Developmental Coordination Disorder: An Overview of Motor Learning, Etiology, and Intervention Strategies

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A Senior Thesis submitted in partial fulfillment
of the requirements for graduation
in the Honors Program
Liberty University
Spring 2023

Acceptance of Senior Honors Thesis

This Senior Honors Thesis is accepted in partial
fulfillment of the requirements for graduation from the
Honors Program of Liberty University.

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Abstract

Developmental Coordination Disorder (DCD) is a neurodevelopmental condition characterized by motor impairments resulting from disrupted communication between the body's nervous system and muscular system. Individuals affected with this disorder struggle with several physical, neurological, and psychological challenges and deal with decreased functionality in activities of daily living (ADLs). Proposed intervention strategies for this population are aimed at the holistic development of a child's motor coordination skills that enable them to participate in ADLs. Therapeutic approaches involving task-oriented elements help promote positive skill transfer to the context of a child's daily environment. For the best results, formal treatment should be supplemented by community support in the school and the home.

Motor Learning in Children with Developmental Coordination Disorder

Motor coordination allows individuals to be able to perform basic activities of daily living. Daily functions such as getting dressed, brushing teeth, eating, writing/drawing, and participating in physical activity all require physical coordination. This coordination ultimately comes from the body's nervous system, which works alongside the musculoskeletal system to allow the body to move efficiently. Developmental coordination disorder (DCD) is a condition characterized by faulty communication between these two body systems, which leads to clumsy movements and lack of motor coordination. Individuals with DCD often have difficulties performing activities of daily living, which can lead to physical and psychological problems. If DCD is identified and treated early, affected children can achieve a sense of normalcy when it comes to carrying out activities of daily living.

What is Motor Learning?

Motor learning relies on the effective interaction between the body's nervous system and musculoskeletal system to produce efficient movement. Smits-Engelsman et al. (2020) defined motor learning as the ability to improve one's movement skills through practice and experience. While the process of motor learning occurs internally, the outcomes are measured externally through means such as the time it takes to perform a task or the accuracy with which one performs a task. Motor learning is a gradual process that is built and refined as people continuously interact with their environments (Bo & Lee, 2013).

Motor control can be divided into three distinct levels within the nervous system (Kobesova & Kolar, 2014). The first level involves primitive reflexes controlled from the spinal cord and brain stem and is predominant during the neonatal stage. Movements within this level

involve the entire body, and there is not much bodily stability due to a lack of antagonistic coactivation. At the neonatal stage, a typically developing child will display gross movements involving the entire body, whereas an abnormally developing child may display movements that are less fluid. The next is the subcortical level, which allows for trunk stabilization during the first year of life. The cortical level is the highest level of motor control and involves multisensory integration and proprioception. Inadequate sensory integration at the cortical level can result from developmental dyspraxia, or developmental coordination disorder.

Developmental Coordination Disorder

Developmental coordination disorder (DCD) is a condition that leads to impairments in the development of motor coordination, affecting both fine and gross motor skills. DCD affects approximately 2-7% of school-aged children and presents both physical and psychological complications (Cacola et al., 2016). Children with DCD struggle with impairments in balance, posture control, and sensorimotor coordination. These impairments make functional tasks and activities of daily living (ADLs) more difficult. As a result, children with DCD often participate less in physical activity. This leads to a higher risk of physical problems such as obesity and cardiovascular disease and psychological problems such as decreased self-esteem. In the absence of intervention, these challenges faced by children with DCD are likely to continue into adulthood. According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), a child may be diagnosed with DCD if they display significantly slower motor skill development than what would be expected for their age, their motor deficits significantly interfere with activities of daily living, their symptoms appear in the early

developmental period, and there are no other disabilities or conditions (intellectual, visual, or neurologic) that would better explain the symptoms (American Psychiatric Association, 2013).

Children with DCD present with a wide range of motor difficulties. They may display an awkward and clumsy gate, difficulties with fine motor skills such as writing and using scissors, and/or poor hand-eye coordination during games and activities (Biotteau et al., 2020). They may also have trouble completing daily tasks such as getting dressed, tying their shoes, and holding eating utensils. As they get older, they are likely to have difficulties playing sports and engaging in physical activity. These deficiencies can have significant psychological effects on children. They are likely to become discouraged at their lack of motor progress compared to other children their age, and this may cause them to avoid difficult activities altogether. It is therefore important to introduce interventions to help improve the motor skills of children with DCD and thus enhance their quality of life.

Etiology of Developmental Coordination Disorder

DCD can be seen as the complex interplay between multiple predisposing factors and comorbidities. Therefore, there is not necessarily a specific etiology that can be pinpointed. Although it has not yet been confirmed by research, it is suspected that genetics and hereditary factors are involved with the formation of DCD (Biotteau et al., 2020). According to Lichtenstein et al. (2010), 70% of the variation in liability for DCD was accounted for by genetic factors. The genetic factors present in those diagnosed with DCD may also be similar to those present in other developmental disorders such as attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and specific language impairment, making these common comorbidities among individuals with DCD (Biotteau et al., 2020; Blank et al., 2011).

While the specific etiology may be yet unknown, recent studies have shown reduced cortical thickness and decreased activation in the frontal, parietal, and temporal lobes of the brain (Langevin et al., 2014). Neural networks among sensorimotor networks have also been shown to be poorly integrated in children with DCD (Caeyenberghs et al., 2016). Furthermore, research has suggested disturbances in brain axonal development in this population (Brown-Lum et al., 2020; Zwicker et al., 2012).

Brain Pathologies

Several hypotheses have been presented regarding which area of the brain is involved with the deficits seen in DCD. Some of the proposed areas of involvement include the cerebellum, the basal ganglia, and the parietal lobe (Biotteau et al., 2020; Bo & Lee, 2013). The cerebellum is an area of the brain that is responsible for voluntary movements, posture, balance, and coordination (Kobesova & Kolar, 2014). It is involved with sensory integration at the cortical level, the subcortical level, and the level of the spinal cord and brain stem. This area of the brain plays an important role in accuracy and precision of movement (D'Angelo, 2018; Kobesova & Kolar, 2014). It develops more slowly compared to other areas of the brain and is therefore thought to be one of the major factors contributing to developmental disorders (Bo & Lee, 2013). Often, children with developmental delays or lack of coordination have similar motor impairments as those seen in patients with cerebellar lesions, which supports cerebellar involvement in motor disorders (Ivry, 2003).

In addition to the cerebellum, studies have shown that the basal ganglia play an important role in the planning, learning, and execution of motor skills (Doyon et al., 2009; Groenewegen, 2003). Impairments in motor learning skills have been seen in patients with Parkinson's and

Huntington's disease where striatal dysfunction is a qualifying characteristic. This area of the brain has also been shown to be important for the retention of learned motor skills. While these associations support the connection between motor learning and the basal ganglia, more research should be conducted to determine the extent to which motor impairments as seen in DCD can be accredited to faulty function of this area of the brain. The parietal region of the brain has also been shown to play a role in spatial cognition, which is an important aspect of motor planning and execution (Sack, 2009). Tasks involving spatial cognition have been linked with fronto-parietal activations. This relationship is supported by studies analyzing the brain through non-invasive brain imaging and brain interference techniques during spatial cognition tasks.

Risk Factors for Developmental Coordination Disorder

One of the most significant risk factors associated with the development of DCD is preterm birth. This may be defined as low gestational age, low birth weight, or a combination thereof. Hoorn et al. (2020) found that children who were born preterm were three to eight times more likely to be diagnosed with DCD once they reached school age. Furthermore, males are more likely than females to be diagnosed with DCD. This is supported by research that shows that male sex is a risk factor for various neurodevelopmental disorders that are often associated with DCD. Blank et al. (2019) found male to female ratios of DCD prevalence ranging from 2:1 to 7:1. However, this risk factor is not as severe among preterm-born children, which implies that preterm birth is a risk that carries more significant weight (Hoorn et al., 2020).

Screening for Developmental Coordination Disorder

The screening process typically begins when a child's parents, caretakers, or teachers notice significant delays in motor skill development and/or notable clumsiness that interferes

with activities of daily living (Harris et al., 2015). A general practitioner should ask questions related to risk factors and key indicators of DCD. The child may be referred to a specialist if other motor disorders, such as cerebral palsy, have been ruled out. The Developmental Coordination Disorder Questionnaire may also be used to identify children with potential DCD.

When DCD is suspected, clinical assessment should begin by recording family history and the child's developmental history, including birth, academic performance, and other known disorders. The examination should consist of cranial nerve testing, assessment of strength and flexibility, observation of motor planning, and assessment of cognitive status. Certain criteria must be met for a formal diagnosis of DCD to be made. Table 1 outlines the diagnostic criteria put forth by the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013, p. 74). These criteria can be assessed through tools such as the Movement Assessment Battery for Children (Henderson et al., 2007), the Bruininks-Oseretsky Test of Motor Proficiency (Bruinks & Bruinks, 2005), and the Developmental Coordination Disorder Questionnaire (Wilson et al., 2000).

Table 1

DSM-5 Diagnostic Criteria for Developmental Coordination Disorder

A. The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g.., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).
B. The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.
C. Onset of symptoms is in the early developmental period.
D. The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

Physical Health Implications

Since children with DCD struggle with motor impairments, they are less likely to attain appropriate amounts of physical activity. The American College of Sports Medicine (ACSM; 2021) recommends that children and adolescents acquire at least 60 minutes of moderate-to-vigorous intensity physical activity every day. This can be achieved through structured exercise such as bodyweight or resistance band training, but for many children, it is achieved through unstructured but developmentally appropriate activities such as running games, jumping rope, dancing, climbing playground equipment, and sports such as soccer and basketball. However, children struggling with motor impairments may not have the capabilities to perform these activities, leading to frustration and a greater risk for a sedentary lifestyle. If these children are not meeting physical activity guidelines important for their development, they will not reap the benefits associated with regular physical activity, such as strengthened bones, improved body composition, decreased risk for cardiovascular and metabolic disease, decreased anxiety and depression, and improved cognitive function. Several studies have shown that children with diminished motor proficiency have greater waist girth and greater percentage of body fat; lower cardiorespiratory fitness as measured by VO2max; lower muscle strength, endurance, and flexibility; and lower anaerobic capacity than their typically developing peers (Blank et al., 2019; Rivilis et al., 2011).

Neurologic and Neuromuscular Implications

DCD often leads to delayed muscle activation and lower peak muscle force during isometric contractions (Fong et al., 2015). As a result, individuals with DCD often have difficulties balancing and take longer to recover when their posture is disturbed. This may be due

to their atypical cerebellar development and function. The neurological deficits prominent in DCD-affected children also impact scholastic achievement. Children with DCD have been shown to perform more poorly in school than typically developing children, particularly in the areas of reading and mathematics (Blank et al., 2019). Increased levels of anxiety relating to their diagnosis may be a contributing factor, but their atypical brain development is likely the primary cause.

Psychological Implications

It is important to note that the complications of DCD go further than physical health. There are many negative psychological outcomes faced by individuals with DCD that may adversely impact their overall well-being. For example, Liberman et al. (2013) found that children with DCD lack enjoyment participating in daily activities when compared to their typically developing peers. This may be due in part to their frustration with their low motor skills and consequent inability to complete tasks. According to the International Classification of Functioning, Disability and Health (ICF), participation, or involvement in life situations, plays an important role in an individual's health and well-being (World Health Organization, 2001). Children with DCD have been shown to demonstrate decreased participation in everyday tasks compared with their peers, which leads to further decreases in self-efficacy and reduced independence (Bart et al., 2011; Blank et al., 2019; Liberman et al., 2013). When they do participate, the activities they choose tend to be quieter and more socially isolated than those chosen by their typically developing peers (Jarus et al., 2011). They have also been shown to display lower levels of coherence (viewing the world as meaningful), hope (specifically in the context of belief in one's ability to achieve desired goals), and effort (Liberman et al., 2013).

Due to their diminished self-efficacy in relation to completing motor tasks, children with DCD are likely to withdraw from structured and unstructured activities with their peers. Furthermore, the motor skill deficits associated with DCD put affected children at a higher risk of experiencing social anxiety (Kristensen & Torgersen, 2008). Lingam et al. (2012) found that children with DCD are twice as likely to report the occurrence of depression and four times as likely to experience mental health struggles as reported by their parents at the age of 9-10 years. Furthermore, children with DCD have a lower self-perception of their health-related quality of life (Karras et al., 2019). They have also been shown to score significantly lower than typically developing peers in the areas of psychosocial well-being, moods and emotions, parent relations and home life, and school environment. Challenges related to behavior and social interaction are more prevalent in these children (Blank et al., 2019). These psychological challenges place a burden on children with DCD and ultimately prevent them from living healthy and functional lives to their fullest potential. It is therefore important to introduce interventions that will address the physical and psychological difficulties faced by these children.

Interventions for Children Diagnosed with Developmental Coordination Disorder

Several different intervention strategies have been proposed that are aimed at improving the motor development of children diagnosed with DCD. These include both process-oriented interventions and task-oriented interventions. Table 2 provides a review of some of the methods that fall under each category. According to Smits-Engelsman et al. (2012), process-oriented interventions focus on global functions such as sensory integration, visual-motor perception, and muscular strength. The idea is that working on the processes that comprise movement will transfer to better overall skill performance. In contrast, task-oriented interventions take into

consideration the distinct needs of the individual by targeting the specific motor skills and tasks that are difficult for the affected child. With this approach, the child is taught how to perform ADLs and how to integrate these tasks into school, sports, and home life. Neuromotor task training, cognitive orientation to daily occupational performance, and imagery training all fall under the task-oriented category. While some research supports the usefulness of process-oriented approaches in treating children with motor deficits, current evidence-based practice emphasizes task-oriented approaches to provide the best results and promote positive skill transfer. When compared with process-oriented interventions and chemical supplements, task-oriented interventions and traditional physical and occupational therapies had the largest effects on motor performance and produced the most benefits among children diagnosed with DCD (Smits-Engelsman et al., 2012).

Table 2

Overview of Intervention Strategies

Process-Oriented Approaches	**Task-Oriented Approaches**
• Balance Training *(Fong et al., 2016)* • Strength Training *(Kordi et al, 2016; Bundy et al., 2020; Kaufman & Schilling, 2007; Menz et al., 2013)* • Virtual Reality Training *(Ashkenazi et al., 2013, Bonney et al., 2017)*	• Neuromotor Task Training *(Niemeijer et al., 2007; Smits-Engelsman et al., 2012)* • Cognitive Orientation to Daily Occupational Performance *(Chan et al., 2007; Schwartz et al., 2020)*

Process-Oriented Interventions

Process-oriented interventions have long been relied on in therapeutic settings to improve motor skill performance by addressing underlying deficits. Strategies such as balance training, strength training, and virtual reality training can be used to treat motor impairments by working on the foundations of movement and motor learning.

Balance Training

Balance can be defined as the process of controlling one's equilibrium, both at rest (static balance) and when moving (dynamic balance). Balance is an important factor in carrying out daily tasks. Children with DCD struggle with diminished balance performance, which leads to increased fall risk and difficulties performing ADLs (Fong et al., 2016). Multiple strategies can be used to maintain balance in sensorially challenging environments, including the hip strategy and the ankle strategy (Blenkinsop et al., 2017; Fong et al., 2016). The hip strategy consists of hip flexion and extension combined with ankle dorsiflexion and plantarflexion and is not ideal because of the postural instability it induces (Nashner, 1993). The ankle strategy is a more effective approach in which balance is maintained as the body rotates about the ankle joints. Children with DCD tend to compensate for weaknesses in ankle balance through increased reliance on the hip strategy, which leads to instability (Fong et al., 2012; Fong et al., 2013). The slow force production in the hamstrings that is characteristic of children with DCD could be one of the underlying factors that causes diminished balance performance, and this force production can be improved through functional power training (Fong et al., 2016). Functional movement power training has been shown to be an effective intervention strategy and has led to significant improvements in balance strategies in children with DCD.

Strength Training

Strength training is a process-oriented approach that focuses on improving underlying deficits related to muscular strength and stability with the goal of improving functional performance (Kordi et al., 2016). The ACSM promotes strength training as an effective method to improve various health and fitness measures in healthy, typically developing children,

provided that the training is carried out and supervised by a qualified professional and follows appropriate safety guidelines (ACSM, 2021). In children with DCD, strength training interventions are often performed with the aim of improving postural control and proprioception. Proprioception is an important concept when it comes to motor coordination and can be defined as the body's ability to sense where it is in space. Proprioception allows the body to know how much force to exert and helps control movement. It is likely that individuals with motor impairments will have diminished proprioceptive abilities. Intervention strategies in which the muscles are contracted against a resistance help generate proprioceptive awareness and thus may help improve motor coordination (Bundy et al., 2020; Kaufman & Schilling, 2007).

Several studies have explored the benefits of strength training in children with DCD. Training programs that emphasize core strength/stability and strengthening the muscles of the lower body involved with balance may lead to increased overall muscle strength and improved static balance and dynamic postural control (Kordi et al., 2016). Menz et al. (2013) conducted a case study of a 6-year-old girl with apraxia and hypotonia who displayed a lack of progress with activity-based physical therapy treatments. The subject exhibited motor difficulties suggestive of DCD, such as coordination problems when riding a bike and using monkey bars, difficulties running, and giving up quickly when tasks were hard. The researchers observed that activity-oriented approaches alone did not seem to produce progress in learning new motor skills. This led them to hypothesize that training proper muscular recruitment and activation may be beneficial in improving coordination. After 24 sessions of targeted strength training, the subject showed improvements in participation, satisfaction, and performance of functional skills, supporting the benefits of strength training for children with motor impairments.

While strength training has the potential to bring about positive changes in children with DCD, there are some limitations to this intervention method. Strength training addresses the underlying issues of stability and coordination, but it fails to address areas such as momentum, locomotion, speed, and agility (Menz et al., 2013). This type of intervention should therefore serve as a starting point for therapy and should be complemented by other training methods that promote the holistic development of the affected child.

Virtual Reality Training

The use of virtual reality systems, such as the Nintendo Wii, is becoming an increasingly popular training modality for improving motor performance in children with various motor impairments. This type of training combines cognitive and motor control processes to help the patient perform functional skills (Ashkenazi et al., 2013). Motor learning is promoted through movement repetition, enhanced instant feedback, and variability in the skills performed. The patient is exposed to real-life situations in a controlled manner that can be tailored to the individual's skill level. Furthermore, such interventions can be implemented in the home environment and therefore reach beyond what can be achieved in limited sessions in a clinical setting. The creativity of this method and the focus on competition and games promote enjoyment and fun for participants, which may increase the chances of them sticking with the treatment and seeing improvements.

Ashkenazi et at. (2013) found that subjects who participated in a virtual reality intervention program saw notable improvements in overall motor skills after training, which was displayed through significant score improvement on the Movement Assessment Battery for Children (M-ABC-2). They also improved significantly in their balance performance. However,

there were no significant improvements in manual dexterity, catching, or throwing. Parents reported improvements in their children in areas such as self-confidence, ball skills, and bicycle riding skills. The mean percentile score on the M-ABC-2 among subjects improved from the 5th percentile to the 27th percentile after intervention. According to Bonney et al. (2017), when a Nintendo Wii training program was compared to a task-oriented functional training program, no significant difference was found between the two interventions. All subjects saw improvements in muscular strength, motor proficiency, functional performance, self-efficacy, and participation in ADLs after intervention. Therefore, virtual reality training should be considered an effective intervention for improving motor skills among children with DCD.

Task-Oriented Approaches

The previously mentioned process-oriented (bottom-up) approaches that focus on underlying neuromuscular deficits to improve functional performance may not be as effective as task-oriented approaches because they fail to cause changes in the brain and bring about Central Nervous System (CNS) adaptation (Chan et al., 2007). Task-specific interventions, or top-down approaches, are more likely to produce improvements in relation to the CNS and thus improve functional balance. These interventions focus on the distinct needs and goals of the client and are specific to a given task and context (Davidson & Wolpert, 2003). The client plays an active role in the treatment and their caretaker is encouraged to promote the transfer of learning to their everyday context. The main goal of task-oriented intervention is functionality.

Neuromotor Task Training

Neuromotor task training (NTT) is a child-centered approach founded in the ideas of cognitive neuroscience. It addresses the preparation, planning, and initiation of functional motor

tasks (Niemeijer et al., 2007), This intervention involves an analysis of which cognitive processes are at the root of diminished performance, such as attention deficits, lack of understanding about a task, or lack of motivation to complete a task. The focus is on functional activities used in the child's context of daily living, and the primary goal of treatment is a high positive skill transfer. To accomplish this, the tasks that are taught and practiced increase in difficulty throughout intervention. Neuromotor task training has been shown to be successful in promoting improvements in gross and fine motor skills and functionality among children with DCD (Niemeijer et al., 2007; Smits-Engelsman et al., 2012).

Cognitive Orientation to Daily Occupational Performance

The Cognitive Orientation to daily Occupational Performance (CO-OP) approach is an example of a task-oriented strategy that is client-centered and considers the distinct needs of the individual by targeting the specific motor skills and tasks that are difficult for the affected child (Chan et al., 2007; Schwartz et al., 2020). With this type of treatment, the emphasis is on collaborative goal setting to increase the participation and motivation levels of the child. Parents, caregivers, and teachers are involved in the process to promote skill transfer. The CO-OP approach is built on the foundation of problem solving and utilities cognitive strategies to enhance motor skill development. It accounts for areas that are meaningful to participating children by empowering them to determine their own goals and take initiative in the problem-solving process.

During a CO-OP therapy session, the child will identify goals he/she would like to reach and will make a plan under the guidance of a therapist to achieve these goals (Schwartz et al., 2020). The collaboration between the therapist and the client improves self-efficacy and helps

the patient gain a sense of control in the intervention process. Once the goals are identified, cognitive strategies are taught to help with performance difficulties, and the child learns how to apply these strategies to other occupation-related skills. The idea is that the learning and application of cognitive strategies will promote enhanced problem-solving skills that can be used to handle motor difficulties. Recent research has supported the CO-OP approach as a successful intervention strategy for improving motor and occupational performance, problem-solving skills, participation, and satisfaction (Anderson et al., 2018; Araujo et al., 2021; Chan, 2007; Thornton et al., 2015).

Prevention

There are several risk factors that predispose an individual to developing DCD. While the condition itself cannot necessarily be prevented, there are ways in which symptoms can be mitigated and even prevented. Early recognition and diagnosis are the keys to the management and prevention of DCD. Early identification leads to early intervention, which may play a role in preventing the secondary effects associated with DCD. Treatment and prevention techniques should focus on enabling the patient to carry out activities of daily living more efficiently. Rehabilitation for patients with DCD should focus on both physical and psychological aspects to provide the best care that focuses on the whole person. Through a comprehensive management of the disorder, secondary symptoms such as physical inactivity and decreased self-esteem can be addressed and prevented (Lee & Zwicker, 2021).

Prevention methods are widely based on the concept of neuroplasticity, or the ability of the brain to adapt and develop in response to certain experiences. Neuroplasticity is the foundation upon which motor learning occurs in the normally developing brain and motor

relearning occurs in an abnormal or injured brain. Early rehabilitation has the capacity to bring about neuroplasticity that can mitigate the potential symptoms of DCD (Novak & Morgan, 2019). To prevent or lessen the severity of symptoms associated with DCD, it is important to take a holistic approach that will help the child gain the skills and confidence necessary to perform the activities that are meaningful to them. Empowering the child to gain confidence in performing motor tasks may help prevent psychological problems such as decreased self-esteem from developing as the child gets older (Blank et al., 2011; Lee & Zwicker, 2021).

Cross-Cultural Considerations

There are some important distinctions to take into consideration when it comes to factors such as gender, socioeconomic status, and cultural context. Research has shown that there is a greater prevalence of DCD among males than among females (Amador-Ruiz et al., 2018; Delgado-Lobete et al., 2019). The study conducted by Amador-Ruiz et al. (2018) found that boys achieved higher scores with aiming and catching tasks, while girls typically did better with tasks related to balance and manual dexterity. This may be partially attributed to differences in the ways that girls and boys are taught to socialize. For example, boys often choose or are expected to participate in sports and activities that involve throwing and catching balls, but girls are less likely to participate in such activities at a young age. When considering which treatment and prevention strategies to implement, it is thus important to expose both boys and girls to a wide variety of physical activity to mitigate these discrepancies between genders.

Children who come from families of lower socioeconomic status are more likely to struggle with the motor difficulties associated with DCD (Delgado-Lobete et al., 2019). This is likely because these families do not have as much access to treatment and learning opportunities.

Furthermore, Amador-Ruiz et al. (2018) found a significant difference in scores between children living in rural areas and children living in urban areas. Those living in rural areas did better in aiming, catching, and balance tasks. This may be due to geographic differences in leisure activities, as there is not as much integration between leisure and physical activity in urban areas. It is also important to consider the cultural context when determining how to assess DCD. Lee & Zwicker (2021) stressed the importance that the "assessments, questionnaires, and tools for early identification of children with/at risk of DCD have been validated in the country and cultural context in which they will be used" (p. 654).

Implications for Clinical Therapy

Motor learning is a complex process that requires effective communication between the brain and the musculoskeletal system. Developmental coordination disorder causes dysfunction in this communication and results in deficiencies in balance, posture, and coordination. Children with DCD also deal with psychological problems such as increased levels of anxiety and decreased self-esteem. If not identified and treated from a young age, DCD can lead to increased risk of obesity and cardiovascular disease. Therefore, it is extremely important to provide interventions for children with motor deficiencies, both in an official clinical therapy setting and in school and home environments.

There are several different types of interventions that could benefit children with DCD. It is important to consider the needs and goals of each individual when determining which interventions to implement. Research has shown that children with DCD see fewer improvements in motor function overtime after intervention than do typically developing children (Smits-Engelsman et al., 2020). These results imply that children with DCD have more

difficulty transferring learned skills to various tasks. It is therefore important to take a holistic approach and incorporate variability in training interventions for children with DCD.

Given the effects of mental health on the participation of children with DCD, it is essential to consider psychological aspects such as anxiety levels when determining treatment plans. Studies have demonstrated that while they may produce improvements in motor performance, large-group interventions focusing on task-oriented activities may lead to higher levels of generalized anxiety in participants. Alternatively, small-group interventions focusing on goal-oriented activities chosen by participants may significantly improve anxiety levels and levels of participation in addition to motor skills (Cacola et al., 2016).

Occupational Therapy

The challenges faced by individuals with DCD typically align most directly with the scope of practice of an occupational therapist. The primary goal of occupational therapy is to help patients attain functionality in carrying out activities of daily living. This includes providing children with the tools and confidence necessary to fully participate in school and social situations. Therefore, occupational therapists often serve on the front lines of treating this disorder. There are many beneficial treatment tools in the realm of occupational therapy when it comes to working with children with this disorder. It is important to take a well-rounded approach that considers the unique needs of each individual patient and aims for functionality and holistic improvements in health and quality of life (Blank et al., 2011).

Based on the current literature, therapy should include some elements of task-oriented training to promote positive transfer of skills (Chan et al., 2007; Smits-Engelsman et al., 2012). The CO-OP approach is promising because it involves the child in the goal-setting process,

giving them a sense of autonomy in their treatment and therefore increasing their sense of accomplishment. Since DCD covers a wide range of motor impairments and associated challenges, it seems that the most successful treatments are those that incorporate elements of multiple strategies and are tailored to individual needs rather than assuming that all participants have the same needs and goals.

Physical Therapy

The primary goal for treating children with DCD in a physical therapy context is to promote motor coordination by improving the mobility and overall function of individual parts of the body (Blank et al., 2011; Offor et al., 2016). Traditional physical therapy methods often take a process-oriented approach and include interventions such as strength training, balance training, and core stability training. Contemporary treatments include avenues such as aquatic therapy, active video games, and trampolines. Neuromotor task training is a task-oriented approach that has also been used by physical therapists. Each of these physical therapy interventions has been shown to be effective in improving outcome measures in children with DCD (Offor et al., 2016).

Community Support

In order for children with DCD to thrive physically, mentally/emotionally, and socially, the treatment and support they receive must extend beyond the realm of the clinical therapy setting. It is of the utmost importance to integrate what the child is learning in therapy into their school and home environments. This integration will promote the highest positive transfer of improvement and will allow the child to apply these improvements in the context of their everyday tasks and environments.

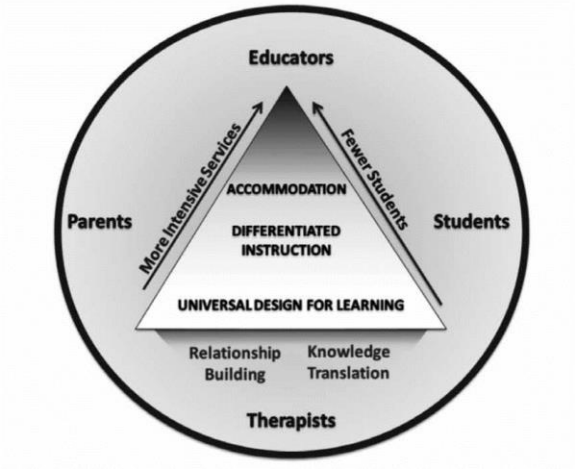
School

One of the primary occupations in childhood is education. School is an environment where many children with DCD discover many frustrations, making it important for intervention and support to occur in this context. Therapists must work with the teachers and staff involved in the school system to provide an educational experience that promotes the highest level of learning and development of every child. Research has shown that integrating a focus of functional movement skills (FMS) into a school's physical education program may lead to improvements in motor skills and increased enjoyment of participation among children with DCD (Sit et al., 2019).

An emerging model for the integration of therapeutic measures into everyday contexts is the Partnering for Change model. Partnering for Change promotes collaboration among therapists and school staff to provide the best experience for children affected with DCD (Missiuna et al., 2012). Figure 1 represents the collaborative relationship among students, therapists, parents, and educators emphasized in this model (Missiuna et al., 2012, p. 43).

Figure 1

Partnering for Change Model



In the context of the Partnering for Change model, therapists are focused on building relationships and passing on knowledge to the school rather than directly to the student (Missiuna et al., 2012). Teachers are taught how to work with children with DCD by modifying the environment and delivery of curriculum. They are also shown how to make accommodations based on the unique needs and abilities of each individual student. The purpose is not merely to improve motor skills in an isolated therapeutic setting, but to address these challenges in the context of a child's daily environment.

Home

It is extremely important for parents and caregivers to be involved in the treatment of the children in their care with DCD. While traditional therapy methods are helpful, children do not live their daily lives in an isolated and controlled environment. To achieve functionality, they must be able to transfer the skills learned in therapy to their activities of daily living, most of which take place in the context of the home. The more involved parents are in their child's treatment, the more successful the child will be. In fact, research has shown that parental involvement increases the chances that skill learning will continue beyond formal intervention (Smits-Engelsman et al., 2012).

Parental involvement may be as simple as using a logbook to track how often a child uses a given treatment method at home, as is done in the CO-OP approach (Schwartz et al., 2020). Parents can also participate by competing against their children in treatments involving active video games (Ashkenazi et al., 2013). While it is important for the children to choose their own goals for therapy, parents can reinforce these goals by helping the child to work toward them at home. It is also for parents to receive education regarding the best way to help their child.

Missiuna et al. (2006) found that parents of children with DCD often lack knowledge regarding how far to push their children to participate in activities that are difficult for them. They are also unsure to what extent they should facilitate independence for their child. When parents are involved in the therapeutic process and receive proper education from a qualified specialist, they will be better equipped to care for their children in the home and promote functional independence.

Conclusion and Directions for Future Research

The motor impairments associated with DCD can have immense effects on a child's development. They bring with them a wide range of physical, neurological, and psychological challenges. However, this diagnosis does not have to control the quality of life of those whom it affects. When effective and well-rounded interventions are used and parental and educational support is integrated, children with DCD will be able to develop and thrive physically, academically, mentally, and socially. While the body of research surrounding motor interventions is growing, it has yet to be determined which intervention strategies should be implemented based on the specific impairments and challenges faced by each individual child. Current research suggests that children respond differently to intervention, and the strategy that works for one child may not work for another. Further research should be conducted comparing the effectiveness of different intervention strategies and should focus on the integration of multiple treatment strategies. Future studies should include a child's entire developmental environment beyond the clinical therapy setting by involving parents and teachers. Additionally, more neuroimaging studies should be conducted to determine the brain mechanisms involved with the disorder and to clarify the relationship between brain function and motor skill

development. Research should focus on differentiating between DCD and other comorbidities with similar symptoms, as these can be confounding factors in research. Whereas the current body of literature related to prevention methods for DCD is limited, future research should be built on the ideas of neuroplasticity, early diagnosis, and early rehabilitation.

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