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**Developmental coordination disorder – clinical features and
treatment options**

Развојни поремећај координације – клиничке карактеристике и
терапијске опције

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Developmental coordination disorder – clinical features and treatment options

Развојни поремећај координације – клиничке карактеристике и терапијске опције

SUMMARY

Developmental coordination disorder (DCD) is a neurodevelopmental disorder that is usually recognized after the age of five but may have lifelong motor, coordination, and cognition consequences. The criteria for setting a diagnosis refer to the presence of: performance of coordinated motor skills below that expected for chronological age, a deficit of motor skills that significantly and persistently interferes with activities of daily living, the onset of symptoms in an early developmental period, and a lack of motor skills that cannot be explained by intellectual disability or other neurological conditions that affect movement. This clinical picture is often comorbid with attention deficit hyperactivity disorder, autism spectrum disorder, and some other neurodevelopmental disorders. Prevailing DCD management includes task-oriented interventions as well as interventions focused on reducing impairment and improving physical function. The aim of the paper is to summarize typical DCD features related to diagnostic criteria, epidemiology, etiology and comorbidities, as well as to present current management options.

Keywords: developmental coordination disorder; diagnostic criteria; comorbidity; task-oriented intervention

САЖЕТАК

Развојни поремећај координације (РПК) представља неуроразвојни поремећај који се углавном препознаје након пете године живота, али може имати целоживотне последице на моторику, координацију и когницију. Критеријуми за постављање дијагнозе одnose се на присуство извођења координисаних моторичких вештина испод очекиваног у односу на хронолошку доб, дефицита моторичких вештина који значајно и перзистентно омета активности свакодневног живота, почетка симптома у раном развојном периоду и недостатка моторичких вештина који се не може објаснити интелектуалном ометеношћу или неким другим неуролошким стањима која утичу на покрете. Ова клиничка слика често је коморбидна са поремећајем пажње са хиперактивношћу, поремећајем из спектра аутизма и неким другим неуроразвојним поремећајима. Протежирајуће интервенције за РПК укључују интервенције оријентисане на задатак, као и интервенције фокусиране на смањење оштећења и побољшање телесне функције. Циљ рада је да сумира специфичности РПК везане за дијагностичке критеријуме, епидемиологију, етиологију и коморбидитете, као и да прикаже савремене терапијске опције.

Кључне речи: развојни поремећај координације, дијагностички критеријуми, коморбидитет, интервенција оријентисана на задатак

INTRODUCTION

The criteria for defining developmental coordination disorder (DCD) (ICD-11 code 6A04) include limitations of motor activities that are not otherwise caused by cognitive, sensory or neurological deficits and are identified in the early developmental period [1, 2]. DCD is a neurodevelopmental disorder characterized by deficit in performing fine (e.g. handwriting and tying shoelaces) and gross motor skills (e.g. playing sports and dressing) at a level appropriate for calendar age, but clinical presentation can be very heterogeneous [3]. Within the clinical picture of DCD there is also a motor and neurodevelopmental component of the diagnosis [4]. In the past, the terms "clumsy child syndrome" and "developmental dyspraxia" were associated with this clinical picture [5].

In some cases, it can be challenging to determine the extent to which typical difficulties seen in DCD affect child's daily activities and participation and meet criteria for diagnosis. Notably, the common DCD description seems to include a large group of children who have a variety of impairments. Structured observation and examination of movement specificity can help in deciding on the diagnosis of DCD in children who have difficulties in coordination, generalization, learning and transfer within motor skills [6].

The aim of this paper is to fuse the specificities of DCD related to diagnostic criteria, epidemiology, etiology and comorbidities, as well as to present current options for management of this condition.

DIAGNOSTIC CRITERIA

Current diagnostic parameters for determining DCD described in ICD-11 [1] and DSM-5 [4] refer to four mandatory criteria that are detailed in Table 1.

Preschool children with DCD master key developmental motor milestones (crawling, standing, walking, climbing stairs, buttoning clothes) at later age compared to children with neurotypical development [1]. For example, it has been reported that 23% of children with DCD assessed between the ages of seven and ten have never learned to crawl [7]. Children with DCD also have limited mobility, but generally the limitations are less pronounced than in children with cerebral palsy [8]. During middle childhood, the symptoms of DCD can become evident in activities such as handwriting, playing with a ball or in tasks of visuo-constructive abilities such as jigsaw puzzles or constructing various models [9, 10, 11]. Deficits in motor coordination in adolescence and adulthood can manifest when trying to master new motor skills (e.g., driving a car, using various tools, or taking notes), but even when motor skills are acquired, movement performance in all developmental stages is generally imprecise and clumsy compared to peers with neurotypical development [1, 9]. Clinical symptoms and signs suggestive but not specific for DCD in different age groups are shown in Table 2.

The diagnosis of DCD is usually made after the fifth birthday when all diagnostic criteria can be met. Due to major changes occurring in the developing brain during the first postnatal years, a certain time must elapse before symptoms and signs become unequivocally noticeable [12]. Although DSM-5 [4] included a new diagnostic criterion for DCD related to the onset of symptoms in an early developmental period, the evidence supporting this criterion is limited since DCD is generally not diagnosed before the age of five, as young children with motor delays

can show spontaneous developmental catch-up. Likewise, the difficulty of a young child's cooperation and motivation to carry out assessment tests in this domain can lead to problems in the interpretation and straightforward diagnosis [13].

Children with DCD show a various spectrum of difficulties in controlling, coordinating and planning motor responses, as well as sensory and perceptual processing, which affects their quality of performing gross and fine motor activities [14]. Given highly heterogeneous presentation of DCD, diagnosis may be particularly challenging, and the experts in this field have made efforts to categorize DCD in distinct subtypes. Three subtypes of DCD have been proposed [15]: ideomotor DCD, presenting with a difficulty in the perception, praxia and imitation of gestures; visual-spatial/constructional DCD, characterized by serious difficulties in visual-motor integration and visual-spatial structuring, while the third subtype refers to a mixed presentation which is comprised of first two subtypes. However, other authors suggest perceiving the categorization of DCD according to cognitive specificities, and point out six subtypes:

1. children at risk – difficulty with jumping, as well as minor problems with manual dexterity and simultaneous coding,
2. children with average values of all cognitive-motor assessments,
3. children with values of all cognitive-motor assessments above the average,
4. children with detected manual dexterity, planning and simultaneous coding problems,
5. children with detected manual dexterity, planning and dynamic balance problems,
6. children with values of all cognitive-motor assessments below the average [16].

Despite the existence of different categorizations of DCD, it could not be claimed that the subtypes are clearly related to specific interventions within the treatment framework. However, in most scientific sources it is considered that children who score below the fifth percentile on standardized tests for the assessment of motor abilities (for example Movement Assessment Battery for Children Second Edition – MABC-2) can be described as children with significant movement difficulties and with the probable presence of DCD. Children who score in the fifth to fifteenth percentile are at risk for DCD [17]. The results of this assessment do not provide a diagnosis of DCD, but contribute to the fulfillment of diagnostic criterion A.

EPIDEMIOLOGY AND ETIOLOGY

The reported prevalence of DCD ranges from 2% to 20% of children [18], the most frequently assessed to be 5% to 6% in school-aged children [13]. Male predominance is a constant finding in studies (two to three times), and the risk of developing DCD increases with lower gestational age at birth [13]. However, despite such a high prevalence, DCD is considered one of the most unrecognized neurodevelopmental disorders, with the least organized support in terms of treatment [18]. Although DCD has been traditionally considered a childhood neurodevelopmental condition, it is estimated that it occurs in about 5% of the general adult population [13].

There is very little data on the cause of DCD and its pathogenetic mechanisms, making it difficult to understand core pathological problems in motor skill learning in order to determine the optimal therapeutic interventions. Yet, the evidence indicates the etiology is multifactorial, with both environmental and genetic factors contributing [19]. In most children with DCD, no obvious brain lesion can be seen. However, neuroimaging studies suggest that the brains of the affected children may show minor structural and functional changes [20]. For example, there is evidence of altered white matter development, indicated by reduced axial diffusivity in motor and sensory tracts [21]. Dysfunction in several brain regions has been implied: the cerebellum, basal ganglia, parietal lobe, frontal lobe areas, and possibly the corpus callosum [22, 23]. Considering the influence of the cerebellum on movement, coordination, balance, learning and cognitive functions, it is expected that its atypical developmental may be noted [19]. Poorer quality of visuospatial processing is most often associated with dysfunction of the parietal lobe, the impairment of motor planning, memory and executive functions indicates problems originating from the frontal lobe, and dysfunction of eye-hand movements implies problems within the corpus callosum [23, 24]. Nevertheless, undoubtedly the neural substrates of DCD have yet to be fully described.

COMORBIDITIES

The heterogeneity of the DCD presentation, in addition to subtypes, also includes the occurrence of comorbidities. There is frequently an overlap with other neurodevelopmental disorders, especially attention deficit hyperactivity disorder (ADHD) [2] and autism spectrum disorder (ASD) [25]. Motor impairments are an integral part of the clinical picture of numerous neurodevelopmental disorders [12, 26], and it is believed that over 50% of children with ADHD

(primarily the inattentive type) or ASD may have a simultaneous diagnosis of DCD [19]. The possibility of a genetic etiology linking DCD and ADHD or ASD has been indicated [27].

When considering a dual diagnosis of DCD and ADHD, it is important to emphasize that the diagnostic criteria for each disorder must be met to officially establish diagnosis of comorbidity. For example, some people with ADHD may appear clumsy (e.g., tripping over obstacles, knocking over objects, dropping things) due to inattention, hyperactivity, and/or impulsivity [28]. DCD in such cases should not be diagnosed [1].

It is important to note that criterion D complicates the diagnosis of DCD in children with ASD because it implies that the motor difficulties must be greater or minimally different from what is expected in children with ASD. In the literature, one comes across a very small number of recommendations on how to determine with certainty whether criterion D for the DCD has been met. It is necessary to establish whether the motor difficulties detected in children with ASD are an integral part of the clinical picture [29] or are a consequence of the simultaneous occurrence of DCD, because each diagnosis, or comorbidity, affects the type of treatment offered to children and families. The authors of this paper did not find any studies that provide clear guidelines on when to diagnose DCD in children with ASD, although the literature suggests that this should be done when criteria for DCD are met. However, no formal recommendations can be found to help clinicians interpret when motor difficulties exceed those typically expected in children with ASD [14].

Specific language impairment (SLI) is a comorbid condition that can occur in DCD. It is thought that about a third of children diagnosed with SLI also have DCD [30]. Children with a dual diagnosis of SLI and DCD have an evident decline in the quality of abilities in several domains of quality of life, which is not so pronounced in children with SLI [31].

Children with DCD are also facing two to four times increased risk of mental health issues, with anxiety detected in 16.7%–33.8% and depression 9.1%–11.8% cases [9, 32].

Recent research indicate that secondary psychological problems (lower quality of life, low self-esteem, poor social relations, abuse, self-isolation) can also be classified as additional difficulties experienced by children with DCD [33, 34]. Hence, DCD can hinder social inclusion of children, potentially leading to emotional and behavioral problems, especially internalizing ones. Research from Korea proves that eight and nine-year-old children with DCD struggle with initiating and maintaining friendships, not only at school, but also at home with their parents. A lack of positive self-regard and low confidence in personal decision-making are

common. However, it is promising that emotional behavioral issues in these children were found to decrease when the quality of their motor coordination is improved [35], so it is important to monitor negative psychological and social manifestations into adulthood [34]. Given all the above, psychological support is considered to be as crucial for individuals with DCD as other types of treatment [33].

In terms of physical health, children with DCD are often overweight or obese (OR 1.79-4.23) with compromised physical fitness and therefore body mass index should be part of their general physical exam [9]. In addition, parent-reported symptoms of DCD are common in childhood epilepsy, which may be associated with additional stigmatization early and later in life [36, 37].

In practice, DCD is usually not considered in people with intellectual disability (ID), because in that case the motor deficit must be significantly greater than the deficit that would be expected in a certain category of ID (mild, moderate, severe, profound). Although this may pose a problem, a formal diagnosis of DCD facilitates access to appropriate support, interventions and treatment and may shed light on shared underlying mechanisms [2]. Procedural learning and motor control deficits in the DCD may be secondary to several neural network dysfunctions (cortico-striatal and cortico-cerebellar) which may have relevance in cognitive and motor functioning later in adulthood [38, 39]. Other comorbid conditions that occur with RPK include various problems in learning and behavior, difficult acquisition of academic skills of reading, writing and following spelling rules, deficit of social communication and social interaction in the sense of difficult social reciprocity and problematic non-verbal communication [40].

TREATMENT

Interventions designed to improve motor performance for children with DCD have numerous components and differ in type, intensity, duration and frequency. When planning the intervention program, it is recommended to take into account both the "strengths" and "weaknesses" of the child in order to improve the quality of motor functions and execution of activities. Such a protocol improves the chance for the most pronounced functional independence in self-care [41]. However, if not all criteria for DCD are met, but there are motor problems in performing activities, the child should be included in various developmental and stimulating activities within his or her environment. This is especially important for children younger than five years

who show significant motor dysfunctions but do not meet all the diagnostic criteria needed to diagnose DCD [13].

Often recommended interventions for children with DCD include a combination of *task-oriented interventions and interventions focused on reducing impairment and improving body function and structure*. Combining these two types of interventions in the treatment has a greater effect on improving the quality of motor skills, than any of the prevailing interventions implemented in isolation [42]. *Task-oriented interventions* are motor activities or motor programs designed to improve the adoption and performance of a specific functional motor task [42, 43]. These interventions are based on theories of motor control and motor learning, using the concepts of active participation and increasing task demands [44]. In the literature, there are four methods of task-oriented intervention related to DCD:

1. Motor Skill Training (exercise and repetition of voluntary body movements in order to achieve the correct execution of a motor task, which achieves functionality and maximum participation within the environment) [45],
2. Neuromotor Task Training (uses individualized simplification of fine or gross motor activities into smaller components, thus enhancing the success of the individually performed step, until the child generalizes the motor skills needed to achieve the goal) [46],
3. Cognitive Orientation to Daily Occupational Performance (acquiring motor skills through the formation of problem-solving strategies, using behavioral and cognitive learning theories) [47],
4. Motor Imagery (a new cognitive approach by which the child practices or simulates a targeted motor activity) [48].

Among the different treatment approaches, the most talked about is the importance of cognition for the effect of intervention in children with DCD. The most effective part of the intervention is a process that obligatorily includes cognitive engagement, that is, a process that enables children to acquire, process, combine, plan and construct information [49]. New cognitive training methods prove that appropriate exercise programs are important for the safe and efficient performance of activities of daily living in children with DCD. These methods include exercises related to mental processes such as perception, memory, attention and planning [50].

Interventions used to reduce impairment and improve body functions and structures are called process-oriented approaches. The strategy of these interventions is based on the fact that improvement in basic motor deficits will lead to changes in motor performance [45].

In the literature, there is no clearly prescribed dosage with which the intervention should be carried out. The dosage of interventions should be based on the ability of the child with DCD to exercise at home, in kindergarten/school and in a health facility. Achieving short-term goals requires a very frequent schedule of exercises, which is adapted to the complexity of the goal. The exercise schedule should be organized in the range of two to five times a week, so that the set individualized goal can be achieved in about nine weeks. The recommended duration of one intervention in the literature ranges from ten minutes to six hours per day [42]. The treatment of fine motor skills is usually significantly more time-intensive than the training of gross motor skills [13].

Within the treatment, it is important to note that multidisciplinary collaboration with clinicians from different fields can be extremely beneficial for people with DCD [51]. A multidisciplinary model could allow experts from different fields to contribute to the creation of treatments for each of the different difficulties present in DCD, in relation to motor, cognitive and secondary symptoms. This approach would significantly help to better understand the DCD and finally confirm its extraordinary complexity [52].

CONCLUSION

DCD is a neurodevelopmental disorder that occurs in 5% to 6% of children. The exact etiology of DCD is unknown, but it has been proven that multiple areas of the brain are affected, with clear genetic and environmental contributions. To be diagnosed with DCD, all four ICD–11/DSM–5 criteria must be met. The effects of motor dysfunction are manifested in the poor performance of daily activities and academic tasks. Comorbid conditions that occur in DCD are ASD, ADHD and SLI.

Task-oriented interventions and interventions focused on reducing impairment and improving body function and structure are first-choice interventions that should be implemented with high frequency with children with DCD. Given that DCD is a very complex condition, it is necessary to form a multidisciplinary team, which will treat the multiple consequences of DCD and other related problems through specialized interventions.

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Table 1. Diagnostic criteria for developmental coordination disorder*

Criterion	Description of criteria
A	Acquiring and performing coordinated motor skills, as well as the possibility for motor learning, are significantly below expectations considering the chronological age of the individual. Difficulties are manifested as clumsiness (e.g., dropping objects, tripping over or hitting objects), as well as slowness and inaccuracy in performing motor skills (e.g., grasping objects, using scissors or cutlery, riding a bicycle or rollerblade, writing with a pencil).
B	The motor skill deficit described in the previous criterion significantly and persistently interferes with activities of daily living that correspond chronological age (e.g., self-care and self-aid) and affects productivity during academic learning, leisure, and play.
C	The onset of symptoms is in the early period of development.
D	Motor skill deficits cannot be explained by intellectual disability or visual impairment and cannot be attributed to a neurological condition that affects movement (e.g., cerebral palsy, muscular dystrophy and degenerative disorder).

*Adapted from World Health Organization [1] and Cunningham et al. [2]

Table 2. Symptoms and signs suggesting possible developmental coordination disorder in different age groups*

Age	Symptoms and signs indicating possible developmental coordination disorder
Preschool children	<ul style="list-style-type: none"> · Persistent delay in motor developmental milestones: sitting, standing, walking, toilet training, speaking · Difficulties with running, hopping and jumping · Difficulties with catching or kicking a ball · Trouble walking up and down stairs · Poor coordination and balance · Frequently tripping and/or falling over things, bumping into objects · Lack of interest in construction toys (e.g. building blocks, Lego®) · Poor at getting dressed, buttoning up clothes, combing hair · Clumsy when picking up small things, tends to break small toys · Poor pencil skills – drawing, holding a pencil (drawings seem very immature compared to those of other children) · Poor at using scissors, fork and other utensils · Poor at puzzles, jigsaws or shape-sorting games · Difficulties with brushing teeth, getting dressed, tying shoelaces and other self-care · Difficulties with oral motor coordination, such as closing lips to blow bubbles or blowing out birthday candles
School children and adolescents	<ul style="list-style-type: none"> · Problems from preschool period may persist · Problems with copying text or drawings from the school board · Difficulties with math and writing · Appearing disorganized · Seeming unable to follow instructions · Avoiding physical education, sports and games · Slow and poor handwriting with higher percentage of errors compared to neurotypical children · Driving difficulties

*Adapted from Harris et al. [9], Morgan et al. [10], and Smits-Engelsman et al. [11]