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Research Article

DEVELOPMENTAL COORDINATION DISORDER AND CO-OCCURRING MOTOR DIFFICULTIES IN CHILDREN WITH ATTENTION DEFICIT AND HYPERACTIVITY DISORDER

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ABSTRACT

Children diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) commonly experience challenges in both fine and gross motor skills. Nevertheless, the specific domains of dysfunction in these children have yet to be established through comprehensive neurological assessments. This study aims to determine the prevalence of Developmental Coordination Disorder (DCD) in children with ADHD and identify the specific domains of dysfunction. Participants were 32 children diagnosed with ADHD aged between 5 and 12 years (M = 8.5; 75% male) and 36 typically developing children in the same age range (M = 8.1; 63.9% male). DCD and neurological examination were performed using DCD-Q and Touwen examination, respectively. Children diagnosed with ADHD were more prone to having DCD compared to their peers ($p < 0.05$). According to Touwen's examination, children with ADHD had dysfunction in the domains of involuntary movements, associated movements, coordination-balance, fine manipulation, and sensory function. When a child is diagnosed with both ADHD and DCD, a personalized approach to evaluating and treating both conditions is necessary. A comprehensive assessment that includes neurological components and identifying dysfunctional domains can help determine the most suitable intervention program for children with ADHD.

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is the most common neuropsychiatric syndrome in childhood (Thomas, Sanders, Doust, Beller & Glasziou, 2015). The reported prevalence among school students ranges from 2% to 17% (Scahill & Schwab-Stone, 2000). The symptoms of this disorder are the inability to sit still, fidgeting, interrupting those who are talking, being unable to continue the task, and being easily distracted (Pediatrics, 2002). ADHD symptoms in children persist into adolescence. From childhood to adolescence, symptoms of hyperactivity decrease, but attention deficits and impulsive symptoms continue to affect their relationships negatively, complicating interpersonal relationships (Zhang & Jin, 2007).

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An essential subset of children with ADHD has impaired motor performance (Czamara et al., 2013). Children with ADHD may have significant rates of fine and gross motor problems (Kleeren et al., 2023). The link between ADHD and Developmental Coordination Disorder (DCD) has been known for decades, and the prevalence of DCD has been reported to be 50% among individuals with ADHD (Watemberg, Waiserberg, Zuk & Lerman-Sagie, 2007). Developmental Coordination Disorder (DCD) is a neurodevelopmental condition characterized by marked impairment in the development of motor coordination, which significantly interferes with daily functioning and academic performance. In accordance with the Diagnostic and Statistical Manual of Mental Disorders (DSM-V-TR), DCD is defined as a significant impairment in the acquisition and execution of coordinated motor skills that is not attributable to intellectual disability or a general medical condition (Segal, 2010). The disorder often manifests as clumsiness, delays in achieving motor milestones, and difficulties in tasks such as dressing, eating, writing, and participating in sports or playground activities, thereby affecting children's independence and participation in age-appropriate activities (Van der Linde et al., 2015). Handwriting difficulties, fine and gross motor delays, abnormal movement programming, and deficits in parameter sets have been reported for children with both diagnoses (Kleeren et al., 2023). While a group of children with ADHD might not satisfy the full diagnostic criteria for DCD, they may still experience noticeable challenges in fine motor tasks. These may include deficiencies in motor parameters such as strength, pressure control, agonist-antagonist timing, and slower execution of skilled movements (Schoemaker, Ketelaars, Van Zonneveld & Minderaa, 2005).

Detailed evaluation of these deficits in children with ADHD is clinically essential. In the literature, it has been reported that the motor skills of these children decrease; however, in which neurodevelopmental areas there is retardation has not been studied much. Various studies have been conducted on the prevalence of motor skill problems in individuals diagnosed with ADHD, and at least half of these individuals have been found to have motor problems associated with DCD (Farran et al., 2020; Lee et al., 2021; Montes-Montes, Delgado-Lobete & Rodríguez-Seoane, 2021). Although the findings reveal that motor difficulties are frequently observed in individuals with ADHD, there is no consensus on the cause of these difficulties. Some studies suggest that these motor difficulties may not be a direct component of ADHD and instead may result from other neurodevelopmental disorders, such as DCD, which often coexist (Meachon, Melching & Alpers, 2024). Therefore, in order to clarify the extent of motor difficulties accompanying ADHD, studies with large participation and cultural diversity that address ADHD and DCD together are needed (Farran et al., 2020; Montes-Montes et al., 2021;

Pillay, Meyer & Mokobane, 2019). However, even when DCD is excluded, individuals with ADHD report more motor problems compared to their typically developing peers (Farran et al., 2020; Kaiser, Schoemaker, Albaret & Geuze, 2015; Klupp, Möhring, Lemola & Grob, 2021). This suggests that motor difficulties accompanying ADHD exist, but these difficulties may be milder in severity compared to DCD (Lee et al., 2021). However, the lack of sufficient focus on motor skill problems in ADHD and the significant overlap with DCD that is often overlooked increases uncertainties in this area (Kaiser et al., 2015; Meachon, Zemp & Alpers, 2022). In addition, the fact that ADHD-specific symptoms of inattention and hyperactivity can also be observed in individuals diagnosed with DCD can cause diagnostic confusion (Bonthrone et al., 2024). This situation is further complicated by the inadequate recognition of DCD in clinical practice and low awareness (Lee et al., 2021). In this context, we planned to conduct an evaluation using age-specific neurological examination methods in order to define these motor difficulties in detail. Based on the current literature, it was hypothesized that children diagnosed with ADHD would demonstrate a higher incidence of Developmental Coordination Disorder (DCD) and more frequent dysfunctions in age-related neurological domains compared to their typically developing peers. Therefore, this study aims to determine the incidence of DCD and dysfunctional areas in children with ADHD.

MATERIAL AND METHOD

This study was designed as a comparative cross-sectional study aiming to examine neurodevelopmental differences between children diagnosed with attention deficit hyperactivity disorder (ADHD) and their typically developing peers. The research was conducted at the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University. ADHD diagnoses were made by a child and adolescent psychiatrist at Gazi University Hospital. The study included children who applied to the relevant clinic between February 2023 and July 2023. Prior to data collection, detailed information about the study's purpose and procedures was provided to both the children and their parents. Written informed consent was obtained from the parents, and verbal assent was also obtained from all participating children. Only children who agreed to participate voluntarily were included in the study, and no child refused participation.

Participants

In the study, outpatients between the ages of 5 and 12 years who met the DSM-IV-TR diagnostic criteria for ADHD were evaluated (American Psychiatric Association &

Association, 2013). In addition, 36 healthy children in the same age range were included in the study. Inclusion criteria were: 1) have an ADHD diagnosis made by a pediatric psychiatrist, 2) no known sensory, motor, neurological, or intellectual impairment, and 3) no emotional or social problems that could affect development. Children with documented substantial learning disabilities, autism, neuromotor issues, or significant medical conditions were excluded from the study due to potential challenges that might hinder their ability to follow the instructions for the Touwen examination tests.

Initially, thirty-six children were deemed eligible; however, four of them were later excluded for meeting specific exclusion criteria, with three diagnosed with specific learning disabilities and one with autism spectrum disorder. Thus, the study included 32 children diagnosed with ADHD, referred by the Department of Child and Adolescent Psychiatry, and 36 typically developing children, who were randomly matched with the ADHD group based on age and sex. The average age in the ADHD group was 8.5 ± 1.8 years, whereas the control group had a mean age of 8.1 ± 1.5 years. In the ADHD group, 75 percent of the children were male, while 63.9 percent of the children in the control group were male.

Using the G*Power program (version 3.1.9.2 Universität Düsseldorf, Düsseldorf, Germany), Based on the results obtained from the reference study (Thomas et al., 2015), it was determined that for a study to achieve 85% power with 95% confidence, a minimum of 64 individuals (at least 32 per group) needed to be included. Considering the dropout possibility, 72 children were evaluated (36 children with ADHD and 36 of their typically developing peers). As a result, 32 children with ADHD and 36 children with typical development were included in the study.

Measurements

All children included in the study were evaluated by a pediatric physiotherapist with approximately ten years of clinical experience. The total assessment time lasted about 40 minutes for each child, depending on the children's motivation. The evaluations were finalized during a subsequent session if the children lacked motivation.

Developmental Coordination Disorder Questionnaire (DCDQ)

A parent self-administered questionnaire assists healthcare professionals in identifying developmental coordination disorders (Wilson, Kaplan, Crawford, Campbell & Dewey, 2000). It provides a quick, inexpensive, and reliable assessment of children's motor skills (Martini & Wilson, 2012). Created as DCDQ with 17 items in 2000, the tool underwent revision in 2007. The updated version employed in this study comprises 15 items designed to assess children

aged between 5 and 15 years (Yıldırım, Altunalan, Acar, Elbasan & Gucuyener, 2019). Administering the scale takes approximately 10-15 minutes and enables a comparison of the child's motor coordination and development with a normative group of typically developing children.

The Turkish adaptation of the DCDQ shows strong psychometric properties. The internal consistency of the total scale is high, with a Cronbach's alpha of .890. All item-deleted Cronbach's alpha values remain lower than the total value, indicating that each item contributes positively to the overall reliability. Test–retest reliability values range from .99 to 1.00, demonstrating excellent temporal stability. These findings support the Turkish DCDQ as a valid and reliable screening tool for assessing motor performance in children aged 5 to 15 years (Yildirim, Altunalan, Acar, Elbasan & Gucuyener, 2019).

The questionnaire includes three subscales: control during movement, fine motor and handwriting, and general coordination. These subdomains provide a comprehensive understanding of different aspects of motor function, facilitating a more targeted assessment of children with suspected DCD (Yildirim, Altunalan, Acar, Elbasan & Gucuyener, 2019).

Touwen Examination

The assessment of neurological development is conducted through a standardized neurological examination tailored to the age of the child, using the Touwen Neurological Examination. The Touwen examination evaluates whether a child's motor performance aligns with age-related expectations and serves as a valid, reliable, and sensitive tool for assessing the quality of motor behavior (Hadders-Algra, 2010). It examines eight functional domains: posture and muscle tone, reflexes, involuntary movements, coordination, fine motor skills, sensory function, cranial nerve function, and associated movements (Hadders-Algra, 2010).

The Touwen examination is widely used in both clinical and research settings, particularly for detecting minor neurological dysfunctions (MND) in children with neurodevelopmental disorders. Studies report high inter-rater reliability and strong construct validity, especially when used by trained professionals in structured settings (Peters, Maathuis, Kouw, Hamming & Hadders-Algra, 2008). Its sensitivity allows for the detection of subtle motor control issues that may not be evident through gross neurological tests alone. Through this examination, dysfunctions in specific neurological domains can be identified and systematically documented, making them valuable components of comprehensive neurodevelopmental assessments (Kakebeeke, Jongmans, S. Dubowitz, Schoemaker & Henderson, 1993).

Statistical Analysis

Data analyses were performed utilizing IBM SPSS version 25 (SPSS Inc., Chicago, IL, USA). Visual means (histograms and probability plots) and analytical techniques (Kolmogorov-Smirnov/Shapiro-Wilk tests) evaluated the variables' normality. Rates of impairments in the Touwen neurological examination and differences in the prevalence of DCD between ADHD and control groups were analyzed using a Chi-square test or Fisher's exact test. When the assumptions of parametric tests were not satisfied, the Mann-Whitney U Test was utilized to evaluate variations between independent groups. A p-value less than 0.05 was regarded as statistically significant in all analyses.

RESULTS

The rate of p-DCD in the ADHD group was statistically higher than in the control group ($p<0.05$). While the percentage of p-DCD in the ADHD group was 46.9, it was 8.3 in the control group (Figure 1). In addition, children with ADHD exhibited lower scores in both the DCDQ subscales (control during movement, fine motor/handwriting, and general coordination) and total scores ($p<0.05$) (as shown in Table 1).

Table 1. Comparison of DCDQ subscales/total scores in ADHD and control groups.

DCDQ subscales	ADHD Group (n=32) Mean (SD)	Control Group (n=36) Mean (SD)	*p*-value
Control during movement	21.03 (7)	26.33(4.7)	**< 0.001[a]**
Fine motor/handwriting	13.50 (4.1)	17.78(2.7)	**< 0.001[a]**
General coordination	16.13 (5)	22 (3.5)	**< 0.001[a]**
DCDQ total score	50.34 (14.2)	66.3(10.2)	**< 0.001[a]**

DCDQ = Developmental Coordination Disorder Questionnaire, p-DCD = probable Developmental Coordination Disorder, ADHD = Attention Deficit Hyperactivity Disorder, a: Man-Whitney U Test.

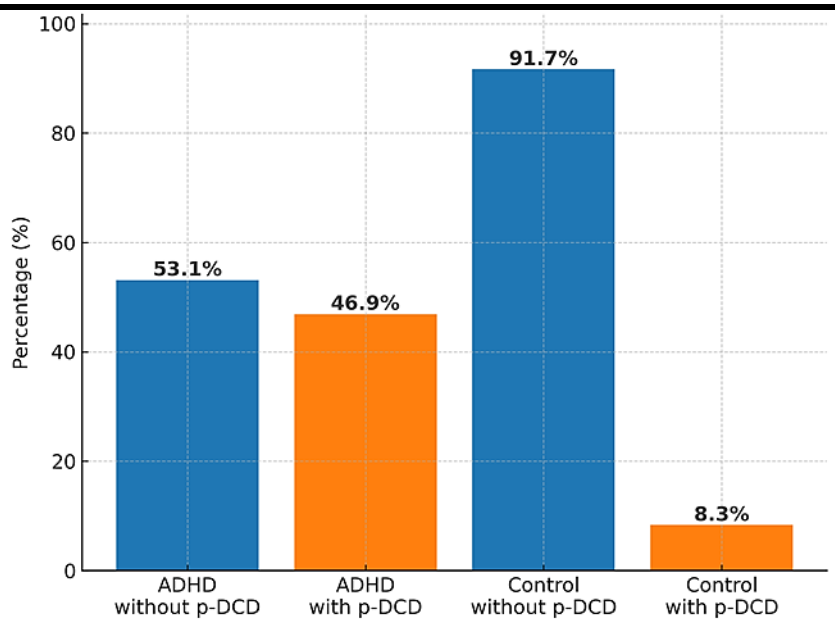

Figure 1. Distribution of p-DCD in the ADHD and control groups

Dysfunction rates were higher in the ADHD group than the control group in the domains of voluntary movements, Coordination and balance, fine manipulation, associated movements, and sensory function, according to the Touwen examination ($p<0.05$). The groups exhibited no distinctions in terms of posture, muscle tone, reflexes, and cranial nerve function ($p> 0.05$) (Table 2).

Table 2. Rates of impairments in the Touwen neurological examination

	ADHD Group n/N (%)	Control Group n/N (%)	*p*-value	OR (CI 95%)
Posture and muscle tone	6/32 (18.8%)	2/36 (5.6%)	0.135[b]	3.92 (0.73-21.05)
Reflexes	3/32 (%)	2/36 (%)	0.66[b]	1.76 (0.28-11.27)
Involuntary movements	7/32 (21.9%)	1/36 (2.8%)	**0.02[b]**	9.8 (1.13-84.74)
Coordination and balance	14/32 (43.8%)	4/36 (11.1%)	**0.002[a]**	6.22 (178-21.77)
Fine manipulation	13/32 (40.6%)	4/36 (11.1%)	**0.005[a]**	5.47 (1.56-19.22)
Associated movements	6/32 (18.8%)	0/36 (0%)	**0.008[b]**	NA
Sensory function	4/32 (12.5%)	0/36 (0%)	**0.044[b]**	NA
Cranial nerve function	2/32 (%)	0/36 (%)	0.218[b]	NA

[a]Chi-square Test, [b]Fisher's exact, OR: odds ratio, CI: confidence interval

DISCUSSION

ADHD is a prevalent condition in childhood, and considering that there are accompanying motor problems, it is essential to identify them. The present study aimed to evaluate the rate of co-occurring DCD in children with ADHD compared to typically developing peers. In addition, it was aimed to detect dysfunctional domains in these children with a detailed neurological examination.

The rate of co-occurring DCD in children with ADHD

ADHD and DCD are both prevalent developmental disorders that frequently occur during childhood. ADHD and DCD have many similarities, such as high prevalence rates, comorbidities, and poor psychosocial outcomes. Studies have indicated that DCD is the most prevalent co-occurring condition with ADHD. Various studies, mainly conducted on clinical groups, indicate a prevalence rate of 50% or more for this co-occurrence (Green, Baird & Sugden, 2006). In the current study, the occurrence of coexisting DCD in children with ADHD was 46.9%, consistent with existing literature. McLeod and colleagues identified commonalities in dysfunctional brain regions among children with DCD and/or ADHD, encompassing the bilateral inferior frontal gyrus, right supramarginal gyrus, angular gyrus, insular cortices, putamen, pallidum, and amygdala. (McLeod, Langevin, Goodyear & Dewey, 2014). Considering that DCD and ADHD mainly occur together, these two disorders may share a similar etiology. The underlying cause of these deficits remains uncertain, but some theories propose that they may stem from inattention and decreased response inhibition (Kaiser, Schoemaker, Albaret & Geuze, 2015). However, recent studies have indicated that motor symptoms may not be inherent to the ADHD phenotype (Lee et al., 2021). Further comprehensive studies could enhance our understanding of the association between ADHD and DCD. In the current study, the proportion of boys in the ADHD group was notably high (75%). Given that sex differences may influence motor development, this imbalance should be considered when interpreting the motor performance results. Previous research suggests that boys and girls may show differing developmental trajectories in fine and gross motor skills, with boys sometimes exhibiting delays or greater variability in coordination tasks (Saidmamatov, Nascimento, Cerqueira, Rodrigues & Vasconcelos, 2022; Samara, Sidharta, Mediana & Noviyanti, 2012). Therefore, the higher percentage of boys in the ADHD group may have contributed to the overall motor difficulties observed. Future studies are encouraged to control for sex or to examine sex-related effects more specifically to better understand their impact on motor skill profiles in children with ADHD.

Scientific literature extensively documents that a significant portion of children with ADHD display diminished motor skills in comparison to their typically developing counterparts, impacting both fine and gross motor abilities (Fenollar-Cortés, Gallego-Martínez & Fuentes, 2017). Studies on clinical and epidemiological aspects indicate that motor coordination problems are present in 30% to 50% of children diagnosed with ADHD (Wilson, 2005). Challenges in motor coordination, commonly observed in community samples of children, may result in non-motor coordination issues such as subpar academic performance,

reduced self-efficacy, and diminished life satisfaction. Children with ADHD seem to exhibit impaired handwriting performance, as demonstrated by illegible written material and/or inappropriate execution speed when compared to their non-ADHD peers (Racine, Majnemer, Shevell & Snider, 2008). This can harm academic performance and self-esteem, as poor handwriting is a life skill that negatively affects this population (Blank et al., 2019). Furthermore, motor impairments may be associated with emotional and behavioral problems in school-aged children (Mikami et al., 2023). Children with motor coordination difficulties are at increased risk of developing psychological problems in adolescence and adulthood, including symptoms of depression and anxiety, which can negatively impact long-term outcomes. (Zwicker, Harris & Klassen, 2013)

Compared to the control group in this study, children diagnosed with ADHD exhibited lower scores across all facets of motor coordination, including control during movement, fine motor/handwriting, and general coordination. Considering the motor and psychological processes that affect each other, identifying motor problems in children with ADHD may be essential in determining the intervention for these children.

Dysfunctional domains in children with ADHD

Children diagnosed with ADHD frequently do not meet the age-appropriate standards for motor control development, specifically in timed repetitive and sequential movements, balance, and motor overflow (Denckla & Rudel, 1978).

Due to the neurological dimension of ADHD, we deemed it valuable to evaluate these children using the Touwen examination. This assessment employs a sophisticated, sensitive, and age-appropriate methodology specifically designed to account for the developmental aspects of the child's rapidly evolving nervous system (Hadders-Algra, 2010). As far as we know, it was used for the first time in children with ADHD in this study. In their research, Stray et al. administered the Motor Function Neurological Assessment (MFNU), similar in content to the Touwen examination, to define motor dysfunction in boys with ADHD. The results showed significant differences between the ADHD and control groups on all subtests, including the total score, suggesting that the MFNU can distinguish between children with ADHD and standard controls (Stray et al., 2009). Children with ADHD made jerky movements, and it was stated that they needed more time to change the direction of movement than controls (Yan & Thomas, 2002). One study found that children with ADHD had difficulty with fine motor skills and balance disorders. Also, another study found that children with ADHD had difficulty with fine motor skills and balance disorders (Raberger & Wimmer, 2003). The present study noted

higher dysfunction rates in domains related to involuntary movements, coordination and balance, associated movements, fine manipulation, and sensory function. The cause of this problem in motor skills may involve synaptic inhibition mechanisms located in or near the motor cortex. However, dysfunction in involuntary movements, associated movements, and sensory function suggested that neurological components were affected in these children. Therefore, a comprehensive evaluation of children with ADHD and identification of dysfunctional domains may guide the intervention to be applied to these children.

Limitations

In our study, the use of the validated DCD-Q to identify children at risk for DCD instead of a formal diagnosis of DCD according to the DSM-5 diagnostic criteria was a limitation, as this scale can only distinguish the presence of probable DCD (Smits-Engelsman, Schoemaker, Delabastita, Hoskens & Geuze, 2015). Additionally, the sample of this study is small to determine the prevalence and generalize the results. A study with a larger sample is needed to determine the prevalence of DCD in children with ADHD. The lack of classification according to the symptoms of ADHD (inattention, impulsivity, and hyperactivity) is a limitation of the study since an adequate number of children with ADHD were not evaluated. Symptom-based classification can provide deeper insight into the neuropsychological profiles and help tailor intervention strategies more effectively. Furthermore, no information was collected regarding whether participants with ADHD were taking medication. Since pharmacological treatment may influence both attention and motor performance, not accounting for medication use might have affected the results. Future studies should consider medication status as a potential confounding factor when evaluating motor difficulties in this population.

CONCLUSION

This study revealed that DCD disorder essentially accompanies ADHD and that children with ADHD have more neurological dysfunctional domains compared to the control group. Having a child diagnosed with both ADHD and DCD requires an individualized approach to the assessment and treatment of both conditions. To determine the most appropriate intervention program for children with ADHD, a detailed evaluation may be helpful, including neurological components and identifying dysfunctional domains.

A detailed evaluation may help identify specific motor and neurological challenges in children with co-occurring ADHD and DCD. In such cases, a multidisciplinary and individualized intervention plan is crucial. For instance, physiotherapy programs focusing on

balance training, postural control, and coordination exercises (e.g., task-oriented motor training, core stabilization exercises) can effectively address motor impairments. Additionally, occupational therapy interventions such as sensory integration therapy, fine motor skill development activities, and executive function training may help improve daily functional performance and participation. Incorporating playful, structured, and goal-oriented activities tailored to the child's unique needs can enhance engagement and outcomes. Early identification and intervention are essential to support both motor and cognitive-behavioral development in these children. Based on the findings of this study, it is important for both families and professionals to recognize that ADHD and DCD may commonly co-occur, and this should be taken into account during assessment and intervention processes. Families' awareness of their children's motor and attention-related difficulties plays a key role in seeking timely and appropriate support. Furthermore, it may be beneficial for researchers to generate more scientific evidence aimed at identifying effective intervention strategies for children with co-occurring ADHD and DCD.

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