in part, underlying capacities related to components of executive function [16]. Daily activities require fundamental motor skills, such as aiming, grasping, and manual dexterity, which are closely linked to various components of executive function [4]. Consequently, deficits in executive functioning can impair the ability to adapt to change, correct suboptimal behaviors, control impulsivity and risk-taking, manage social interactions, and perform effectively in learning tasks [17]. Therefore, executive functions play a critical role in ensuring a high quality of life for children, influencing their emotional, social, and academic development [18].

If children with DCD are not diagnosed promptly and appropriate interventions are not implemented, their symptoms may persist into adolescence and adulthood, potentially leading to issues such as obesity, depression, and social maladjustment [8, 9]. It is important to note that DCD occurs across different cultures, ethnicities, and socio-economic groups; however, the functional impact of the disorder may vary depending on daily lifestyle factors [12]. High correlations between motor performance and executive functions may also be influenced by uncontrolled or unanticipated environmental factors [19]. Despite growing interest in the diagnosis and intervention of DCD over the past decade, awareness outside of academic contexts remains limited, and DCD continues to be largely unrecognized by healthcare professionals despite its prevalence [20]. Timely assessment of children's motor development provides opportunities for educational interventions and perceptual-motor exercises, which can prevent and treat movement disorders and support executive function development. Conversely, lack of awareness and neglect in the care of children with DCD can exacerbate deficits in executive function, interfering with daily life activities [21].

Given the limited information on executive functions in children with DCD in Iran and the critical role of executive functions in human development, this study aims to determine whether significant differences in executive functions exist between children with DCD and typically developing peers in Iran. Furthermore, the findings seek to provide parents, primary school teachers, and preschool educators with essential knowledge regarding children's motor disorders and their impact on executive functioning.

## Methods

### *Participants*

In this causal-comparative study, 250 boys and girls (mean age = 8.86, SD = 0.44) were initially screened using the *Movement Assessment Battery for Children - Second Edition* (MABC-2) [22]. From this population, 20 children with DCD and 20 typically developing (TD) peers were identified through a convenience sample from five public primary schools in the central region of Sepidan. The adequacy of the sample size was confirmed using G*Power software ($\alpha = 0.05$, power = 0.80). Ethical approval for the study was obtained from the Ethics Committee of Shiraz University (Approval ID: SEP.14033.48.1459).

*Inclusion and Exclusion Criteria*

Children were included in the DCD group if they scored below the 5th percentile on the MABC-2, and in the TD group if they scored above the 16th percentile.

All participants were required to be 8 or 9 years old at the time of the study.

*Instruments*

**Movement Assessment Battery for Children, Second Edition [MABC-2**]: The MABC-2 is a standardized instrument used to assess and identify children with motor disorders [22]. It comprises three subscales: *manual dexterity*, which includes three tasks: placing pegs, threading a string, and tracing a path. *Aiming and catching*, which includes two tasks: catching a ball with both hands and throwing a beanbag onto the floor. And *balance*, which includes three tasks: one-legged balance on a balance board, heel-to-toe walking, and hopping on the floor.

Children who score above the 16th percentile are classified as having typical motor development (TD), while those scoring below the 5th percentile are identified as having developmental coordination disorder (DCD) [23]. Inter-examiner and intra-examiner reliability for all tasks were within the desired range, with overall test reliability reported as 0.86 and 0.99, respectively [24].

In addition to the MABC-2, two tests were administered to assess the children's executive functions.

**N-Back Working Memory Test:** The N-Back test is widely recognized as a robust measure of working memory performance, as it assesses both the maintenance and manipulation of cognitive information [25]. In this test, participants are presented with a sequence of stimuli, typically visual, one at a time. They must determine whether the most recently presented stimulus matches the one presented *n* steps earlier in the sequence. The duration of the test is approximately three minutes. Performance is evaluated based on two indices: the number of correct responses (Score 1) and the response time (Time 1). Previous studies have confirmed the reliability and validity of the N-Back test, with a reported reliability of 0.78 [26].

**Cognitive flexibility:** To assess response inhibition and cognitive flexibility in children, the Simple Stroop test was employed. In this test, participants are presented with 48 congruent and 48 incongruent color words displayed in red, blue, yellow, and green. In incongruent stimuli, the color of the word differs from its semantic meaning (e.g., the word *green* displayed in red, blue, or yellow). A total of 96 congruent and incongruent color words are presented randomly and sequentially.

Participants are instructed to respond only to the visible color of the word, regardless of its written meaning. Before the test, participants are informed that the color of the word may differ from its meaning (e.g., the word *blue* written in red) and are reminded to identify only the displayed color. Each stimulus is presented for 2 seconds, with an interstimulus interval of 800 milliseconds.

The level of inhibition or interference is calculated by subtracting the number of correct responses to incongruent stimuli from the number of correct responses to congruent stimuli. Additionally, a longer mean response time for incongruent stimuli compared with congruent stimuli is considered another indicator of interference. Incorrect responses to incongruent stimuli are also calculated as an interference score. The objective of the test is to evaluate participants' maximum cognitive capacity while maintaining both accuracy and speed [27]. The test-retest reliability of this measure has been reported to range from 0.80 to 0.91 [28].

*Procedure*

After obtaining approval from the city's physical education expert for the participation of elementary school students in this research and coordinating with school administrators and teachers, written informed consent was obtained from the parents. Each child was assessed by a trained motor behavior specialist using the Movement Assessment Battery for Children-Second Edition (MABC-2) and executive function tests across two 60-minute sessions, conducted at a convenient time and location.

Based on the MABC-2 results, 20 children who scored below the 5th percentile were identified as having developmental coordination disorder (DCD), and 20 children who scored above the 16th percentile were classified as typically developing (TD). Subsequently, two executive function tests were administered to all participants: the N-Back working memory test (1-back condition) to assess working memory performance and the Simple Stroop test to evaluate response inhibition and cognitive flexibility.

Before the formal administration of each test, the examiner engaged in brief informal conversations with the participants to increase comfort and ensure familiarity with the computer keyboard. After entering each participant's personal information into the test profile, a practice (example) trial was administered, followed by the main test. During both the practice and main trials, instructions were displayed on the screen and were also explained verbally by the examiner to ensure comprehension before proceeding.

Following data collection, descriptive statistics were used to calculate means, standard deviations, and data distributions. The Shapiro-Wilk test was applied to assess data normality, and Levene's test was used to examine the homogeneity of variances. Multivariate analysis of variance (MANOVA) was conducted to investigate differences between the DCD and TD groups across executive function components, including working memory and cognitive flexibility. All statistical analyses were performed using SPSS software (version 23), with the significance level set at $P \leq 0.05$

## Results

The descriptive results presented in Table 1 indicate that there were no significant differences between children with developmental coordination disorder (DCD) and typically developing (TD) children in terms of age ($t = 0.01$, $P = 0.998$), weight ($t = 1.26$, $P = 0.215$), or height ($t = -1.22$, $P = 0.228$).

**Table1:** Sample characteristics and executive function by groups: Mean [SD]

| Group | DCD (N=20) | TD (N=20) |
|---|---|---|
| Age (years) | 8.75 (0.44) | 8.98 (0.45) |
| Height (Cm) | 126.95 (26.11) | 134.4 (17.55) |
| Weight (Kg) | 33.6 (21.4) | 27.4 (14.63) |
| Working memory (Result1) | 56.6 (21.4) | 97.9 (13.4) |
| Working memory (Time1) | 910.35 (174.92) | 745.4 (164.35) |
| Cognitive flexibility (Interference score) | 11.2 (6.32) | 5.4 (2.99) |

** SD: Standard Deviation; DCD: Developmental coordination disorder; TD: Typically developing; Result1: Result of the performance or the number of correct answers; Time1: time that the subjects have spent answering; Interference score: the wrong response to incongruent stimuli.

According to the descriptive data presented in Table 1, the mean working memory score, measured by the number of correct responses (Result1), was higher in typically developing (TD) children than in children with developmental coordination disorder (DCD). In contrast, the mean scores for working memory response time (Time1) and cognitive flexibility (interference score) were higher in children with DCD compared to TD children. Univariate analysis demonstrated significant differences between DCD and TD children in working memory performance (Result1) ($F = 53.32$, $P = 0.001$, $\eta^2 = 0.548$), working memory response time (Time1) ($F = 9.44$, $P = 0.004$, $\eta^2 = 0.199$), and cognitive flexibility (interference score) ($F = 13.74$, $P = 0.001$, $\eta^2 = 0.226$). Overall, the results indicate significant differences between children with DCD and typically developing children in both components of executive functions, namely working memory and cognitive flexibility, in the Iranian population.

## Discussion

The purpose of this study was to compare executive function in children with developmental coordination disorder (DCD) and typically developing (TD) children. Despite not controlling for potential limitations such as environmental factors, including the cultural and economic conditions of families of children with DCD and TD, as well as the relatively small sample size, the results demonstrated significant differences between DCD and TD children in working memory performance (number of correct responses and response time) and cognitive flexibility (interference score).

The mean scores for working memory (number of correct responses) were higher in TD children than in children with DCD. In contrast, the mean scores for working memory response time and cognitive flexibility (interference score) were higher in children with DCD compared to TD children.

These findings are consistent with previous studies indicating that individuals with DCD exhibit weaker performance in both motor skills and executive function components [12, 29, 30]. The results also align with research demonstrating impaired motor-cognitive coupling in children with DCD. From this perspective, visuospatial working memory plays a continuous role in movement preparation and planning, and deficits in this process may contribute to both cognitive and motor impairments observed in this population [31].

On the other hand, these findings suggest that disturbances in cognitive flexibility may be attributable to impairments in visuospatial processing among children with DCD, which can adversely affect reaction time [32]. Children with DCD experience difficulty with specific motor tasks that require distinguishing similarities and differences; therefore, they often require more time to engage visual attention to complete such tasks [33]. Consequently, these difficulties impair the ability to shift perspectives during thinking and action, to process information efficiently, to understand different aspects of others' behavior, to recognize possible forms of objects, and to participate effectively in motor activities [34, 35].

These findings suggest that motor delays in children are, at least in part, related to deficits in components of executive functions, particularly working memory and cognitive flexibility [16]. The results are further supported by well-established executive function models, such as Barkley's model [٣٦], which explains the close relationship between executive function components and motor control.

Several studies have demonstrated strong correlations in this relationship. For example, Asonitou et al. [37] stated that movement initially involves cognitive and perceptual processes, followed by the motor response; therefore, movement should not be considered a single isolated factor. Similarly, Michel et al. [38] reported that children with poor motor skills perform more slowly on cognitive tasks. Children with DCD also exhibit slower and more limited cognitive decision-making processes (i.e., response selection) compared with their typically developing peers [39].

Overall, developmental coordination disorder is not attributable to a lack of effort; rather, it may result from a neurodevelopmental condition that affects motor-cognitive systems [21]. Cognitive control develops and matures throughout childhood and beyond [40], and the reduced executive function observed in children with DCD may reflect a developmental delay in cognitive control and its interaction with feedforward or predictive motor control mechanisms.

In general, the tasks used in the present study (N-Back working memory and response inhibition in cognitive flexibility) require rapid responses and are performed under open-loop control conditions. Since children with DCD tend to "live on feedback" [٤٠], this type of control may not be optimal for tasks that demand fast online corrections.

In other words, because the planning process is not fully completed in children with DCD before action initiation, they rely more heavily on feedback during movement execution. As a result, their movement

control is slower and more repetitive, requiring multiple adjustments to complete a task [40].

Overall, given the importance of executive function components in daily, academic, and social life across childhood and adulthood, the findings of this study contribute to a clearer understanding of the relationship between executive functions and movement disorders in Iranian children with DCD, compared with previous research.

These results emphasize the importance of assessing both motor performance and executive functioning in children nationwide to facilitate early identification of DCD and associated executive-function impairments, thereby enabling targeted, task-specific interventions.

Early intervention is essential for children with DCD, as it can help them develop strategies to improve executive functioning and motor coordination. Such interventions may enhance self-confidence and reduce the risk of long-term academic, social, and emotional difficulties.

These programs should incorporate combined executive-motor challenges to enhance learning mechanisms in children with motor coordination disorders [16].

Given modern lifestyles characterized by low levels of physical activity, parents should provide children with opportunities to engage in a variety of movement activities before school age to help prevent motor coordination disorders and cognitive dysfunction.

Several limitations of this study should also be acknowledged. For example, the amount and type of children's daily physical activity, as well as family lifestyle factors, were not assessed in both groups, which may have influenced the results.

Overall, given the observed differences in executive functions between children with DCD and their typically developing peers, future research is recommended to examine the effects of motor-cognitive skill training programs (e.g., open-skill activities) on executive function in children with developmental coordination disorder.

## Conclusions

According to the results of this study, there is a significant difference between children with DCD and typically developing (TD) children in two components of executive function. In both working memory and cognitive flexibility, TD children performed significantly better than children with DCD. These findings emphasize the importance of timely assessment of children’s motor development for the prevention, early identification, and management of developmental coordination disorder and associated executive function deficits.

Based on these results, future research should examine the role of motor skills training within cognitively enriched environments in enhancing executive functions in children with DCD and in supporting the prevention of developmental coordination disorder.

## Author Contributions

F.Sharafian. developed the Protocol/project and wrote the main manuscript text. GH . Nazemzadegan. Analyzed the data and prepared the tables. F. Sharafian. collected data and managed the data analysis. All authors reviewed the manuscript.

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