DEVELOPMENTAL COORDINATION DISORDER AND DAILY PERFORMANCE IN SCHOOL-AGED CHILDREN

AN INTERRELATION OF INDIVIDUAL, ENVIRONMENTAL AND ACTIVITY FACTORS

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DEVELOPMENTAL COORDINATION DISORDER AND DAILY PERFORMANCE IN SCHOOL-AGED CHILDREN. AN INTERRELATION OF INDIVIDUAL, ENVIRONMENTAL AND ACTIVITY FACTORS

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El Dr. Sergio Santos del Riego, catedrático de escuela universitaria en el Departamento de Fisioterapia, Medicina y Ciencias Biomédicas de la Universidade da Coruña y doctor en Medicina y Cirugía, y la Dra. Sonia Pértega Díaz, profesora asociada en el Departamento de Ciencias de la Salud de la Universidade da Coruña y doctora en Matemáticas,

CERTIFICAN QUE:

La presente memoria de tesis titulada "*Developmental Coordination Disorder and Daily Performance in School-Aged Children. An Interrelation of Individual, Environmental and Activity Factors*" presentada por Doña Laura Delgado Lobete, graduada en Terapia Ocupacional por la Universidad de Oviedo, ha sido realizada bajo nuestra supervisión y reúne todas las condiciones necesarias de originalidad, calidad y rigor científico para ser defendida públicamente y optar al grado de Doctora con Mención Internacional en Ciencias de la Salud por la Universidade da Coruña.

Y para que así conste a los efectos oportunos, firmamos en A Coruña, 2021

Fdo. Dr. Sergio Santos del Riego Fdo. Dra. Sonia Pértega Díaz

Part of the research presented in this thesis dissertation has been carried out under the supervision of **Dr. Marina M. Schoemaker**, PhD, professor in the Center for Human Movement Sciences, University Medical Center of Groningen at the University of Groningen, during two three-months fellowships in 2019 and 2020.

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in fulfilment of the requirements for the degree of International PhD Mention.

A José Luis y Marisol, mis padres
Por haberme criado en la convicción
de perseguir siempre mis sueños

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compañera infatigable,
Por compartirlo todo conmigo y ser siempre
el mejor ejemplo de resiliencia y amor

A la niña que quería ser científica
y al crecer comprendió
que había muchas maneras de hacer ciencia

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ABSTRACT

Developmental Coordination Disorder (DCD) is one of the most frequent neurodevelopmental disorders in school-aged children worldwide, but it is a highly under-diagnosed condition in Spain. Moreover, little is known about the interrelation of sociodemographic factors, sensory processing and daily activities in DCD and functional performance in school-aged children with and without DCD. Thus, the aims of this thesis were: (1) to examine the prevalence and associated sociodemographic factors of DCD in Spanish school-aged children; (2) to identify how sensory processing patterns present in children with DCD in comparison to typically developing children and children with ADHD; and (3) to explore the role of individual, environmental and activity factors on performance and participation in motor-based daily activities in children with and without motor coordination difficulties. Two samples including more than 800 Spanish school-aged children were analyzed. Findings show that prevalence of p-DCD in this population ranges from 8% to 13%. In addition, we found a complex influence between individual (i.e., age, sex, sensory processing), environmental (i.e., family-related factors [educational background, area of residence and siblings] and country) and activity-related factors over daily functioning, where motor performance mediates the relationship between individual and environmental constraints, learning of activities and daily participation.

RESUMEN

El Trastorno del Desarrollo de la Coordinación (TDC) es una condición del neurodesarrollo frecuente en población escolar en otros ámbitos geográficos, pero ampliamente desconocida en el contexto español. Además, existe poca información sobre la interrelación de factores sociodemográficos, del procesamiento sensorial y de las actividades diarias en el TDC y en el desempeño funcional en población escolar con y sin TDC. Los objetivos de esta tesis fueron: (1) examinar la prevalencia de TDC y los factores sociodemográficos asociados en escolares españoles; (2) identificar los patrones de procesamiento sensorial presentes en el TDC; y (3) estudiar el papel de los factores individuales, del entorno y de la actividad en el desempeño y participación en actividades motoras de la vida diaria. Para ello se analizaron dos muestras de más de 800 escolares españoles. Los hallazgos muestran que la prevalencia de probable TDC en España alcanza el 8%-13%. Se encontró una compleja influencia entre los factores individuales (edad, sexo, procesamiento sensorial), del entorno (factores familiares y geográficos) y relacionados con la actividad sobre el TDC y sobre el funcionamiento diario, donde el desempeño motor media la relación entre las constricciones personales y del entorno, el aprendizaje de actividades diarias y la participación.

RESUMO

O Trastorno do Desenvolvemento da Coordinación (TDC) é unha condición do neurodesarrollo frecuente en poboación escolar noutros ámbitos xeográficos pero moi descoñecida no contexto español. Ademais, existe pouca información sobre a interrelación de factores sociodemográficos, do procesamento sensorial e das actividades diarias no TDC e no desempeño funcional en poboación escolar con e sen TDC. Os obxectivos desta tese foron: (1) examinar a prevalencia de TDC e os factores sociodemográficos asociados en escolares españois; (2) identificar os patróns de procesamento sensorial presentes no TDC; e (3) estudar o papel dos factores individuais, da contorna e da actividade no desempeño e participación en actividades motoras da vida diaria. Para iso analizáronse dúas mostras de máis de 800 escolares españois. Os achados mostran que a prevalencia de probable TDC en España alcanza o 8%-13%. Atopouse unha complexa influencia entre os factores individuais (idade, sexo, procesamento sensorial), da contorna (factores familiares e xeográficos) e relacionados coa actividade sobre o funcionamento diario, onde o desempeño motor media a relación entre os constrinximentos persoais e da contorna, a aprendizaxe de actividades diarias e a participación.

OUTLINE OF THIS THESIS

This doctoral thesis is a compendium of four scientific studies that explore probable Developmental Coordination Disorder (DCD), daily performance and its association with several individual, environmental and activity factors in Spanish school-age children.

The theoretical framework of the definition, aetiology and functional implications of DCD is outlined in *Chapter 1 (General Introduction)*, which ends by drawing the aims of this thesis.

In *Chapter 2 (Study 1)*, the prevalence of probable DCD and its association with sociodemographic factors in Spanish school-age children are examined through a population-based study.

Chapter 3 (Study 2) explores how differences in sensory processing interrelate with individual and environmental factors among children with probable DCD, Attention Deficit and Hyperactivity Disorder (ADHD), co-occurrent disorders, and typical development.

In *Chapter 4 (Study 3)*, the interrelated influence of sex, country and activity constraints on daily motor performance and participation is investigated through a comparative study of Spanish and Dutch children.

Based on the findings of *Chapters 2* to *4*, *Chapter 5 (Study 4)* examines a novel model on the mediating role of motor performance in the relationship between individual and environmental constraints, learning of activities of daily living and participation in motor-based daily activities in children with and without DCD.

Finally, *Chapter 6 (General Discussion)* provides a summary, overall discussion, practical implications, future research directions and final conclusions of the four studies presented in this doctoral thesis. This chapter is also available in Spanish.

INDEX

CHAPTER 1
GENERAL INTRODUCTION AND AIMS OF THE THESIS

DEVELOPMENTAL COORDINATION DISORDER

Developmental Coordination Disorder (DCD) is a motor neurodevelopmental disorder listed within the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)[1] and the International Statistical Classification of Diseases and Related Health Problems, Eleventh Edition (ICD-11)[2]. DCD is one of the most prevalent neurodevelopmental conditions during childhood and it has relevant consequences for child's functional performance[3]. This common and chronic disorder is characterized by four diagnostic criteria: deficits in motor coordination skills (criterion A) that present during early development (criterion C) without an apparent cause (criterion D) and which result in considerable restrictions in daily life (criterion B)[1,3]. DCD is present across cultural contexts, ethnicities and socio-economic conditions worldwide. However, it is frequently underrecognized by health care and educational professionals[4-6], especially in the Spanish context where clinical identification of DCD is extremely scarce[7,8].

Aetiology

According to current evidence DCD is an idiopathic disorder, but several hypotheses for the underlying mechanisms in DCD have been proposed[3]. A recent and large systematic review of experimental literature revealed that several behavioural, cognitive and neural factors are present in DCD[9]. Children with DCD appear to show a broad cluster of deficits in motor control and learning and in executive function or cognitive control, which are moderated by task aspects, such as activity type and difficulty. In addition, findings from neuroimaging research show some functional and structural neural deficits in children with DCD, such as reduced cortical thickness and differences in activation across functional networks in prefrontal, parietal and cerebellar regions[10-16].

Sensorimotor processing issues seems to play an especially relevant role on DCD mechanisms, moreover within the multi-component account of DCD and the internal modelling deficit hypothesis, which depends on spatiotemporal

parameters and sensory processing to successfully feedforward movement[17]. Findings from magnetic resonance imaging studies have shown alterations in the white matter microstructural organization in sensorimotor tracts, and a poorly integrated neural network of sensorimotor structures[18-21]. Within the sensory processing framework, a high percentage of children with DCD may have issues regarding sensory sensitivity, and they report difficulties in the stimuli detection of body awareness, balance and sensorimotor planning and ideation[22]. Sensory processing of visual, proprioceptive and tactile stimuli is also a common issue in children with DCD[23,24]. Altogether, these differences between children with and without DCD may influence anticipatory planning and observational motor learning, as well as a reduced automatization of movement skills due to slower sensory feedback-based control.

These emerging high-quality data show that neuromaturational factors are undoubtedly relevant underlying mechanisms for DCD. However, there is evidence that other individual, environmental and activity factors exist that significantly account of DCD as well. Therefore, the current hypotheses propose a multi-component model that blends both cognitive neuroscience and classical dynamic systems, ecological theories[25-27].

The European Academy of Childhood Disability (EACD) supports a unified multi-component explanatory framework of DCD that considers individual, environmental and task constraints (Figure 1). Apart from the neuromaturational factors described before at the individual level, the motor control deficits in DCD are highly sensitive to the nature of the activity the child may be performing, as motor coordination difficulties are more apparent for complex, ecological activities (i.e., dual tasks, tasks that are part of a multi-step activity and that take place within the daily environment, tasks that demand more spatial and temporal precision). In addition, this model takes into account the environmental setting where the motor action is being performed[3].

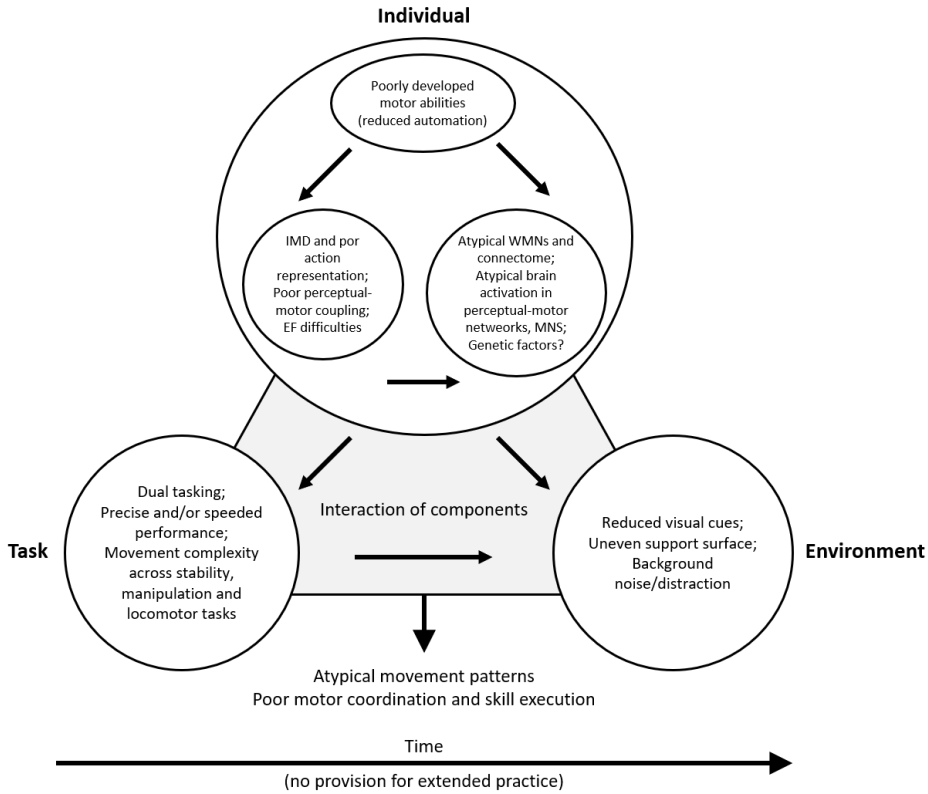

Figure 1. Blank et al.[3]. Multi-component account of motor skill development showing correlates of performance in DCD. IMD = internal modelling deficit; EF = executive function; WMN = white matter network; MNS = mirror neuron system.

Overall, the inter-related combination of individual, task and environment constraints contributes to the appearance and development of atypical movement patterns, poor motor coordination and skill execution that will result in the eventual manifestation of DCD if the child is not provided of extended and tailored, goal-oriented practice opportunities[3].

Epidemiology

There is no consensus on the prevalence estimates for DCD worldwide, as findings regarding DCD and risk of DCD rates highly differ across country and diagnostic assessment. According to several population-based studies, prevalence rates range from 2% to 20% of school-age children, being higher in southern regions[28-34], although the most frequently reported prevalence is 5% to 6%[1,3]. At the beginning of this doctoral thesis, there was not reliable published data about presence of DCD or risk of DCD among Spanish children. The only study reporting preliminary prevalence of DCD in the Spanish context at that time assessed criterion A exclusively (i.e., deficits in motor coordination skills) in a small sample of Spanish preschool children[35]. However, diagnostic assessment of DCD in young children requires extreme caution, as psychomotor performance shows a high variability during early development, and thus motor coordination difficulties at these ages can be overcome. Nonetheless, findings from that study alert that DCD may be a prevalent condition in Spain, as authors found a 17% rate of risk of movement problems[35]. These tentative results highlight the underrepresentation of DCD within the Spanish context, especially considering that less than 1.1% of school-age children seek Primary Care attention for motor coordination issues[8].

Regarding predictive factors of DCD, this disorder is more commonly reported for males than for females[32,36,37]. Motor coordination difficulties consistent with DCD are more frequent in prematurely-born children[32,38-40]. In addition, DCD seems to be more prevalent among families with low socio-economic and educational background[29,32,41]. Overall, the closest socio-demographic environment of the child seems to be strongly associated with the impact of motor deficits on daily functioning.

Co-occurring Conditions

Findings from international studies in the last two decades demonstrate that DCD rarely presents alone, as it is associated with several neurodevelopmental, emotional, psychosocial and behavioural disorders[3].

Co-occurring Neurodevelopmental Disorders

Regarding co-occurring neurodevelopmental conditions, Attention Deficit Hyperactivity Disorder (ADHD) has been repeatedly reported to be highly co-occurring with DCD[42-49]. The most frequently informed rate of co-occurrence between DCD and ADHD is of at least 50% in clinical samples[42,50], although recent studies suggest rates above 60% and 74%[49,51]. This evidence highlights that those children with DCD also encounter attention difficulties and deficits in inhibitory control. In addition, both disorders often co-occur with deficits in sensory processing[22,52,53]. This is of great importance for the prognosis of these conditions, as individuals with co-occurrent DCD and ADHD face a significantly worse behavioural, psychosocial and functional outcome in comparison with children, adolescents and adults with DCD or ADHD alone[48,54,55].

The extremely frequent overlap between motor coordination issues and attentional and hyperactivity difficulties has led to the consideration that both DCD and ADHD may share a common aetiology of an atypical development of the brain with different clinical manifestation, with some children more likely to show motor coordination deficits, and other children more prone to present attentional and hyperactivity behaviour[56]. However, recent evidence supports that DCD and ADHD are distinct conditions with specific aetiology and different neurophysiological mechanisms[17,57,58]. For instance, abnormalities in the frontal regions and in white matter connections underlying the primary and somatory motor cortices differ between children with ADHD and children with DCD[57].

Autism Spectrum Disorder (ASD) is another neurodevelopmental condition highly associated with DCD[3,59]. While the Fourth Edition did not permit a dual diagnosis of DCD with ASD, the DSM-5 now permits this co-occurrence[1,60].

Findings from a population-based study reported 4% and 8% of co-occurrent ASD in children with moderate DCD and severe DCD, respectively[32]. The co-occurrence of DCD in children with ASD is far more prevalent, with approximately 80% of these children presenting significant motor coordination deficits[61,62]. In addition, specific coexisting specific language impairment and other learning disorders have also been reported in children and adolescents with motor coordination issues, including a higher risk of difficulties in handwriting, attention, reading, mathematical understanding and social cognition[63-67].

Co-occurring Psychosocial Disorders

Children with DCD or with motor coordination difficulties usually face co-occurring mental health conditions, emotional and behavioural issues such as internalizing problems (e.g., depression, anxiety) and externalizing behaviours (e.g., peer and conduct problems, impulsivity and hyperactivity)[68-74]. Lower levels of self-concept, self-esteem and self-efficacy have also been reported for children and adolescents with DCD during the last three decades[75-77].

Diagnostic Criteria and Assessment

The DSM-5, ICD-11 and EACD all provide similar recommendations on the diagnostic management of DCD[1-3]. In order to get a clinical diagnosis of DCD, children need to be assessed for four diagnostic criteria (Table 1).

Table 1. DSM-5 diagnostic criteria for Developmental Coordination Disorder[1].

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 as well as slowness and inaccuracy of performance of motor skills.
B. The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age 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 or visual impairment and are not attributable to a neurological condition affecting movement.

According to international recommendations, the multidisciplinary team should start the diagnostic assessment of DCD with the operationalization of criteria C and D, and then move to the assessment of criterion B and criterion A[3]. Alternatively, the diagnostic procedure could start with the operationalization of criterion B, as limitations in motor-based ADL often account for the first and most visible signal of potential deficits in motor coordination skills[6,78,79]. Therefore, it should be mandatory to include a paediatric occupational therapist in the evaluation team to assess issues in daily performance and participation. A clinical diagnosis of DCD can only be set after an individual evaluation of all diagnostic criteria.

Additional recommendations highlight the caution required when evaluating motor assessment in children younger than five years, as a formal diagnosis of DCD should not generally be given in children this young due to the intrinsic variability of motor performance and development during early childhood. Children this young need two motor assessments over at least three months[3].

Functional Consequences

According to the EACD, DCD is by far the most frequent motor disorder relevant for daily functioning in childhood[3]. Accumulating evidence from clinical and population-based studies shows that poor motor coordination has a negative impact on long-term functional outcomes, including lower quality of life and well-being and significant performance limitations and participation restrictions across the life span.

Quality of Life and Well-being

DCD impacts satisfaction and health-related quality of life as well, on both physical and mental domains[80-82]. Children and adolescents with DCD are at higher risk for obesity and poorer cardiorespiratory fitness, and display lower flexibility, muscle strength and muscle endurance[83-86].

As previously mentioned, DCD plays a significant role in the development of mental health issues, especially of internalizing problems. This particular connection has such a relevant impact on well-being that it has been extensively explored due to its relationship with individual and environmental protective and risk factors. Cairney et al.[73,87] and Mancini et al.[88,89] developed 'The Environmental Stress Hypothesis' to provide a theoretical framework for understanding the interrelationships between DCD, individual and environmental factors, and the resulting mental health outcomes (Figure 2).

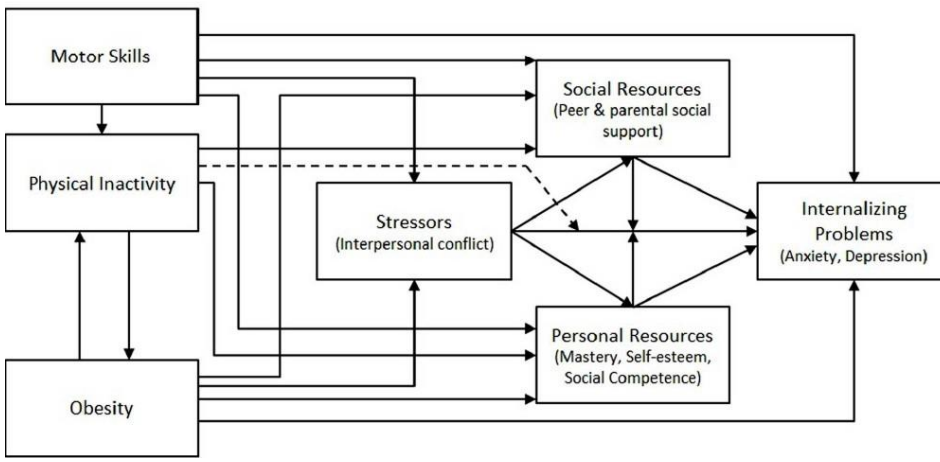

Figure 2. Mancini et al.[88]. An adapted Elaborated Environmental Stress Hyptothesis.

According to this framework, motor coordination is a primary stressor which exposes individuals to a broad range of secondary stressors (e.g., physical inactivity; obesity; poor concept of self; social support) that directly and indirectly contribute to internalizing problems (i.e., depression and anxiety). This hypothesis has been proven useful to assess psychological distress in young adults with motor coordination difficulties as well[89,90], further demonstrating that functional consequences of DCD do not resolve after childhood and that DCD is a chronic condition with long-term outcomes.

Daily Performance and Participation

DCD and poor motor coordination directly influence daily functioning of children. Magalhães et al.[91] conducted a systematic review to identify daily activity limitations and participation restrictions of children with DCD. According to the 44 studies reviewed by the authors, deficits in motor coordination skills lead to reduced participation in self-care and self-maintenance activities of daily living (ADL), academic, social and motor-based leisure activities, school and academic-related ADL and instrumental activities. During the last decade, new research has supported these findings.

For instance, Soref et al.[92] reported that preschool children with mild and moderate motor difficulties show less independence and diversity in their daily participation in comparison with age- and sex-matched typically developing peers. In this line, Van der Linde et al.[93] conducted a case-control study including children with and without a clinical diagnosis of DCD. They concluded that children with DCD display poorer performance, reduced participation and delayed learning of motor-based ADL than children with typical development. More recently, Izadi-Najafabadi et al.[94] comprehensively explored participation frequency and involvement of home, school and community contexts between children with and without DCD. They found significant and moderate-to-strong differences for participation frequency and involvement, especially in school and community settings. In addition, participation in physical activities is extremely reduced in children with DCD or motor coordination difficulties, which further contributes to lower their physical and mental health[95-97].

Functional impairments associated with DCD persist into adolescence and adulthood. Research on daily performance in adults with DCD is scarce but revealing. Kirby et al.[98] found that adults with DCD encounter significant problems in several daily activities, including self-care and instrumental activities, academic-related activities, spatial and temporal organisational planning, and leisure and social participation ADL.

Similarly, Tal-Saban et al.[99] reported more difficulties in both non-academic and academic functioning among young adults with DCD in comparison with typically developing peers. In addition, it seems that motor performance issues directly and indirectly influence executive functioning, academic and non-academic performance and success in young adulthood[100].

Therapeutic Approach

As recommended by the EACD, indications for intervention in individuals with DCD are mainly dependent on criterion II (i.e., the impact of motor deficits on daily activities). Even if there is not a clinical diagnosis of DCD but performance of ADL is compromised due to motor coordination issues, strategies should be implemented to promote satisfactory performance and participation in the home, community and school contexts[3]. Interventions should address the performance issues in daily activities. For instance, fine motor problems may be more related with academic-related participation or certain self-care activities, while gross motor problems are more closely associated with participation in play, social interactions and leisure activities[3,93]. Therefore, occupational and physical therapists play a relevant role in the therapeutic management of DCD.

Approaches to intervention for DCD have been traditionally classified into two broad areas according to the therapeutic focus: the Bottom-Up approaches (i.e., process-oriented or body-function-oriented approaches), aimed to reduce impairment and to improve the deficits in body structures and functions that would underlie functional issues; and the Top-Down approaches (i.e., task-oriented, activity-oriented or participation-oriented approaches), aimed to address the performance issue itself[3]. The later approaches have demonstrated more efficiency and better functional outcomes in children with DCD, and thus the current recommendations are to implement activity-oriented or participation-oriented approaches in the intervention of children with motor coordination issues, such as the Neuromotor Task Training and the Cognitive Orientation to daily Occupational Performance[3,101-106].

DAILY PERFORMANCE

According to the International Classification of Functioning (ICF)[107], *performance* is the execution of daily activities in the person's current environment, while *participation* is defined as "involvement in a life situation"[7(p.10)]. Both constructs have been a topic of main interest for Occupational Therapy for the last four decades[108-115]. Since the publication of the Uniform Terminology for Occupational Therapy in 1979, the American Occupational Therapy Association (AOTA) has advocated for numerous aspects of occupational performance, which reflects the act of accomplishing a selected activity or occupation that results from the dynamic transaction between the person, their context and the activity. Overall, it can be concluded that the relationship between the person, the environment and the activity performance should be approached through a transactive perspective, as a person's performance cannot be separated from the context within which it occurs. As Turpin and Iwama stated, daily performance is "the result of particular people doing particular things in particular times and places"[116(p.101)]. Thus, during the last decades several occupational therapists have developed theoretical frameworks and models that explore the dynamic and transactive results of performance, such as the Ecology of Human Performance[117] and the Person-Environment Occupation models[115].

The dynamic, complex relationship between individual and environmental factors, activity and participation was also recognized in the ICF, which states that a person's functioning (i.e., performance and participation in meaningful activities) results from the dynamic interaction between the health condition, the personal factors and the environmental factors (Figure 3)[107].

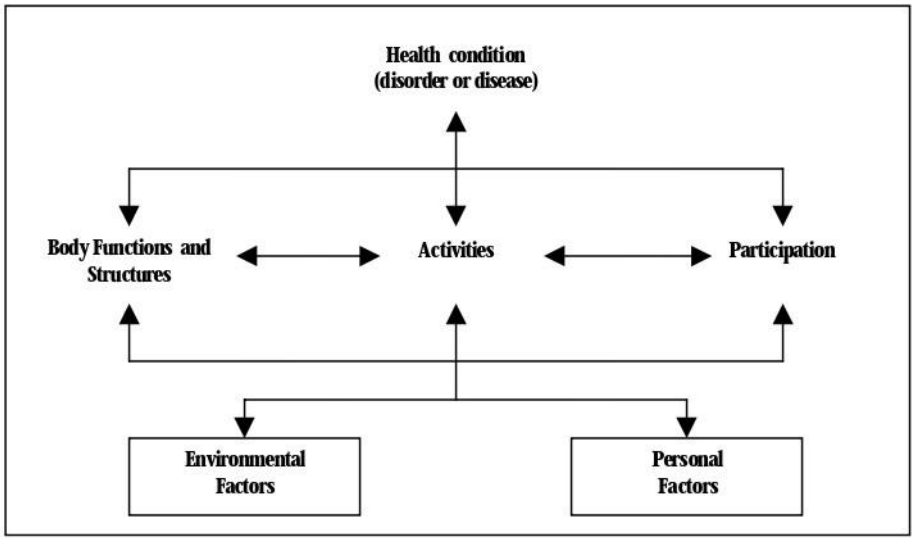

Figure 3. World Health Organization[107]. Interaction between the components of ICF.

Although these models were developed to guide and inform intervention of occupational therapists and other health professionals across the broad range of health conditions, their transactive perspectives are consistent with the classic ecological theories of motor development and performance, such as the Newell's constraints model[25,26]. Thus, constraints model can be a useful approach to investigate which individual, environmental and task factors account for performance and participation in motor-based daily activities of children with and without DCD.

Constraints Model

Newell's constraints model[25,118,119] proposes that movement emerges from the interactions of the individual, the environment in which such movement occurs, and the task or activity to be performed (Figure 4). This model reflects the dynamic ever-changing interactions in motor development, and it provides a coherent framework for understanding how coordination patterns result to achieve a goal-directed motor behaviour.

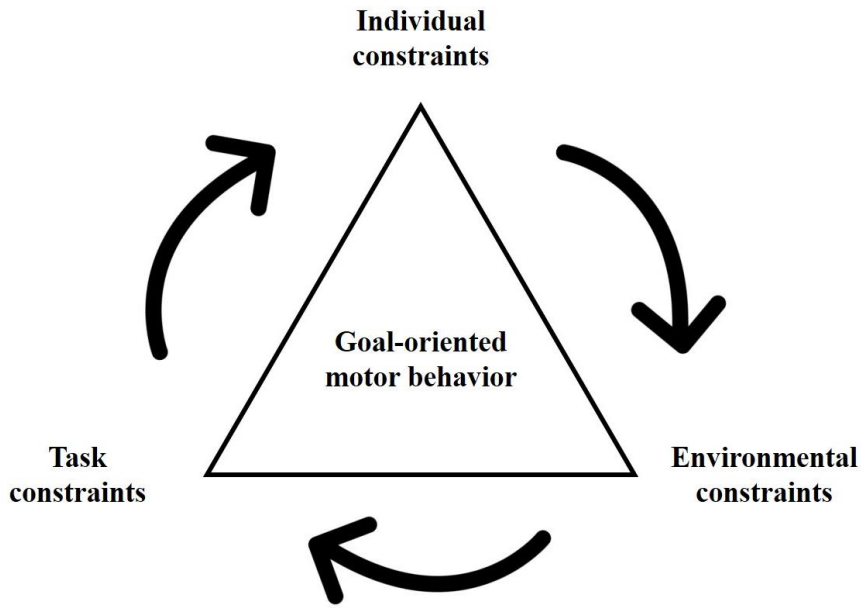

Figure 4. Constrains model of motor performance.

Constraints are interpreted as those components that limit, permit and shape movement, and they can be classified into three categories: *organismic* (or *individual* when referred to human movement), *environmental* and *task*.

Individual Constraints

Individual constraints relate to the person's specific physical and mental characteristics that can all influence the movement. Individual constraints can be classified into structural or functional.

Structural constraints refer to those factors involved in biological organization and growth process. Relevant examples of structural constraints in DCD include neuromaturational factors, sensory processing and muscle mass[3,17].

Functional constraints refer to those factors involved in the behavioural function. Relevant examples of functional constraints in DCD include attentional focus and self-concept[3,88].

Environmental Constraints

Environmental constraints relate to the context outside the individual's body, and they can be classified into physical or sociocultural.

Physical constraints refer to those characteristics of the environment. Relevant examples of physical constraints in DCD include support surface, background distractors or ambient light[3].

Sociocultural constraints refer to those social environmental factors that also can influence movement behaviours. Relevant examples of sociocultural constraints in DCD include cultural and country context and family educational and economic background[38,120-123].

Task Constraints

Task constraints relate to the unique and specific characteristics of the task or activity to be undertaken, and they include task goals, rules, and equipment used to perform an activity.

Research shows that there are several activity-related factors that influence performance of children with DCD, such as delayed learning and type of daily activity. While children with DCD do not seem to have a learning deficit as such[124], it has been reported that they take longer to learn complex motor activities, and they use less efficient strategies and are required more practice and tailored feedback[125,126], which eventually results in less participation in those ADL[93,124]. Furthermore, daily performance of children with and without DCD differ across the range of occupations and contexts (i.e., self-care, school-related activities, play, social participation)[92-94].

AIMS OF THIS THESIS

There are not enough data on the epidemiological profile of DCD in the Spanish context, even though this is a prevalent condition that frequently overlaps with other neurodevelopmental disorders, such as ADHD. Providing reliable and representative research regarding DCD presence and display in Spanish children will contribute to inform tailored interventions aimed to promote functioning in children with motor coordination difficulties. In addition, accumulative research shows that there are individual, environmental and activity-related factors associated with daily motor performance and participation in children with and without DCD. However, studies have mostly focused on the specific relationships between those constraints, performance and participation separately. It is yet unclear how individual and environmental factors interrelated relationship influences motor coordination difficulties or daily performance in school-aged children. Moreover, the mediating role of motor performance between individual, environmental and task constrains and daily participation has not been explored.

The aims of this thesis were as it follows:

Aim 1: To examine the prevalence and related sociodemographic factors of DCD in Spanish school-aged children.

Aim 2: To identify how sensory processing patterns present in children with DCD in comparison to typically developing children and children with ADHD.

Aim 3: To explore the role of individual, environmental and activity factors on performance and participation in motor-based daily activities in children with and without motor coordination difficulties.

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CHAPTER 2

PREVALENCE OF SUSPECTED DEVELOPMENTAL COORDINATION DISORDER AND ASSOCIATED FACTORS IN SPANISH SCHOOL-AGED CHILDREN

Delgado-Lobete L, Santos-del-Riego S, Pértega-Díaz S, Montes-Montes R. Prevalence of suspected developmental coordination disorder and associated factors in Spanish classrooms. Res Dev Disabil. 2019;86:31-40.

ABSTRACT

Developmental Coordination Disorder (DCD) is a multifactorial, neurodevelopmental motor disorder that severely affects the activities of a child's daily life and classroom performance. The aim of this study was to determine the prevalence of suspected DCD in a sample of Spanish schoolchildren and its association with socio-demographic factors. We conducted a cross-sectional study including a random sample of 460 children attending mainstream schools in northwest Spain in 2017. The Developmental Coordination Disorder Questionnaire-European Spanish was used to evaluate suspected DCD prevalence. We performed multivariate logistic and linear regression analysis to determine the socio-demographic variables associated with suspected DCD and problematic motor coordination performance. The prevalence of suspected DCD was 12.2%. According to the multivariate analysis, DCD symptoms were significantly associated with males (OR = 3.0), ages above 10 years old (OR = 5.0) and low participation in out-of-school physical activities (OR = 2.3). Preterm birth children were twice as likely to show suspected DCD, although this association was not statistically significant (OR = 2.1). A high percentage of Spanish schoolchildren are at risk for developing DCD. There is a strong connection between suspected DCD and socio-demographic factors. Protocols aimed to detect DCD and intervention programmes in classrooms designed to promote motor coordination skills need to take these factors into consideration.

INTRODUCTION

Developmental Coordination Disorder (DCD) is a motor neurodevelopmental disorder characterized by a significant delay in the acquisition and execution of coordinated motor skills as expected for the child's chronological age and opportunities for learning[1,2]. DCD affects approximately 5–19% of school-aged children, varying according to the diagnosis criteria and country[2-8]. The underlying motor and behavioural difficulties of DCD are chronic and severely limit activities of daily living, including educational achievement and classroom performance[9]. Children with DCD show great difficulties in social and academic tasks and in scholastic achievements[2]. De Milander, Coetzee, and Venter[10] found that motor coordination difficulties were associated with impaired reasoning, numerical skills, pattern repeating, fine motor skills and memory outcomes in children aged 5–8 and concluded that children with DCD experience more learning-related problems than children without DCD. Previous research has shown that this disorder significantly interferes with classroom tasks and demands like reading and writing, maintaining attention and numerical-mathematical comprehension[11-13].

According to the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-5), DCD is defined by the following four criteria: A) Motor coordination performance is substantially below that expected given the person's chronological age and opportunity for skill learning and use; B) This motor coordination deficit significantly and persistently interferes with typical chronological age activities of daily living, including school performance; C) Onset of symptoms is in the early developmental period; and D) The motor coordination deficit is not better explained by intellectual disability or visual impairment and cannot be attributable to a neurological condition affecting movement[1].

The European Academy of Childhood Disability recommends using the Movement Assessment Battery for Children-Second Edition (MABC-2) and the

Developmental Coordination Disorder Questionnaire (DCDQ) as assessment tools to evaluate criteria A and B, respectively[2].

Research shows that the underlying mechanisms of DCD include both internal and external factors[2]. It has been proposed that neurological, behavioural and contextual variables influence movement performance through a dynamic systems approach[14,15]. Recent meta-analysis studies have found that children with DCD show anomalies in sensorimotor processes, attention and task-oriented process neurobiology that could contribute to some of their underlying problems in anticipatory motor planning[16-18].

To understand the underlying factors of DCD, it is necessary to know how socio-demographics affect motor coordination development. Although some variables are commonly associated with DCD, there is not a consensus regarding this topic. The prevalence of DCD is found to be higher in boys[3,19], while some studies have not found a significant association with the sex of the children[5,20]. This fact could be influenced by the tool used to assess DCD, since boys tend to score better on gross motor and aiming and catching tasks, but girls usually perform fine motor activities better than boys[3,21,22]. Low gestational age at birth has been noted as a risk factor for developing DCD, especially in young children, due to cognitive and behavioural outcomes[4,5,23]. Low socio-economic family status has been previously associated with DCD, as well as poor motor coordination. Children coming from disadvantaged families may have increased difficulties with accessing learning opportunities or resources, which may be a risk factor for developing DCD[5,24,25]. Another well-documented factor associated with DCD is low participation in out-of-school physical activities. Children with DCD tend to engage less in physical activities and sports than children without motor difficulties[9,26]. While restrictions in physical activities limits the number of opportunities to practice and improve motor skills, children with DCD show low self-perception about their physical competence, which may explain their reduced participation[27,28]. The Spanish national curriculum for elementary

education only requires two weekly hours of physical education and previous research has suggested that this allotted time may not be in compliance with the World Health Organization guidelines on physical activity for school-aged children[29,30]. For this reason, it is important to assess participation in out-of-school physical activity when addressing a DCD evaluation.

Due to the adverse impact that DCD can have on the daily life activities and classroom performance of schoolchildren, it is necessary to know the epidemiology of this disorder in Spanish, general education classrooms to provide guidance and early identification programmes to teachers and schools. Considering DCD often goes undiagnosed, it is important that teachers and health practitioners working in schools can detect children that struggle because of learning difficulties, due to motor coordination issues, and the primary socio-demographic factors associated with DCD in schoolchildren[31]. Early detection of motor difficulties could prompt effective control of these children to prevent worse, secondary consequences, help teachers design an Individualized Education Plan that accommodates the children's strengths and needs or promote access to targeted materials and resources[32].

In this context, Spanish classrooms may have a difficult time detecting and assessing this disorder because of several factors, such as the lack of information and underdiagnosis of DCD in the Spanish population[21,33]. To our knowledge, only one study has explored DCD in Spanish children, but it used a small study sample to evaluate criterion A, did not include children older than six years old, and did not consider gestational age at birth or participation in out-of-school physical activities[21]. Considering the existing problems for the diagnosis of DCD in children under 5 years of age and the lack of stability of DCD at early ages[2], their findings may differ in older Spanish children. Additionally, the absence of health care practitioners who are familiar with DCD and could assist in detecting children with motor coordination difficulties in mainstream schools, like occupational or physical therapists, adds to the difficulty of detecting and

assessing DCD in Spanish classrooms. For this reason, knowing the suspected prevalence of DCD and associated socio-demographic factors in Spanish schoolchildren can provide useful information to guide specific detection strategies and intervention programmes. International researchers could compare the prevalence of suspected DCD in Spanish schoolchildren in relation to other regions due to sociodemographic or cultural differences. Additionally, knowing how interconnected socio-demographic factors associate with motor coordination difficulties can contribute to the theoretical background explaining the underlying factors involving DCD.

To date, few studies have explored the underlying associations between DCD, motor coordination dimensions and socio-demographic factors using multivariate regression models, and no study has established suspected DCD prevalence in a large sample of Spanish school-aged children. It is important to explore how socio-demographic factors individually associated with DCD interconnect in schoolchildren. Teachers and health care practitioners working in schools can easily obtain children's sex, age, participation in out-of-school physical activity, family socioeconomic background and preterm status. Knowing how these factors associate with DCD could help teachers and health practitioners in Spain, and other regions, to design strategies for the early detection of children more vulnerable to the development of motor coordination difficulties that could impact academic achievement, social performance and behaviour in classrooms.

The objective of this study was to estimate the prevalence of suspected DCD in a large sample of Spanish children aged 6–12 years, attending mainstream schools, and to determine the associations between suspected DCD, problematic motor coordination ability in different areas and socio-demographic factors.

METHODS

Procedure and participants

We conducted a cross-sectional study in A Coruna, northwest Spain. According to the Galician Institute of Statistics, 14,466 schoolchildren between six and twelve years of age were eligible for the study[34]. With 95% confidence limit, an expected DCD prevalence of 15% and a precision of .035, the required sample size was 432 as calculated by EPIDAT 3.1.

Eight general education schools, randomly selected, were invited to participate in the study, of which six agreed to collaborate. A dossier including the Developmental Coordination Disorder Questionnaire-European Spanish (DCDQ-ES) and a socio-demographic questionnaire was issued to 1,002 randomly selected parents of children from first to sixth grade (aged 6 to 12 years). Parents were also asked whether their children had a clinical diagnosis of any developmental disorder or learning difficulties. The dossiers were anonymously answered at home and then returned to schools and then collected by the researchers. Only fully completed DCDQ-ES were considered valid and therefore included in the study.

Ethical approval for this study was obtained from the Autonomic Research Ethics of Galicia Committee (code 2017/166). All participants consented to take part anonymously and confidentially.

Assessment measures

Children were defined as having suspected DCD using the European Spanish cross-cultural adaptation of the DCDQ (Montes-Montes, Delgado-Lobete, Pereira & Pousada, in press). The DCDQ is a parent-questionnaire consisting of 15 items that asses three coordination factors when performing activities of daily living: control during movement, fine motor/handwriting and general coordination. Each item scores from 1 to 5, where lower scores are indicative of coordination difficulties. As recommended by Wilson et al.[35], children were

defined as having suspected DCD if they had a total score of 46 or below (ages 6 years to 7 years 11 months), 55 or below (ages 8 years to 9 years 11 months) or 57 or below (ages 10 years to 12 years 11 months). The DCDQ has shown good psychometric properties (Cronbach α=0.94; overall sensitivity=85%; overall specificity=71%)[35]. The DCDQ is a well-validated tool, useful as a first step diagnostic assessment, especially to support and operationalize criterion B[2].

Covariables included were gender, age, gestational age at birth, participation in out-of-school physical activities and educational and occupational family levels. The parents' educational level was measured using the International Standard Classification of Education[36], while occupational level was assessed with the occupational classification proposed by the Spanish Society of Epidemiology and the Spanish Society of Family and Community Medicine[37].

Data analysis/calculation

We conducted a descriptive analysis calculating percentages with their 95% confidence interval (CI) for categorical variables (e.g., suspected DCD, sex, family educational level, etc.), and means and standard deviation (SD) for numerical variables (e.g., age, motor coordination factors). Student t test, ANOVA analyses and Chi Square were used to determine the associations between suspected DCD, problematic ability in the coordination factors and socio-demographic variables. Student t tests were conducted for assessing associations between problematic ability in motor coordination factors and sex, gestational age at birth, out-of-school physical activity and father, mother and family educational and occupational levels, while ANOVA analyses were conducted for assessing associations between motor coordination factors and age groups. Chi Square tests (X^2) were used to explore the associations between suspected DCD and socio-demographic variables (e.g., sex, age groups, gestational age at birth, etc.).

Finally, logistic and linear regression models were used to determine which variables were associated with suspected DCD and problematic coordination performance. All analyses were performed using SPSS v. 20 and EPIDAT v. 3.1. A minimum alpha level of 0.05 was set for all statistical tests.

RESULTS

The sample for this study was comprised of 460 schoolchildren (45.9% rate of valid response) (Mage = 8.66, SD = 1.79; girls = 53.0%). Only one child had a parent reported, clinical diagnosis of Attention Deficit and Hyperactivity Disorder (ADHD, 0.2%, 95% CI = 0.0–1.2) and was included in the study. Socio-demographic characteristics are shown in Table 1. Fifty-six children were identified as having suspected DCD (12.2%, 95% CI = 9.1%–15.3%). Boys were more likely to show suspected DCD than girls in all age groups as shown in Figure 1.

Table 1. Socio-demographic characteristics of participants.

	Participants	Mean±SD or % (95% CI)
Age	459	8.66±1.8
6-7 years	143	31.1 (26.8-35.4)
8-9 years	154	33.5 (29.1-37.9)
10 and more years	163	35.4 (31.0-39.9)
Sex (girls)	244	53.0 (48.4-57.7)
Developmental disorders or learning difficulties	1	0.2 (0.0-1.2)
Full term birth	326	83.6 (79.8-87.4)
Out-of-school physical activity (≥3 hours/week)	221	49.1 (44.4-53.8)
Father educational level (third level studies)	304	70.7 (66.3-75.1)
Mother educational level (third level studies)	361	80.8 (77.0-84.5)
Family educational level (third level studies)	389	84.9 (81.6-88.3)
Father occupational level (occupation corresponding to university studies)	109	25.6 (21.3-29.9)
Mother occupational level (occupation corresponding to university studies)	123	27.6 (23.3-31.78)
Family occupational level (occupation corresponding to university studies)	160	35.1 (30.6-39.6)

Note: SD=standard deviation; 95% CI=95% confidence interval.

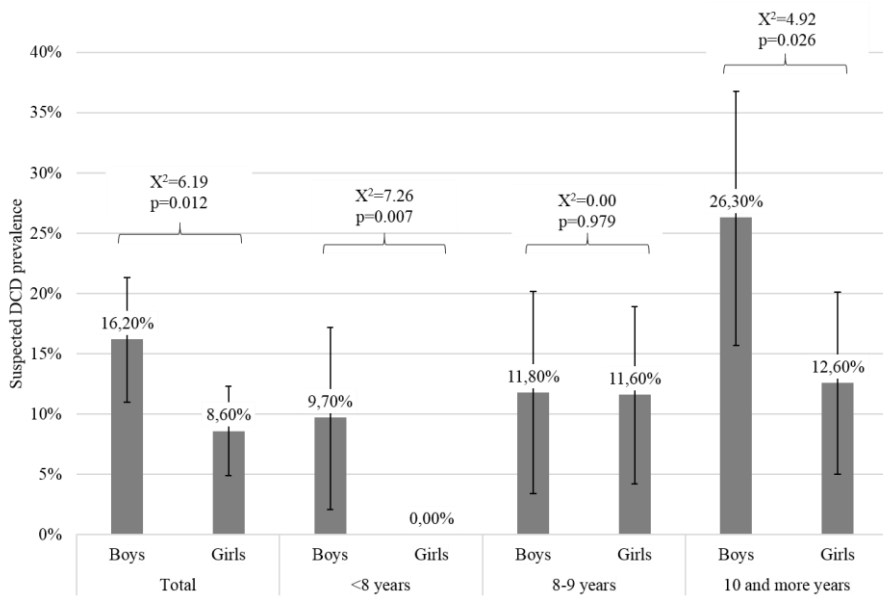

Figure 1. Suspected DCD prevalence differences according to sex and age groups.

Suspected DCD was associated with being male, age, preterm birth, low out-of-school physical activity and family educational level (Table 2). Prevalence of suspected DCD was higher among boys (16.2% vs 8.6%, $X^2 = 6.19$, df = 1), children older than 10 years of age (19.0% vs 8.4%, $X^2 = 14.26$, df = 2), preterm children (18.8% vs 9.8%, $X^2 = 4.27$, df = 1), children who enjoy less than three hours per week of out-of-school physical activities (15.3% vs 8.1%, $X^2 = 5.52$, df = 1) and children with a low family educational level (20.3% vs 10.5%, $X^2 = 5.27$, df = 1) regardless of family occupational level.

Table 2. Association between socio-demographic factors and suspected DCD using Chi-square test.

	No DCD N (%)	Suspected DCD N (%)	X^2	*p*	OR	95% CI
Sex			6.19	0.013	2.05	1.2-3.7
Boys	181 (83.8)	35 (16.2)				
Girls	223 (91.4)	21 (8.6)				
Age			14.26	0.001		
6-7 years	136 (95.1)	7 (4.9)			1	-
8-9 years	136 (88.3)	18 (11.7)			0.22	0.1-0.5
10 and more years	132 (81.0)	31 (19.0)			0.57	0.3-1.1

Note: X^2=chi square value; *p*=p value; OR=odds ratio; 95% CI=95% confidence interval.

Table 2 (cont.). Association between socio-demographic factors and suspected DCD using Chi-square test.

	No DCD N (%)	Suspected DCD N (%)	X^2	*p*	OR	95% CI
Gestational age at birth			4.27	0.039	2.12	1.0-4.4
Preterm	52 (81.2)	12 (18.8)				
Full term	294 (90.2)	32 (9.8)				
Out-of-school physical activity			5.52	0.019	2.03	1.1-3.7
<3 hours/week	194 (84.7)	35 (15.3)				
≥3 hours/week	203 (91.9)	18 (8.1)				
Father educational level			2.40	0.122	1.60	0.9-2.9
First or second level studies	106 (84.1)	20 (15.9)				
Third level studies	272 (89.5)	32 (10.5)				
Mother educational level			3.18	0.075	1.80	0.9-3.4
First or second level studies	71 (82.6)	15 (17.4)				
Third level studies	323 (89.5)	38 (10.5)				
Family educational level			5.27	0.022	2.16	1.1-4.2
First or second level studies	55 (79.7)	14 (20.3)				
Third level studies	348 (89.5)	41 (10.5)				
Father occupational level			2.13	0.144	1.74	0.8-3.7
Occupation not corresponding to university studies	274 (86.4)	43 (13.6)				
Occupation corresponding to university studies	100 (91.7)	9 (8.3)				
Mother occupational level			0.04	0.840	1.07	0.6-2.1
Occupation not corresponding to university studies	284 (87.9)	39 (12.1)				
Occupation corresponding to university studies	109 (88.6)	14 (11.4)				

Note: X^2=chi square value; *p*=p value; OR=odds ratio; 95% CI=95% confidence interval.

Table 2 (cont.). Association between socio-demographic factors and suspected DCD using Chi-square test.

	No DCD N (%)	Suspected DCD N (%)	X^2	*p*	OR	95% CI
Family occupational level			0.80	0.371	1.33	0.7-2.5
Occupation not corresponding to university studies	258 (87.2)	38 (12.8)				
Occupation corresponding to university studies	144 (90.0)	16 (10.0)				

Note: SD=standard deviation; 95% CI=95% confidence interval.

Logistic regression analysis outcomes are presented in Table 3. We found that being male [OR = 3.0, 95% CI (1.5–6.0)], being above 10 years of age [OR = 5.0, 95% CI (1.9–13.1)] and having a low participation in out-of-school physical activities [OR = 2.3, 95% CI (1.1–4.7)] were statistically associated with suspected DCD. Family educational level and preterm birth were not statistically associated factors according to this analysis, although preterm children were twice as likely to show suspected DCD compared to children who were not preterm [OR = 2.1, 95% CI (1.0–4.6)].

Table 3. Logistic multivariate analysis to identify socio-demographic factors associated with suspected DCD.

Variable	B	SE	p	OR (95% CI)
Sex (boys)	1.081	0.358	0.003	3.0 (1.5;6.0)
Age			0.004	
6-7 years				1
8-9 years	0.932	0.518	0.072	2.5 (0.9;7.0)
10 and more years	1.603	0.496	0.001	5.0 (1.9;13.1)
Preterm birth (<37 weeks)	0.745	0.397	0.06	2.1 (1.0;4.6)
Out-of-school physical activity (<3 hours/week)	0.838	0.364	0.021	2.3 (1.1;4.7)
Family educational level (first or second level studies)	0.450	0.426	0.291	1.6 (0.7;3.6)

Note: B=B coefficient value; SE=standard error; OR=odds ratio; p=p value; 95% CI= 95% confidence interval.

Table 4. Independent samples t-tests between socio-demographic and problematic motor coordination ability

	Control during movement		Fine motor/ Handwriting		General coordination		Total score	
	Mean±SD	T value	Mean±SD	T value	Mean±SD	T value	Mean±SD	T value
Total sample	26.09±3.7		17.3±2.7		21.24±3.4		64.64±8.6	
Sex								
Boys	26.03±3.9	0.329	16.67±2.9	4.824[c]	20.73±3.6	3.067[b]	63.43±9.3	2.853[b]
Girls	26.15±3.6		17.87±2.3		21.70±3.1		65.72±7.8	
Age								
6-7 years	25.30±3.9	4.900[b]	16.75±2.8	4.576[a]	20.64±3.6	3.373[a]	62.69±8.8	5.487[b]
8-9 years	26.57±3.4		17.64±2.5		21.42±3.1		65.62±7.7	
10 and more years	26.34±3.8		17.49±2.7		21.60±3.5		65.43±8.9	
Gestational age at birth								
Preterm	25.88±3.9	0.911	17.41±2.7	0.030	21.06±3.7	0.736	64.34±9.2	0.699
Full term	26.33±3.6		17.42±2.7		21.40±3.3		65.14±8.2	
Out-of-school physical activity								
<3 hours/week	25.41±3.9	4.373[c]	16.93±2.7	3.365[c]	20.55±3.5	4.953[c]	62.89±8.7[c]	4.971[c]
≥3 hours/week	26.90±3.4		17.77±2.5		22.08±3.0		66.75±7.8	
Father educational level								
First or second level studies	25.44±3.9	2.651[b]	16.69±2.8	3.104[b]	20.67±3.6	2.311[a]	62.79±8.9	3.040[b]
Third level studies	26.47±3.6		17.58±2.7		21.50±3.4		65.55±8.4	
Mather educational level								
First or second level studies	24.80±4.0	3.847[c]	16.57±2.7	2.797[b]	20.64±3.2	1.871	62.01±8.4	3.301[c]
Third level studies	26.48±3.5		17.47±2.7		21.40±3.4		65.34±8.4	
Family educational level								
First or second level studies	24.57±4.0	3.804[c]	16.36±2.8	3.166[b]	20.32±3.2	2.526[a]	61.25±8.6	3.667[c]
Third level studies	26.39±3.6		17.47±2.7		21.43±3.4		65.29±8.4	
Father occupational level								
Occupation not corresponding to university studies	25.86±3.7	3.199[c]	17.23±2.8	0.979	21.02±3.5	2.423[a]	64.10±8.8	2.630[b]
Occupation corresponding to university studies	27.14±3.1		17.52±2.6		21.94±3.1		66.60± 7.7	
Mother occupational level								
Occupation not corresponding to university studies	26.03±3.7	1.202	17.22±2.7	1.013	21.08±3.5	1.610	64.33±8.5	1.486
Occupation corresponding to university studies	26.50±3.7		17.51±2.6		21.66±3.3		65.67±8.5	
Family occupational level								
Occupation not corresponding to university studies	25.79±3.7	2.680[b]	17.22±2.7	0.929	20.98±3.5	2.288[a]	64.00±8.6	2.367[a]
Occupation corresponding to university studies	26.76±3.5		17.47±2.6		21.74±3.2		65.97±8.2	

Note: [a]p<0.05; [b]p<0.01; [c] p<0.001

Table 5. Linear multivariate analysis to identify socio-demographic factors associated with motor coordination factors

	Control during movement		Fine motor/Handwriting		General coordination		Total score	
Variable	B	95% CI	B	95% CI	B	95% CI	B	95% CI
Sex (boys)	-0.140	-0.8-0.6	-1.185[c]	-1.7-(-0.7)	-0.916[b]	-1.6-(-0.3)	-2.241[b]	-3.8-(-0.6)
Age								
6-7 years	0		0		0		0	
8 y 9 years	1.512[c]	0.7-2.4	0.954[b]	0.3-1.6	0.747	0.0-1.5	3.214[c]	1.3-5.2
10 and more years	1.090[a]	0.2-2.0	0.916[b]	0.3-1.6	0.928[a]	0.1-1.7	2.934[b]	0.9-4.9
Preterm birth (<37 weeks)	-0.316	-1.3-0.6	-0.079	-0.8-0.6	-0.329	-1.2-0.6	-0.724	-2.9-1.5
Out-of-school physical activity (<3 hours/week)	-1.194[c]	-1.9-(-0.5)	-0.790[b]	-1.3-(-0.3)	-1.437[c]	-2.1-(-0.8)	-3.420[c]	-5.0-(-1.8)
Family educational level (first or second level studies)	-1.101[a]	-2.2-0.0	-0.950[a]	-1.7-(-0.2)	-0.538	-1.5-0.4	-2.589[a]	-5.0-(-0.2)
Family occupational level (occupation not corresponding to university studies)	-0.501	-1.3-0.3	-0.028	-0.6-0.5	-0.515	-1.2-0.2	-1.044	-2.8-0.7

Note: B=B coefficient value; CI= 95% confidence interval; [a]p<0.05; [b]p<0.01; [c]p<0.001

Regarding the socio-demographic factors associated with coordination factors and the total DCDQ-ES score, girls, children who participated in three or more hours in out-of-school physical activities and children whose families had high educational and occupational levels scored significantly higher in DCDQ-ES, showing fewer problematic levels of ability (Table 4).

Thus, the outcomes of the linear regression analyses showed that being female, age, engaging in out-of-school physical activity and family educational level were associated with fewer problematic levels of motor coordination ability (Table 5).

DISCUSSION

This study aimed to determine the prevalence of suspected DCD and its associations with socio-demographic factors in Spanish schoolchildren. To our knowledge, this is the first study to assess the prevalence of suspected DCD in a large sample of school-aged children in Spain. In this study, 12.2% of children attending mainstream schools were identified as having suspected DCD and none of children had a previous clinical diagnosis of DCD according to parent reports. These findings are in line with other studies that report a similar rate of DCD. In Europe, the indication of DCD prevalence ranges from 4.9% in the United Kingdom to 19% in Greece, with similar outcomes in other regions such as Canada and South Africa[5,10,38]. However, it is noted that DCD prevalence rates may differ depending on the assessment used to establish DCD diagnosis. The studies that defined DCD cases using only one of the criteria derived from the DSM-IV or DSM-5 usually found a higher prevalence of DCD. For instance, Tsiotra et al.[38] found that 8% of Canadian children and 19% of Greek children met DSM-5 criterion A of a DCD diagnosis that assessed motor competence, but did not evaluate the impact of motor coordination difficulties on everyday performance (i.e., criterion B). Using the MABC-2, 17.4% of Spanish pre-schoolers and 12% of South African grade 1 children were defined as having either DCD or at risk for DCD, but their functional performance was not

evaluated, as only criterion A was considered[10,21]. The studies that have defined DCD primarily using criterion B (everyday functional impairment due to motor coordination difficulties), have also found a higher prevalence of DCD or suspected DCD. In Brazil, several studies using the DCDQ reported that approximately 30% of Brazilian children were classified as having DCD[39,40]. By contrast, Lingam et al.[5], conducted a study with a large cohort of 7- and 8-year-old children in the United Kingdom, assessing all DSM-IV criteria for DCD diagnosis, and found a significantly lower DCD prevalence, where only 1.8% of the children were diagnosed with DCD. It is important to consider all DSM-5 criteria to establish a DCD diagnosis, but this is often difficult when conducting large, population-based studies. While questionnaires and motor coordination test battery alone can be useful in identifying potential motor coordination problems, a definite diagnosis of DCD can only be established by considering all criteria[2]. A recent study conducted in northwest Spain showed that only 1.09% of children received a clinical diagnosis of a neurodevelopmental motor disorder[33]. Given the high prevalence of suspected DCD in our study, in line with the findings of Amador-Ruiz et al.[21], this fact suggests that in Spain, DCD is a hidden, unknown and underdiagnosed disorder.

Boys showed a higher prevalence of suspected DCD and higher frequency of problematic levels of motor coordination ability than girls, which has been reported by other studies and may be an indicator that boys are more likely to present motor coordination difficulties during early development[3,4,22]. The underlying causes are not clear, though it has been suggested that differences in neurobiological and cultural factors between boys and girls may affect the development and quality of motor coordination[2,19]. It has been noted that preterm boys show increased adverse neurological outcomes than preterm girls, which could be a reason for the greater prevalence of DCD and other pervasive developmental disorders in boys[41,42]. Regarding cultural factors, girls are often encouraged to engage in fine motor activities and therefore score higher in fine

motor assessment tasks and tend to show a better motor coordination performance during early development[21,22]. Conversely, some studies have not found differences in DCD prevalence between boys and girls[5,20,21]. This fact could be attributed to methodological differences, such as the selection of the assessment tools or the age of the children. Boys tend to score higher than girls in gross motor or aiming and catching tasks included in most of the motor coordination assessment batteries used in those studies and as such, boys are less likely to be identified as having DCD[5,21].

Older children showed a higher prevalence of suspected DCD but scored significantly higher in all motor coordination factors. As noted in previous research, children aged eight and older are more likely to present DCD symptoms, while simultaneously scoring better on the DCDQ[4,25,39]. This could be because motor skills improve with age, and therefore, the DCDQ scores increase. However, those children with poor motor skills are more likely to be identified by the DCDQ as having suspected DCD. It has been noted that DCD diagnosis at early ages lacks stability[2]. Additionally, DCD is a chronic condition that affects everyday performance and academic achievement, even during adolescence and adulthood[43], therefore it is possible that DCD becomes more evident and readily detected in older children because their motor coordination difficulties have a greater impact on their everyday activities.

In line with previous research, low gestational age at birth was associated with suspected DCD prevalence[4,5,23]. An immature central nervous system can severely affect psychomotor development, which may explain why DCD is significantly more prevalent in preterm children, particularly among younger children. Low birth weight and gestational age at birth have both been shown to affect cognitive and behavioural outcomes, which may contribute to motor coordination difficulties in preterm children[23]. In our study, low gestational age at birth was not statistically associated with suspected DCD according to logistic regression analyses, although preterm children were two times more likely to

show DCD symptoms. This could be attributed to the age of the sample population, which included children older than eight years old. A meta-analysis conducted by Kieviet et al.[23] indicated that the effect of gestational age on motor development may decrease as age increases, so older preterm children and adolescents could show similar DCD prevalence than their term-born peers.

Children with low participation in out-of-school physical activities were more than twice as likely to present DCD symptoms and problematic motor coordination ability skills. Children identified as having DCD tend to engage in less physical activities and sports than their typically developing peers, and usually show lower self-perception about their motor competence[9,26,27,44]. Limited physical activity participation reduces the number of opportunities to practice and improve motor skills, which may contribute to the development of DCD. Therefore, these children will engage less in social play and sports that require the fundamental movement skills they lack, and this process is likely to become a pattern that perpetuates itself[28]. As low physical activity has been associated with low bone mineralization in children with DCD, this should be a major concern when approaching this disorder[45]. Children with DCD show higher clinical obesity and low cardiorespiratory fitness prevalence than children without DCD[38]. Bone mineralization loss in obese, DCD children could contribute to the development of future clinical conditions.

Finally, low family educational level was also a factor associated with suspected DCD and problematic motor coordination skills. While previous research has demonstrated that family socioeconomic status is associated with DCD, studies usually focus solely on family economic level[4,5,24,25,46]. In our study, family educational level predicted DCD and motor coordination regardless of the occupational level of the family. As previously noted, children could be more likely to develop DCD if their parents have decreased recognition of motor coordination disability and access to health care[5]. Parents with a high educational level may be more conscious of the importance of psychomotor development or

could be more likely to detect motor coordination difficulties, and thus could provide more opportunities of stimulation or have more access to health care services.

Several limitations of this study should be considered. First, although we used an established measure of daily living related motor skills, we could not establish a definite diagnosis of DCD since criterion A was not fully assessed and the DCDQ is not recommended for population screening[2]. While motor coordination ability should be assessed using objective tests, parental reports can be valid instruments to assess motor coordination during everyday performance if the items are cross-culturally adapted and allow parents to compare motor skills within the same age groups[2,47]. As we aimed to evaluate a large sample size, the use of a motor coordination test battery was not feasible, and we chose to use a well-validated and cross-culturally adapted questionnaire to identify those children with suspected DCD. A second limitation is that we used a parent report of developmental disorders or learning difficulties without gathering clinical documentation. Only one child was reported as having a clinical diagnosis of developmental disorder (ADHD). While the sample came from mainstream schools, this may suggest that developmental disorders, and more precisely motor coordination disorders, are often underdiagnosed in Spain[33]. Socio-demographic factors associated with suspected DCD in our sample cannot be counted as risk factors due to the cross-sectional nature of our study, although this is valuable information that can be used in future studies. Finally, there may be a potential bias with the sample. It is possible that parent participation was influenced by their children's own motor performance or socioeconomic status. The sample comes from one city in Spain, and thus there may be differences when inferring to other Spanish regions. Parents were randomly selected and came from different socioeconomic districts and from both public and private schools to try to prevent this bias.

Implications for Spanish and international classrooms

This study has important implications for Spanish and international classrooms. Our findings show that at least three children in a mainstream, Spanish classroom are at risk for developing DCD. This disorder is often hidden and underdiagnosed, not only in Spain, but in other regions, and yet the largest proportion of children that receive school-based occupational therapy is referred for handwriting difficulties[31,32]. According to these findings, Spanish mainstream schools should consider including occupational therapists who would contribute to detecting and addressing occupational and scholastic limitations derived from motor coordination issues in children. Research has shown that task-oriented intervention methods are the most effective strategies to improve motor performance, but contextual barriers and socio-demographic factors need to be considered to design specific, effective programmes that accommodate the child's needs and characteristics[2]. Schools in Spain and other regions could use these findings to address appropriate detection protocols that include those socio-demographic factors known to be associated with suspected DCD and to design strategies that allow children with suspected DCD to practice motor skills in an environment in which they can effectively engage in physical activities.

The DCDQ-ES scores provided here can be used by researchers in future studies and by teachers and health care practitioners in their daily classroom or clinical work. Researchers can also use the suspected DCD prevalence found in our study to warn national and international communities about this disorder. Future studies could explore the associations of additional socio-demographic and contextual factors, alongside those included in this study, to further investigate the external variables that may contribute to the development of DCD.

WHAT THIS PAPER ADDS?

This is the first study to investigate the epidemiology of suspected Developmental Coordination Disorder (DCD) in a large sample of Spanish schoolchildren aged 6–12 years old. Approximately three children in a general Spanish classroom are at risk for DCD. Boys are three times more likely to show coordination difficulties. Age, premature birth and low participation in out-of-school physical activities are also associated with DCD symptoms. These findings indicate that factors associated with motor coordination difficulties in schoolchildren span across neurological and socio-demographic domains, and should be addressed during early development to promote prompt interventions. Schools offer the best setting to detect learning difficulties due to motor coordination issues, and teachers and health care practitioners working in schools can use this study to design specific strategies to promote full participation according to these children's needs and characteristics.

CONCLUSIONS

Suspected DCD affects approximately 12% of Spanish schoolchildren. Suspected DCD and problematic motor coordination ability skills are associated with age, sex, limited participation in out-of-school physical activities, low gestational age at birth and family educational status. These are important findings as they point to the need to consider socio-demographics as relevant factors when assessing DCD in school-aged children. The impact of DCD on education achievement is not limited to childhood, but remains during adolescence[43], and thus it should be addressed as soon as motor coordination difficulties are displayed during development. Teachers and health care practitioners working in schools could use well-validated questionnaires to screen motor coordination difficulties, since they are easily accessed tools and useful for collecting information about the child's everyday performance. However, a DCD diagnosis should always include complementary assessments and the evaluation of all criteria.

Schools offer the best environment for the early detection of motor coordination related learning difficulties and to develop strategies that promote motor coordination and minimize the impact of DCD on academic achievement. Occupational and physical therapists working in schools can help to detect and address this disorder using task-oriented intervention strategies that consider sociodemographic and contextual factors associated with DCD.

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CHAPTER 3
SENSORY PROCESSING PATTERNS IN DEVELOPMENTAL COORDINATION DISORDER, ATTENTION DEFICIT HYPERACTIVITY DISORDER AND TYPICAL DEVELOPMENT

Delgado-Lobete L, Pértega-Díaz S, Santos-del-Riego S, Montes-Montes R. Sensory processing patterns in developmental coordination disorder, attention deficit hyperactivity disorder and typical development. Res Dev Disabil. 2020;100:103608.

ABSTRACT

Sensory processing difficulties (SPD) are present in children with Developmental Coordination Disorder (DCD) and Attention Deficit and Hyperactivity Disorder (ADHD). However, little is known about sensory processing variability in these disorders. The purpose of this study was to explore SPD among children with DCD, ADHD and co-occurring symptoms in comparison to children with typical development (TD) and to determine how potential social confounders may influence these associations. The study involved 452 children aged 6–12 years. The Short Sensory Profile-2 was used to assess sensory processing patterns. Multiple linear regressions were utilized to investigate the relationship between DCD, ADHD and co-occurring symptoms and sensory processing patterns, adjusting for social covariates. Findings revealed that children with DCD and ADHD symptoms showed greater variability of atypical sensory processing patterns compared with TD children. Low registration and sensory sensibility issues were more prevalent in the DCD group. ADHD children showed higher rates of low registration, sensory sensibility and sensory seeking, and all children in the co-occurring symptoms group presented sensory sensibility. In conclusion, this study reports significant variability in sensory processing among children with DCD, ADHD and co-occurring symptoms using a population-based sample. These differences can contribute to understand how neurological and social factors correlates across diagnoses.

INTRODUCTION

Developmental Coordination Disorder (DCD) and Attention Deficit and Hyperactivity Disorder (ADHD) are two of the most prevalent neurodevelopmental disorders and their consequences have a long-term impact in everyday life performance[1,2]. While prevalence rates vary across countries and definitions, it is estimated that DCD is present in at least 6% of schoolchildren, while ADHD prevalence is up to 9.5%[3,4]. DCD and ADHD often co-occur and it has been suggested that as many as 50 % of children with ADHD are diagnosed with DCD as well, particularly among clinical samples[3]. Despite this common co-occurrence, evidence supports that DCD and ADHD are separate disorders with different etiology and distinct neural mechanisms[5,6]. There is evidence that sensory processing difficulties (SPD) are part of the DCD and ADHD phenotypes with significant impact on movement, behavior and everyday performance[5,7,8].

Sensory processing refers to the ability to manage detection, modulation, interpretation and organization of incoming sensory information[9]. According to Dunn's Sensory Processing Framework, sensory processing is the emerging result of the interaction between neurological threshold and self-regulation[10]. The neurological threshold refers to the amount of sensory stimuli needed by a person for noticing and responding to it and range from quick to detect (low threshold) to slow to detect (high threshold). In addition, self-regulation refers to the behavioral management of said sensory input. Children with passive strategies do not counteract the stimuli, while children with active self-regulation strategies plan a reaction to counteract it. As result, four sensory processing patterns emerge from the interaction of neurological threshold and self-regulation: low registration or bystander (high threshold and passive self-regulation), seeking or seeker (high threshold and active self-regulation), sensitivity or sensor (low threshold and passive self-regulation) and avoiding or avoider (low threshold and active self-regulation). The child behavior will be heavily influenced by their sensory processing patterns. For example, children with low registration (who

detect stimuli slowly and do not try to counteract it) often fail to notice external sensory stimuli and may thus be perceived to be inattention. In addition, difficulties detecting internal proprioceptive input may be perceived as clumsiness[10].

Sensory processing issues are highly prevalent in children with neurodevelopmental conditions and impact their everyday performance[8,11]. Studies demonstrate that children with ADHD or DCD differ in sensory processing as compared to their typically developing (TP) peers[7,12]. Children with ADHD are more likely to seek out sensory input (seeking pattern), be more aware of sensory stimuli (sensor pattern), be more bothered by certain input (avoiding pattern) and also to notice less sensory input than TD children (low registration/bystander pattern)[13]. Sensory processing disorders are also present in children with DCD, who have issues regarding sensory sensitivity and difficulties with the stimuli detection of body awareness, and with balance and planning and ideation[5,7]. Research shows that children with DCD or ADHD have sensory processing deficits, and that there is great sensory processing both between and within-disorder variability, as they do not exhibit just one predominant sensory pattern. Moreover, children with similar sensory processing patterns but different neurodevelopmental conditions may act differently[13].

It has been proposed that sensory processing issues may be contributing to the etiology and development of neurodevelopmental conditions[5,14], and recently have been included as a diagnosis criterion for Autism Spectrum Disorder[1]. Data shows that children with DCD suffer from a deficit of the internal modelling (IMD) of the movement, which heavily relies on spatiotemporal parameters and sensorimotor and visual processing to successfully feedforward movement[3,5]. Therefore, sensorimotor processing discrepancies may be partially responsible for motor learning and control difficulties. Regarding SPD and ADHD, children with ADHD show higher sensory sensitivity and have issues in proprioception, vision, auditory and tactile sensory processing. These deficits in sensory

processing are related with functional, social, behavioral and learning difficulties[15]. However, there is no data about sensory patterns variability between children with DCD, ADHD or co-occurring symptoms in comparison to typical development and between groups, so it remains unclear how sensory processing differs in children with DCD or ADHD.

Evidence indicates that children with DCD and ADHD co-occurring disorders exhibit unique neurobiology characteristics in comparison to children with DCD alone or ADHD alone[5]. Potential differences in sensory processing between children with DCD and those with ADHD or with co-occurring DCD and ADHD may contribute to understand how neurological factors with respect to neurological thresholds and self-regulation strategies correlates across diagnoses.

While neurobiology and genetics have been proposed as the main factors explaining neurodevelopmental disorders, social and environmental variables are associated with DCD and ADHD as well[5,16,17]. Some authors have found associations between sensory processing and sociodemographic factors, such as sex and family socioeconomic status. In children with TD or SPD, low family education is associated with sensory processing issues[14,18,19], but there is no data about if and how sensory processing and sociodemographic factors interrelate in children with DCD or ADHD. According to the Dynamic Systems Theory motor behavior is influenced by many factors, including both internal and external constraints[20,21]. Therefore, exploring the interrelationship of sensory processing and social factors could contribute to understand the underlying mechanisms of motor coordination and inattention/hyperactivity problems not only in children with DCD or ADHD, but in children with typical development.

The main purpose of this study was to explore sensory processing patterns in association with social factors in children with DCD, ADHD and co-occurring symptoms in comparison to TD children using a population-based sample.

METHODS

Design

Data was collected from a larger cross-sectional study involving neurodevelopmental and socio-demographic factors in Spanish children[16]. This study was approved by the Autonomic Research Ethics of Galicia Committee (code 2017/166).

Participants and procedure

Sample included 452 randomly selected parents of children aged 6–12 (M_{age} = 8.7±1.8; girls = 53.3%). Socio-demographic characteristics are shown in Table 1.

Table 1. Socio-demographic characteristics according to neurodevelopmental disorders symptoms.

	TD N = 369	**DCD N = 46**	**ADHD N = 27**	**Co-occurring N =10**	**F or X^2**
Sex (N, %)					7.34
Boys	166 (45.0)	278 (60.9)	10 (37.0)	7 (70.0)	
Girls	203 (55.0)	18 (39.1)	17 (63.0)	3 (30.0)	
Age (M ± SD)	8.6 ± 1.8	9.6 ± 1.7	8.2 ± 1.5	8.8 ± 1.2	5.17**
Family education level (N, %)					9.30*
Non-tertiary education	46 (12.5)	11 (24.4)	7 (25.9)	3 (30.0)	
Tertiary education	322 (87.5)	34 (75.6)	20 (74.1)	7 (70.0)	
School (N, %)					3.60
Public	192 (52.0)	24 (52.2)	19 (70.4)	6 (60.0)	
Concerted/Private	177 (48.0)	22 (47.8)	8 (29.6)	4 (40.0)	

Note: TD = typically developing; DCD = developmental coordination disorder; ADHD = attention deficit hyperactivity disorder; M = mean; SD = standard deviation; F = ANOVA statistic; X^2 = chi square; * = $p < 0.05$; ** = $p < 0.01$.

All participants were recruited from a northern city in Spain during 2017 and came from six of the forty-four eligible mainstreaming schools in the region. The schools distributed the Short Sensory Profile-2, the Developmental Coordination Disorder Questionnaire and the Attention Deficit Hyperactivity Disorder Rating Scale-IV to the students' parents, who anonymously and voluntarily completed the questionnaires at home and then returned them to the schools.

In order for a participant to be included in the study, all the questionnaires had to be completely fulfilled. Children with a parent reported diagnosis of DCD, ADHD or any other neurodevelopmental or learning disorder were excluded. Valid response rate was 45.2%.

Outcome measures

Each parent completed the Spanish versions of the Short Sensory Profile-2 (PS-2B), the Developmental Coordination Disorder Questionnaire (DCDQ-ES) and the Attention Deficit Hyperactivity Disorder Rating Scale-IV (ADHD-RS-IV-ES). An additional question regarding family educational level was included ad-hoc.

The PS-2B is a 34-item parent-report measure of sensory processing characteristics and behavioral response of the child. It provides scores on each sensory quadrant (i.e., registration, seeking, sensitivity and avoiding), where higher scores reflect higher frequency of described behaviors. Quadrant scores are latter categorized as sensory patterns (bystander, seeker, sensor or avoider). Scores between one and two standard deviations from the mean are expressed as atypical sensory patterns (less or more than others). Scores two standard deviations or more from the mean indicates a definite difference in sensory processing (much less or much more than others). The PS-2B has demonstrated excellent psychometric properties within Spanish population (internal consistency α = 0.72–0.90; test-retest stability = 0.93–0.97)[10]. As reported by Dean, Dunn & Little[22] the Sensory Profile 2 shows good construct validity. Confirmatory factor analysis has demonstrated a good fit with the four-factor model based on the four sensory quadrants/patterns[22].

The DCDQ-ES is a 15-item parent-report measure that evaluates three motor coordination dimensions (control during moving, fine motor/handwriting and general coordination), where higher scores are associated with better motor coordination. A diagnosis of probable DCD is given according to child's total

score (46 or below for children aged 6–7y11m; 55 or below for children aged 8–9y11m or 57 or below for children aged 10–12y). The DCDQ has been cross-culturally adapted into Spanish population[23]. The DCDQ is one of the most recommended tools to asses for DCD indication and has shown good psychometric properties (Cronbach $\alpha = 0.94$; overall sensitivity = 85%; overall specificity = 71%)[3,24].

The ADHD-RS-IV-ES is a parent-report behavioral scale that comprises 18 items corresponding to the 18 nuclear DSM-IV ADHD symptoms criteria[25]. The ADHD-RS-IV-ES provides scores for inattention, hyperactivity-impulsivity and total ADHD symptoms, where higher scores reflect greater frequency and intensity of ADHD symptoms. Child is identified as having probable ADHD if they obtain scores above the 90th percentile calculated for their age and sex. The ADHD-RS-IV-ES has demonstrated excellent internal consistency in Spanish children (Cronbach $\alpha = 0.85–0.95$)[25].

Children were identified as having probable DCD or probable ADHD according to total scores on the DCDQ-ES and the ADHD-RS-IV-ES. A co-occurring diagnosis was established if the child showed symptoms of both DCD and ADHD as measured by the DCDQ-ES and the ADHD-RS-IV-ES.

Data Analysis

SPSS v 20 was used for analyses. The prevalence of probable DCD, ADHD and co-occurring disorders in the sample were estimated and 95% confidence intervals (CI) were calculated for the prevalence estimates. Significance was set at $p < 0.05$. Data were examined for normality using visual inspection and Kolmogorov-Smirnov's test results. We performed one-way analysis of variance (ANOVA) to examine differences in sensory quadrants scores (registration, seeking, sensitivity and avoiding) between diagnosis groups (i.e., TD, DCD, ADHD, co-occurring). Specific differences between groups were assessed with Bonferroni post-hoc tests.

Pearson Chi square test (X^2) was used to compare sensory patterns (bystander, seeker, sensor and avoider) between groups. In order to determine the correlation between sensory quadrants and scores on the dimensions of the DCDQ/ADHD symptom scales, we conducted Pearson correlations.

Finally, we determined how sensory processing quadrants and social factors predicted coordination performance and ADHD symptoms. Seven stepwise multiple linear regression models were performed on coordination dimensions as measured by the DCDQ-ES (control during movement, fine motor, general coordination ad total score) and ADHD symptoms as measured by the ADHD-RS-IV-ES (inattention, hyperactivity-impulsivity and ADHD). Independent variables regarding sensory processing quadrants (low registration, seeking, sensitivity and avoiding) and social factors (age, sex and family education level) were entered in the analysis. The final model for each analysis only included those variables that added a statistically significant amount to the overall multiple R squared.

RESULTS

Prevalence of neurodevelopmental disorders symptoms was 18.4% (95% CI = 4.7–22.0) (probable DCD = 10.2%, 95% CI = 7.3–13.1; probable ADHD = 6.0%, 95% CI = 3.7–8.3; co-occurring = 2.2%, 95% CI = 0.8–3.7).

Parents of children with DCD, ADHD and co-occurring symptoms rated them significantly higher on all sensory quadrants. These children showed higher prevalence of atypical sensory patterns than their TD peers (Table 2).

Parents of children with probable DCD scored them significantly lower on all sensory quadrants than children with ADHD or co-occurring symptoms, and parents of children with probable ADHD reported them to show significantly lower sensory difficulties than co-occurring group in sensitivity and avoiding, but not in registration or seeking.

Table 2. Quadrant scores and sensory patterns in TD, DCD, ADHD and co-occurring children.

	TD N = 369	DCD N = 46	ADHD N = 27	Co-occurring N =10	F or X^2
Quadrant scores					
Low registration (M ± SD)	10.5 ± 3.1	13.2 ± 4.7	15.8 ± 6.9	19.2 ± 5.7	38.35[a]
Seeking (M ± SD)	12.3 ± 4.0	13.9 ± 5.1	19.7 ± 4.5	22.5 ± 5.5	44.58[a]
Sensitivity (M ± SD)	17.0 ± 5.1	19.5 ± 5.9	27.7 ± 7.2	34.3 ± 3.9	65.09[b]
Avoiding (M ± SD)	14.3 ± 5.1	17.0 ± 6.0	22.4 ± 7.5	30.0 ± 7.5	45.66[b]
Sensory patterns					
Bystander (N, %)	37 (10.0)	12 (26.1)	14 (51.9)	9 (90.0)	80.13***
Seeker (N, %)	39 (10.6)	9 (19.6)	18 (66.7)	8 (80.0)	88.87***
Sensor (N, %)	35 (9.5)	10 (21.7)	21 (77.8)	10 (100.0)	136.19***
Avoider (N, %)	48 (13.0)	13 (28.3)	13 (48.1)	9 (90.0)	60.28***

Note: TD = typically developing; DCD = developmental coordination disorder; ADHD = attention deficit hyperactivity disorder; M = mean; SD = standard deviation; F = ANOVA statistic; X^2 = chi square; a = significant differences between all groups except for ADHD and co-occurring; b =significant differences between all groups; *** = $p < 0.001$.

As expected, atypical sensory processing was increased in children with ADHD and co-occurring symptoms for all quadrants and patterns, especially in the sensitivity quadrant, where more than three-fourths of children with probable ADHD and all children with co-occurring symptoms showed a sensor pattern. At least one atypical sensory pattern was present on 25.7% in the TD group. Presence of at least one atypical sensory pattern in the DCD, ADHD and co-occurring groups was higher at 45.7%, 85.2% and 100.0%, respectively (X^2 (df = 3) = 65.71; $p < 0.001$). Definite difference in at least one sensory pattern was present at 7.0%, 19.6%, 51.9% and 80.0% in TD, probable DCD, probable ADHD and co-occurring groups, respectively (X^2 (df = 3) = 91.32; $p < 0.001$).

As seen in Table 3, scores on all sensory quadrants significantly correlated with the scores on the three coordination dimensions of the DCDQ-ES, although this correlation was weak to moderate (r = 0.204–0.432 $p < 0.001$). ADHD symptoms showed stronger correlations with sensory patterns (r = 0.492–0.798; $p < 0.001$), especially with sensitivity quadrant.

Results for the regression analyses are shown in Table 4. Linear regression revealed that passive self-regulation patterns were associated with poorer motor performance. Low registration predicted control during movement, general coordination and DCDQ-ES total score, while sensitivity predicted fine motor, general coordination and DCDQ-ES total score. In addition, sensory seeking and sensitivity predicted inattention, hyperactivity-impulsivity and ADHD symptoms. Additionally, at least one social factor contributed to explain motor performance and ADHD symptoms in all models. Family education level played a relevant role in DCDQ-ES dimensions and total score, and sex was significant in predicting ADHD symptoms.

Table 3. Correlations between sensory quadrants scores, coordination dimensions and ADHD symptoms.

	Control during movement	Fine motor	General coordination	DCDQ total score	Inattention	Hyperactivity-impulsivity	ADHD
Low registration	−0.323***	−0.293***	−0.399***	−0.391***	0.574***	0.492***	0.586***
Seeking	−0.204***	−0.261***	−0.347***	−0.309***	0.638***	0.691***	0.728***
Sensitivity	−0.247***	−0.373***	−0.432***	−0.396***	0.798***	0.616***	0.780***
Avoiding	−0.226***	−0.320***	−0.357***	−0.340***	0.636***	0.511***	0.632***

Note: DCDQ = Developmental Coordination Disorder Questionnaire; *** = $p < 0.001$.

Table 4. Multiple linear regression models to identify coordination dimensions and ADHD symptoms using sensory processing and social factors as predictors (stepwise method).

	Control during movement		Fine motor		General coordination		DCDQ total score	
Variable	**B**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**
Age	0.23*	0.05, 0.41	–	–	0.19*	0.03, 0.35	0.55**	0.15, 0.96
Sex	–	–	−0.97***	−1.43, −0.51	–	–	−1.43*	−2.86, -0.03
Family education level	−1.51**	−2.43, −0.60	−0.79*	−1.44, −0.14	–	–	−2.91**	−4.93, −0.89
Low registration	−0.28***	−0.36, −0.20	–	–	−0.17***	−0.23, -0.08	−0.47***	−0.70, −0.23
Seeking	–	–	–	–	–	–	–	–
Sensitivity	–	–	−0.14***	−0.18, −0.11	−0.16***	−0.22, −0.10	−0.29**	−0.44, −0.13
Avoiding	–	–	–	–	–	–	–	–

	Inattention		Hyperactivity-impulsivity		ADHD	
Variable	**B**	**95% CI**	**B**	**95% CI**	**B**	**95% CI**
Age	–	–	–	–	–	–
Sex	0.78**	0.19, 1.37	–	–	1.41**	0.39, 2.43
Family education level	–	–	–	–	–	–
Low registration	–	–	–	–	–	–
Seeking	0.12*	0.03, 0.21	0.55***	0.45, 0.65	0.65***	0.49, 0.81
Sensitivity	0.53***	0.46, 0.61	0.19***	0.12, 0.27	0.70***	0.57, 0.83
Avoiding	0.10**	0.04, 0.17	–	–	0.14*	0.03, 0.26

Note: DCDQ = Developmental Coordination Disorder Questionnaire; ADHD = attention deficit hyperactivity-impulsivity disorder; B = linear regression statistic; CI = confidence intervals; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

DISCUSSION

The purpose of this study was to explore sensory processing differences and variability of sensory patterns between children with DCD, ADHD or co-occurring symptoms. This study is the first to compare sensory processing patterns across these diagnosis groups. Our findings are in line with previous research regarding sensory processing variability between disorders in children with neurodevelopmental conditions and in comparison with typically developing children. Furthermore, results showed that sensory processing interrelate with social factors to predict motor coordination performance and ADHD symptoms in general population.

A great variability in sensory patterns were found within the probable DCD group, with the least common pattern being seeker (19.6%) and the most frequent being avoider (28.3%) and bystander (26.1%). Parents of the majority of the children with DCD symptoms did not report atypical or definite different sensory processing, although the prevalence of atypical sensory patterns was significantly higher than in the TD group. This outcome supports the findings of Allen and Casey[7] regarding definite differences in sensory processing in children with DCD. In their study, 18% of children with DCD were identified as having definite different sensory processing in the Sensory Processing Measure, indicating presence of SPD. In this study, children with DCD symptoms showed a higher bystander pattern than the TD group (26% vs 10%), indicating low registration of sensory stimuli. Low registration issues commonly include difficulties with proprioceptive stimuli, which refers to the subconscious and conscious awareness of spatial and kinesthetic parameters of the musculoskeletal framework and plays a relevant role in body awareness and balance[26]. Although there is not previous research about sensory patterns in children with DCD and therefore a direct comparison cannot be made, Allen and Casey also found similar percentages of body awareness and balance problems in this population (24–33%), which links to low registration issues in DCD[7]. Using bivariate analyses, all sensory patterns

correlated with motor coordination dimensions. However, when considering social factors in the multivariate linear regression analysis, only low registration and sensory sensitivity predicted motor coordination performance. This finding suggests a relationship between DCD and passive self-regulation strategies, indicating that children with DCD may not try to actively counteract difficulties in stimuli detection.

As internal modelling deficit has been proposed as one of the main factors contributing to the etiology of DCD[3,5,27], discrepancies in body awareness registration and processing may be adding to the development of this disorder. Internal modelling relies on spatiotemporal parameters to feedforward movement in order to forward plan or predict motor actions, and therefore sensorimotor kinesthetic and visual processing integrity is crucial to generate signals than allow children to learn, adapt and plan movement[5]. Research has demonstrated that children with DCD struggle in processing visual-spatial information[27] and proprioceptive and tactile stimuli[28]. Visual feedback has been suggested to play a less significant role in adaptation to novel motor dynamics than kinesthetic information[29], which could mean that difficulties in kinesthetic-related sensory stimuli, such as proprioceptive, vestibular or tactile stimuli may have a greater role in internal modelling discrepancies. Therefore, low registration issues regarding proprioceptive stimuli detection may contribute to the underlying sensorimotor processing factors that influence internal modelling deficit in DCD.

Children with poor motor coordination show an increased risk of psychosocial and emotional problems, including psychological distress, negative self-esteem, anxiety and social participation difficulties[3]. The link between motor proficiency and social participation has been extensively highlighted in previous research[7]. It may be possible for sensory sensitivity to play a role in behavioral and social issues in DCD. Sensor children are extremely sensitive to external information such as hearing and tactile information, but do not counteract these overwhelming

inputs and instead typically react anxiously and irritably[10], thus potentially leading to behavioral problems.

Regarding sensory processing issues in ADHD, our findings show that most of the children with ADHD symptoms exhibited at least one atypical sensory pattern. While most of these children showed higher sensitivity, a significant number also showed seeker and bystander patterns. Previous research has demonstrated that ADHD is heavily associated with both hypo and hyper-sensitivity and especially with sensitivity, seeking and low registration, and that these issues impact everyday function and social behavior[8,13].

In our study, ADHD symptoms were strongly correlated with sensory sensitivity, suggesting an intimate relationship in assessment of both constructs. As a matter of fact, it has been questioned whether ADHD and SPD may pose as a unique disorder due to the high overlapping between both conditions. However, recent studies indicate that these disorders are differentiated by distinct somatic, behavioral and physiological characteristics with different clinical conditions, assessment and treatment approaches needed[8,9,14]. For example, children with SPD or co-occurring SPD and ADHD present more sensory issues than children with ADHD alone in tactile, taste/smell, visual/auditory and movement sensitivity, and encounter more difficulties to adapt or be flexible in the presence of unexpected occurrences, making them more vulnerable to emotional problems[9]. Research also indicates that presence of sensory modulation difficulties in children with ADHD increases daily dysfunction compared to children with ADHD only[8]. There are also differences in physiological reactivity to sensory stimuli between children with SPD and children with ADHD. Children with sensory modulation disorders have greater electrodermal reactivity compared to children with ADHD, suggesting that sensory-stimulus-elicited electrodermal responses may contribute to the diagnosis of children with SPD from children with ADHD when assessing for co-occurrence of both disorders[9]. Furthermore, it has been proposed that different clusters based on tactile and

auditory sensory processing differences can effectively identify and differentiate children with ADHD or SPD, adding to the evidence of ADHD and SPD being two frequently overlapping but distinct conditions[14].

Findings from this study contribute to demonstrate that DCD and ADHD are different diagnosis although commonly overlapping. Children with probable DCD showed different sensory processing patterns than children with probable ADHD or co-occurring conditions, who presented more sensory processing difficulties in all quadrants. Although DCD and ADHD share prevalence rates and co-occurrence alongside similar psychosocial issues, research demonstrates that they may be separate conditions due to differences in motor, attention and executive functioning and disparities in brain underpinnings[6,30]. Sensory patterns variability found in this study highlight that sensory processing differences may manifest differently in children with DCD or ADHD.

In this sample, children with co-occurring symptoms showed the highest scores on all patterns. This was to be expected as research has demonstrated that children with co-occurring conditions usually face more challenges in multisensory integration, behavior and participation[3,7,15,31]. An important clinically relevant finding of this particular outcome is that sensory patterns variability in DCD and DCD and ADHD co-occurring symptoms had not been previously evaluated. Occupational therapists working with children with motor coordination and inattention/hyperactivity difficulties can use these findings to further assess the sensory processing features of these children in order to plan intervention programs that consider both individual sensory pattern preferences and characteristics, and child's specific social background.

Limitations and Future Research Prospects

This study has several limitations that need to be disclosed. We used parent report measures, and although all questionnaires are well-validated and ecologically valid to assess DCD and ADHD symptoms and sensory processing, they could lead to potential biases, and therefore future studies may consider methods of direct and objective assessment. This work was also limited as other conditions that may be related to differences in sensory processing patterns in DCD or ADHD were not considered (i.e., social anxiety). The sample size of the group with DCD and ADHD co-occurring symptoms was little and sex imbalanced, and therefore this may introduce bias. Finally, this research used cross-sectional data from a specific region population-based sample. Although this is interesting regarding how sensory features are present in general population, future research is needed to explore how underlying neurological mechanisms of sensory processing disclose over time in clinical samples.

WHAT THIS PAPER ADDS?

This is the first study to explore differences in sensory processing patterns among children with DCD, ADHD and co-occurring symptoms in comparison to typically developing children using a population-based sample and adjusting for social covariates. Our results indicate that children with these disorders show more sensory processing difficulties and greater sensory patterns variability than peers without motor coordination or inattention/hyperactivity issues. Children with co-occurring symptoms experienced more sensory processing variability than any other group. Presence of DCD, ADHD or co-occurring symptoms were significantly and independently associated with atypical sensory processing, but social characteristics such as age, sex and family educational level were also significantly related. These findings highlight the need to consider both sensory processing variability and social background when examining motor coordination or attention/hyperactivity in children with potential neurodevelopmental disorders.

CONCLUSIONS

Children with DCD, ADHD or co-occurring symptoms show greater variability in sensory processing patterns and more sensory processing issues than TD children. Frequency of atypical sensory patterns increased in children with DCD or ADHD symptoms, and all children with co-occurring symptoms exhibited at least one atypical sensory pattern, being sensitivity the most prevalent pattern. When considering social factors, low registration, sensitivity, age and family educational level predicted motor coordination performance, while sex, seeking and sensitivity were associated with ADHD symptoms (i.e., inattention and hyperactivity-impulsivity). This study highlights that motor coordination difficulties and ADHD in general population are heavily influenced by sensory processing variability and social factors, and therefore assessment of these disorders needs to address sensory processing and environmental features.

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CHAPTER 4

INTERRELATION OF INDIVIDUAL, COUNTRY AND ACTIVITY CONSTRAINTS IN MOTOR ACTIVITIES OF DAILY LIVING AMONG TYPICALLY DEVELOPING CHILDREN

Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Cruz-Valiño JM, Schoemaker MM. Interrelation of Individual, Country and Activity Constraints in Motor Activities of Daily Living among Typically Developing Children: A Cross-sectional Comparison of Spanish and Dutch Populations. Int J Environ Res Public Health. 2020;17(5):1705.

ABSTRACT

Motor performance is influenced by individual, environmental, and task constraints. Children perform differently according to individual (i.e., sex), environmental (i.e., country), and task (i.e., type of activity) factors. However, little is known about the effect of the interaction between sex and country factors across different activities of daily living (ADL) learning, participation, and performance. The main aim of this study was to examine the relationship between sex, country, and type of activity in motor-based ADL learning, participation, and performance in five-to-eight-year-old, typically developing children. Additionally, we aimed to compare the prevalence of probable Developmental Coordination Disorder (DCD) across sex and country. The DCDDaily-Q was used to assess ADL learning, participation, and performance in 300 age and sex-matched children from Spain and The Netherlands. The prevalence of probable DCD was determined based on the total ADL performance score. Results showed that differences in ADL learning, participation and performance differed across sex and country ($p < 0.05$). Prevalence of probable DCD was statistically similar in both countries. These findings show that daily participation and performance in typically developing children may be influenced by individual, country, and task constraints, and that country and sex may have different influences on particular tasks.

INTRODUCTION

The Dynamic Systems Theory proposes that motor performance results from the interaction of individual, environmental, and task constraints[1-3]. Previous research has proposed that both motor performance and the presence of Developmental Coordination Disorder (DCD) are influenced by different constraints such as sex, lifestyle, physical activity routines, environmental settings, and participation in activities of daily living (ADL)[4-9]. The influence of these factors varies from one country to another, even within a Western European context, and there is an increasing interest in literature to explore motor performance patterns in children from different regions[4,6,10-13].

Previous studies investigating geographical or country influences using the Movement Assessment Battery for Children-Second Edition (MABC-2) have found significant differences in motor competence between regions. Findings indicate that Brazilian children perform significantly poorer on manual dexterity and balance than American children[10], while Czech children outperform children from the United Kingdom (UK) in the same domains[11]. Apart from geographical constraints, also individual constraints such as age and sex may influence motor performance even within the same country. While the performance of 3–6-year-old Dutch children was similar to children in the UK, Dutch children older than 6 showed better outcomes on manual dexterity, aiming and catching-ball skills, and balance on the MABC-2[12]. In some studies, individual constraints such as age were found to interact with country constraints. For instance, Zoia et al. found that younger Italian children obtained lower scores than children in the UK on manual dexterity, balance and aim, and catching-ball skills, while this difference was overturned when children get older, as older Italian children generally performed better than British children in all components[13].

Additionally, the influence of sex as an individual constraint on motor coordination has been repeatedly reported in previous studies, but the results are inconclusive, as not every study has found differences between boys and girls. This inconsistency could be due to the different methods used to assess motor competence (i.e., objective motor tests such as the MABC-2 or parental questionnaires such as the Developmental Coordination Disorder Questionnaire), since it has been reported that boys tend to outperform girls in gross motor-based evaluations while girls are more proficient in fine motor skills and control during movement skills, as handwriting and balance[8,11].

Sex differences in motor performance can also be influenced by country context, as children's everyday participation is still sex-biased, and boys and girls are often encouraged to engage in different physical and leisure activities[14,15]. As a consequence, motor performance across sex can present differently in different countries. Psotta et al. found that Czech girls showed better manual dexterity than UK girls, despite boys' performance is similar in both countries[11]. Brazilian girls are less proficient in manual dexterity than American girls, while Brazilian boys score significantly poorer on ball skills[10]. Children with DCD struggle with a broad range of daily motor activities and especially with self-care activities[7], but little is known about if and how country differences influence participation and performance in self-care ADL.

Country constraints may also have an effect on the performance of motor Activities of Daily Living (ADL). Motor performance during ADL is usually assessed with parent questionnaires, being the Developmental Coordination Disorder Questionnaire (DCDQ), the most often used measure. Caravale et al. found that parents rated the motor performance of Italian children lower than parents of Canadian children with the DCDQ, suggesting poorer daily motor performance in Italian children[16]. Conversely, parents rated the ADL performance of five-to-eight-year-old German children as significantly better than parents of Canadian children[17]. In both cases, specific cutoff scores for

Italian and German children were developed in order to assure a correct evaluation of motor performance in these populations.

When motor coordination difficulties have a significant and constant impact on the performance of daily living activities (i.e., limiting self-care activities performance and participation), then the child may be at risk for DCD[18]. The DCD is a chronic condition with lifelong consequences in physical and psychosocial health, participation restriction, and academic achievement[19-24]. The American Psychiatric Association estimates that this disorder affects approximately 6% of school-aged children[18], but different rates have been reported for children of European, American, and Latin American regions, suggesting an influence of country factors on prevalence rate. Southern European and Latin American children usually showed a higher prevalence of DCD or probable DCD than Northern European or American children[8,25-28], but few studies have directly compared the prevalence of DCD in two or more populations from different countries.

Tsiotra et al. found that Greek children demonstrate higher DCD prevalence rates when compared to Canadian children despite both samples coming from Western countries, suggesting a direct influence of differences in lifestyle on the prevalence of DCD[6]. More recently, Valentini et al. reported that Brazilian children were twice more likely to show probable DCD than American children[10]. In both studies, the prevalence of DCD was established with objective motor coordination evaluation (the Bruininks–Oseretsky Test of Motor Proficiency and the MACB-2, respectively). It should be noted that children were classified as having DCD using original cutoffs and not country-adjusted cutoffs, which could partially explain these outcomes. These studies demonstrate that cultural background associate with DCD rates across regions.

Overall, there seems to be a significant difference in both motor performance and prevalence of DCD between children from Southern and Northern regions, both in America and within Europe. However, no studies exist that further explore the influence of sex (individual constraint) on learning, participation, and performance of motor-based ADL across countries (environmental constraint) and type of activity (task constraint). Further research regarding the interrelation of these factors is needed to understand how individual, environmental, and task constraints may associate with daily performance and participation in typically developing children. Therefore, the aims of this study are:

- To explore country differences between children from a Northern European country (The Netherlands) and a Southern European country (Spain) in learning, participation, and performance of motor-based ADL as evaluated by the DCDDaily-Q.
- To examine the relationship between sex and country and learning, participation and performance of ADL as evaluated by the DCDDaily-Q.
- To explore country differences in the prevalence of probable DCD between Dutch and Spanish children as operationalized by the DCDDaily-Q.

METHODS

Study Design, Participants and Procedure

We conducted a multicenter cross-sectional study in Spain and The Netherlands. This study was approved by the Autonomic Research Ethics Committee of Galicia, Spain (code 2018-606). The Dutch part of the study was approved by the Medical Ethics Committee of the University Medical Centre Groningen. All participants consented to take part in the study anonymously and confidentially.

The sample comprised two subgroups of 150 Spanish and 150 Dutch five-to-eight-year-old typically developing children matched by exact age and sex. This sample size was estimated in order to measure the effect of country on ADL performance (effect size d = 0.389, $\alpha = 0.05$, power $(1 - \beta) = 0.90$)[29,30]. Spanish children were randomly selected from a larger sample from ten randomly selected schools in four different regions in northwest, north, and central Spain between January and December 2019[30]. The Dutch group was randomly matched by age and sex from a previously recruited reference sample of Dutch children from different regions of the Netherlands[29]. Children were excluded beforehand if they had a parent-reported or clinically diagnosed neurodevelopmental disorder, such as DCD, Attention Deficit Hyperactivity Disorder, or Autism Spectrum Disorder. In both samples, parents anonymously completed the DCDDaily-Q within a week and then returned it to the researchers.

Outcome Measurements

The Dutch and Spanish versions of the DCDDaily-Q were used to assess ADL learning, participation, and performance. The DCDDaily-Q is a 23-item parent questionnaire that evaluates a broad range of ADL in children aged five-to-eight years old, including self-care, fine motor, and gross motor activities[29]. Parents are asked to state how frequently their child perform each activity (1 = regularly, 2 = sometimes, 3 = seldom, 4 = not yet/never, total score = 23 to 92), their proficiency while doing so (1 = good, 2 = medium, 3 = poor, total score = 23 to 69) and whether their child took longer to learn the activity than other children (0 = no, 1 = yes, total score = 0 to 23). Higher scores on participation and performance subscales reflect less participation and poorer motor performance, respectively, while total learning scores show how many ADL the child took longer to learn compared to their peers. The total ADL and subscales scores (i.e., self-care, fine motor, and gross motor ADL) are calculated for learning, participation and performance. Based on learning total and subscale scores, children can be classified as “typical learning” if they score 0 or “took longer to learn at least one

ADL" if they score ≥ 1. Additionally, the child can be identified as having probable DCD according to the total ADL performance score; the child can be identified as having probable DCD. An example of the items of the DCDDaily-Q is provided in Appendix Table A1. The DCDDaily-Q was originally developed and validated in Dutch children, showing excellent psychometric properties and capacity to discriminate children with DCD from typically developing children (Cronbach alpha = 0.85; sensitivity = 88%; specificity = 92%)[29].

This questionnaire has recently been cross-culturally adapted and validated in the Spanish population, and its three-dimensional structure, reliability, and validity have been confirmed (Cronbach alfa = 0.86) (to be published). Country-adjusted reference norms have also been developed for Spanish children aged 5 to 10 years old[30]. Based on the total ADL performance score, a child has probable DCD if they have a total score ≥ 95th percentile of their age group (Dutch criteria = age 5 ≥ 43; age 6 ≥ 40; ages 7 and 8 ≥ 37; Spanish criteria = ages 5 and 6 ≥ 45; ages 7 to 10 ≥ 39)[29,30].

Data Analysis

Analyses were performed using the IBM Statistical Package for Social Sciences Version 25 (SPSS Inc., Chicago, IL, USA). The sample size was estimated using G*Power version 3.1.9.4. (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany)[31]. Data were examined for normality using visual inspection and skewness and kurtosis[32]. Differences in participation and performance according to country and sex were assessed with independent t-tests and multivariate analyses. Differences in the prevalence of delayed learning of ADL were calculated using Chi-square tests.

First, differences were explored between Spanish and Dutch children and boys and girls independently. Further analyses were conducted to determine differences in learning, participation, and performance in Spanish and Dutch children according to sex. Next, linear regression models using a stepwise method

were performed to explore the interrelation between sex and country on those ADLs, which were independently and differently influenced by sex and country during bivariate analysis. Assumptions of normality, linearity, homoscedasticity, and absence of multicollinearity were tested.

Finally, differences in the prevalence of probable DCD between Spanish and Dutch children and boys and girls were calculated using chi square tests.

RESULTS

Sample characteristics are displayed in Appendix Table A2. The sample was balanced by age, sex and country (n = 300; 5 years old = 24.0%, 6 years old = 25.3%, 7 years old = 25.3%, 8 years old = 25.3%; boys in each age group = 50.0%; Spanish = 50.0%).

The Interrelation of Sex, Country, and Activity on motor Performance and Daily Participation

Differences in ADL Learning

Bivariate analysis showed that there were no significant differences in the time it took to learn self-care, fine motor, gross motor, or total ADL between Spanish and Dutch children as reported by parents (Table 1). Parents in the combined sample reported that boys took longer to learn self-care, fine motor and total ADL (Table 1).

Table 1. Learning, participation, and performance of ADL according to country and sex (n = 300).

DCDDaily-Q subscales	Spanish n = 150	Dutch n = 150	p Value	Boys n = 150	Girls n = 150	p Value
	N (%)	N (%)		N (%)	N (%)	
Delayed learning of ADL						
Self-care ADL	22 (14.7)	18 (12.0)	0.497	27 (18.0)	13 (8.7)	0.017
Fine motor ADL	17 (11.3)	14 (9.3)	0.569	23 (15.3)	8 (5.3)	0.004
Gross motor ADL	16 (10.7)	8 (5.3)	0.089	11 (7.3)	13 (8.7)	0.670
Total ADL	38 (25.3)	28 (18.7)	0.163	42 (28.0)	24 (16.0)	0.012

Note: ADL = activities of daily living; SD = standard deviation.

Table 1 (cont.). Learning, participation, and performance of ADL according to country and sex (n = 300).

DCDDaily-Q subscales	Spanish n = 150	Dutch n = 150	p Value	Boys n = 150	Girls n = 150	p Value
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Participation of ADL						
Self-care ADL	15.4 (3.8)	13.9 (3.2)	0.000	15.2 (3.8)	14.1 (3.3)	0.011
Fine motor ADL	9.4 (2.4)	9.7 (2.2)	0.433	9.9 (2.4)	9.2 (2.1)	0.006
Gross motor ADL	12.1 (2.9)	11.9 (2.9)	0.561	12.1 (2.8)	12.0 (2.9)	0.888
Total ADL	37.0 (7.4)	35.5 (6.2)	0.072	37.2 (6.8)	35.3 (6.8)	0.022
Performance of ADL						
Self-care ADL	13.9 (3.2)	12.9 (2.4)	0.004	13.8 (2.9)	13.0 (2.8)	0.017
Fine motor ADL	9.2 (2.3)	9.2 (2.1)	0.958	9.8 (2.3)	8.6 (1.9)	<0.001
Gross motor ADL	9.5 (2.5)	8.7 (2.3)	0.006	9.0 (2.3)	9.2 (2.6)	0.495
Total ADL	32.5 (6.7)	30.8 (5.5)	0.015	32.6 (6.0)	30.8 (6.2)	0.012

Note: ADL = activities of daily living; SD = standard deviation.

However, some differences in learning were found between countries, as parents reported that Dutch boys took overall longer to learn fine motor, and total ADL, but these differences were not reported by Spanish parents (Table 2). Finally, learning of ADL was similar between Spanish and Dutch children when analyzing boys and girls separately (Table 3).

Differences in ADL Participation

Parents of Dutch children reported more participation in self-care activities in their offspring than parents of Spanish children (Table 1). Boys in the overall sample were reported to participate less than girls in self-care, fine motor and total ADL. Further analysis across each country and sex groups showed that both Spanish and Dutch boys participated less than girls in fine motor ADL, but some differences were present (Table 2). Dutch boys participated less than Dutch girls in total ADL, but Spanish boys participated less than Spanish girls in self-care activities according to parents. When analyzing boys and girls separately, both Spanish boys and girls participated less in self-care ADL than Dutch boys and girls, although differences were higher and more significant in boys (Table 3).

Table 2. Differences in learning, participation and performance of ADL in boys and girls according to country (n = 300).

DCDDaily-Q subscales	Spanish subsample			Dutch subsample		
	Boys n = 75	Girls n = 75	p Value	Boys n = 75	Girls n = 75	p Value
	N (%)	N (%)		N (%)	N (%)	
Delayed learning of ADL						
Self-care ADL	15 (20.0)	7 (9.3)	0.065	12 (16.0)	6 (8.0)	0.132
Fine motor ADL	11 (14.7)	6 (8.0)	0.198	12 (16.0)	2 (2.7)	0.005
Gross motor ADL	7 (9.3)	9 (12.0)	0.597	4 (5.3)	4 (5.3)	1.000
Total ADL	22 (29.3)	16 (21.3)	0.260	20 (26.7)	8 (10.7)	0.012
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Participation of ADL						
Self-care ADL	16.1 (4.0)	14.7 (3.5)	0.021	14.3 (3.3)	13.6 (3.0)	0.197
Fine motor ADL	9.6 (2.4)	9.3 (2.3)	0.561	10.3 (2.3)	9.0 (1.8)	<0.001
Gross motor ADL	12.0 (3.0)	12.3 (2.8)	0.551	12.1 (2.7)	11.8 (3.1)	0.430
Total ADL	37.6 (7.6)	36.3 (7.2)	0.261	36.7 (6.0)	34.4 (6.3)	0.025
Performance of ADL						
Self-care ADL	14.4 (3.3)	13.3 (3.1)	0.027	13.1 (2.4)	12.7 (2.4)	0.278
Fine motor ADL	9.8 (2.4)	8.6 (1.9)	0.001	9.8 (2.2)	8.6 (1.9)	0.001
Gross motor ADL	9.3 (2.4)	9.7 (2.6)	0.398	8.7 (2.0)	8.7 (2.6)	0.917
Total ADL	33.5 (6.8)	31.5 (6.5)	0.065	31.6 (5.1)	30.1 (5.8)	0.086

Note: ADL = activities of daily living; SD = standard deviation.

Differences in ADL Performance

Finally, differences in performance according to country and sex were analyzed. Dutch children performed better than Spanish children in self-care, gross motor, and total ADL as reported by parents (Table 1). Parents in the overall sample reported that girls performed better than boys in self-care, fine motor and total ADL (Table 1). Both Spanish and Dutch boys performed worse than Spanish and Dutch girls in fine motor ADL, but Spanish boys also performed worse than Spanish girls in self-care activities, according to parents, while Dutch boys and girls performed equally in self-care activities (Table 2).

Table 3. Differences in learning, participation and performance of ADL in Spanish and Dutch children according to sex (n = 300).

DCDDaily-Q subscales	Boys			Girls		
	Spanish n = 75	Dutch n = 75	p Value	Spanish n = 75	Dutch n = 75	p Value
	N (%)	N (%)		N (%)	N (%)	
Delayed learning of ADL						
Self-care ADL	15 (20.0)	12 (16.0)	0.524	7 (9.3)	6 (8.0)	0.772
Fine motor ADL	11 (14.7)	12 (16.0)	0.821	6 (8.0)	2 (2.7)	0.146
Gross motor ADL	7 (9.3)	4 (5.3)	0.347	9 (12.0)	4 (5.3)	0.147
Total ADL	22 (29.3)	20 (26.7)	0.716	16 (21.3)	8 (10.7)	0.075
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
Participation of ADL						
Self-care ADL	16.1 (4.0)	14.3 (3.3)	0.003	14.7 (3.5)	13.6 (3.0)	0.045
Fine motor ADL	9.6 (2.4)	10.3 (2.3)	0.073	9.3 (2.3)	9.0 (1.8)	0.391
Gross motor ADL	12.0 (3.0)	12.1 (2.7)	0.773	12.3 (2.8)	11.8 (3.1)	0.280
Total ADL	37.6 (7.6)	36.7 (6.0)	0.385	36.3 (7.2)	34.4 (6.3)	0.090
Performance of ADL						
Self-care ADL	14.4 (3.3)	13.1 (2.4)	0.006	13.3 (3.1)	12.7 (2.4)	0.208
Fine motor ADL	9.8 (2.4)	9.8 (2.2)	0.917	8.6 (1.9)	8.6 (1.9)	0.966
Gross motor ADL	9.3 (2.4)	8.7 (2.0)	0.096	9.7 (2.6)	8.7 (2.6)	0.032
Total ADL	33.5 (6.8)	31.6 (5.1)	0.046	31.5 (6.5)	30.1 (5.8)	0.144

Note: ADL = activities of daily living; SD = standard deviation.

Differences in the performance of ADL between Spanish and Dutch subsamples emerged across sex as well (Table 3). Spanish boys performed worse than Dutch boys in self-care and total ADL as rated by parents. Although Spanish girls also participated less in self-care ADL, their performance in self-care ADL was similar to Dutch girls' performance. However, parents rated Spanish girls to perform significantly poorer than parents of Dutch girls in gross motor ADL, even though the gross motor performance was rated similarly for Spanish and Dutch boys.

Overall, discrepancies in findings for between sex, country, and type of activity were present for total ADL performance, self-care participation and self-care performance, and therefore, three linear regression models were conducted with these three factors as dependent variables, and sex and country as predictors (Table 4). The three models met the assumptions of normality, linearity,

homoscedasticity, and absence of multicollinearity. The analysis showed that both country and sex significantly predicted total ADL performance and self-care ADL participation and performance. However, the country showed a greater effect on participation in self-care ADL than sex.

Table 4. Linear regression models for total ADL performance, self-care ADL participation and self-care ADL performance (stepwise method) (n = 300).

Dependent variable: Total ADL performance				
Predictors	B	95% Confidence interval		*p* Value
		Lower limit	Upper limit	
Sex	1.773	0.396	3.150	0.012
Country	1.720	0.343	3.097	0.015
Dependent variable: Self-care ADL participation				
Predictors	B	95% Confidence interval		*p* Value
		Lower limit	Upper limit	
Sex	1.040	0.256	1.824	0.009
Country	1.440	0.656	2.224	< 0.001
Dependent variable: Self-care ADL performance				
Predictors	B	95% Confidence interval		*p* Value
		Lower limit	Upper limit	
Sex	0.793	0.154	1.433	0.015
Country	0.940	0.300	1.580	0.004

Note: ADL = activities of daily living; B = B coefficient value.

Prevalence of probable Developmental Coordination Disorder

Prevalence of probable DCD was statistically similar in Spanish and Dutch groups (Spanish = 8.0%, Dutch = 6.7%, p = 0.658). Prevalence of probable DCD was almost twice in boys compared to girls, but this difference was not significant (boys = 9.3%, girls = 5.3%, p = 0.184). This higher but non-significant difference between boys and girls was also present when analyzing across countries (prevalence in Spanish children: boys = 10.7%, girls = 5.3%, p = 0.229; prevalence in Dutch children: boys = 8.0%, girls = 5.3%, p = 0.513).

DISCUSSION

The main objective of this study was to explore sex and country differences in motor-based ADL learning, participation, and performance in five-to-eight-year-old, typically developing children from two countries of South and North Europe.

Preliminary bivariate analyses highlighted country and sex differences in self-care, fine motor, gross motor and total ADL learning, participation, and performance. Further analyses determined that differences in ADL learning, participation, and performance diverged across sex and countries, especially in relation to total ADL performance and self-care ADL participation and performance.

Results from this study contribute to explain disagreements found in previous research regarding motor competence and sex. The two main instruments used to assess motor proficiency and performance are the MABC-2 and the DCDQ, which involve balance/control during movement, fine, and gross motor activities[5,33,34]. While there seems to be an agreement regarding girls outperforming boys in fine motor activities, results concerning a sex gap in other areas or in general coordination are often inconclusive. Previous research has already argued that girls get fewer opportunities to practice gross motor activities, encouragement and reinforcement, while simultaneously participating more in drawing and cutting activities, resulting in different motor competence patterns[35]. Consequently, it is to be expected to find that, in general, children show more proficiency in those activities which they engage in and practice more frequently (i.e., fine motor and self-care activities for girls, and gross motor and dynamic activities for boys).

These findings also suggest a country's influence on differences in motor performance patterns across sex, especially in self-care activities. The sex gap in participation in self-care and household chores has been consistently and repeatedly reported in previous studies carried out in different countries,

socioeconomic, and cultural backgrounds[36-39]. Interestingly, in this study, the sex gap was only present in the Spanish group, as Dutch boys and girls showed similar participation and performance in self-care ADL.

This is consistent with previous studies showing different patterns across sex in participation in self-care and house chores between children from northern and southern Europe[36,37]. For instance, Giménez-Nadal et al. found that the sex gap in self and house care participation is greater in Spanish children in comparison with German children[37]. While these studies focused on children older than eight years, the present work suggests that a sex gap in ADL participation may be present before the age of eight and will likely persist as children grow older[36].

Our findings contribute to support a complex relationship between the influence of environmental, activity and sex factors on daily participation and performance, as country and sex had a similar effect over total ADL and self-care ADL motor performance, but country played a more relevant role in participation in self-care ADL. This situation has not been explored before but has relevant implications for the understanding of the underlying factors of both participation and performance in daily living in typically developing children. As those two aspects are correlated in both samples, it can be assumed that Spanish girls but not Dutch girls outperforming boys in self-care activities points to sex stereotyping related factors, as girls are encouraged to participate more in self-care activities, instead of actual sex differences in motor capacity. In conclusion, these outcomes link to the Dynamic System Theory and suggest an even further interrelationship between individual (i.e., sex), environmental (i.e., country and participation differences), and task (i.e., type of activity) constraints regarding motor performance.

Despite self-care activities being one of the main occupational areas of interest in childhood, they are rarely part of motor assessment tools, and consequently, relevant information is often lacking in studies regarding the daily impact of

DCD. Self-care and instrumental ADL are two of the area's that children with DCD and other neurodevelopmental conditions most struggle with[7,40-42]. Therefore, assessment protocols of motor coordination in daily living aimed to identify children at risk for DCD should systematically include self-care and instrumental ADL evaluation.

Regarding DCD prevalence, boys were twice as likely as having probable DCD than girls, but this difference was not significant. This was also observed when the country was considered, as both Spanish girls and Dutch girls showed a higher but not significantly different prevalence of probable DCD than boys. Overall, these findings are consistent with two recent studies in Spanish preschoolers and school-aged children that found similar rates of probable DCD using the DCDQ and the MABC-2[8,25]. Thus, the inclusion of self-care activities in the assessment of motor performance and risk for DCD makes for a more comprehensive evaluation without misrepresenting DCD prevalence in the population.

Although differences in probable DCD between Spanish and Dutch children were not significant, a higher prevalence of DCD in southern European children has been persistently reported[6,8,12,25,26,28,43-46]. It is to be expected to find higher prevalence in regions with lower performance scores on DCD assessment measures, but a higher percentage of children with probable DCD in southern European regions is present even in those countries with population-adjusted cutoff scores, like Italy or Spain[25,26]. It should be noted that the prevalence of DCD can be influenced by the instrument used to determine the diagnosis, as objective motor coordination assessment through motor tests may differ from parent evaluation. However, high probable DCD rates have been reported in south Europe regardless of the type of instrument used[8,25].

One country-related factor in explaining these findings could be the existing differences in physical activity rates between European regions, as low participation in physical activities has been previously associated with risk for

DCD and poor moto competence[6,8,47,48]. However, the results of studies investigating differences in participation in physical activity across European countries are inconclusive[47]. This situation adds to the evidence of motor behavior and coordination difficulties resulting from the dynamic interrelation of different factors, as individual and geographical constraints determine motor learning and practice opportunities.

Overall, this study has several implications for clinical practice and research. Health and rehabilitation practitioners, such as pediatric occupational therapists, can use these findings to further promote performance through participation in children with motor coordination issues, which is in compliance with the International Classification of Functioning, Disability, and Health[49]. These outcomes further support the Dynamic Systems Theory, which has relevant implications for research practice and can contribute to understanding the underlying mechanisms of motor performance both in typically developing children and in children with DCD.

Limitations and Future Research Directions

The current study is subject to certain limitations and recommendations for future research directions. This was a cross-sectional study, and therefore, causal relationships cannot be estimated. The Dutch subsample came from the DCDDaily-Q standardization study in The Netherlands, which could influence the prevalence of probable DCD in Dutch children. Efforts have been made to obtain a representative and balanced sample to try to avoid further biases and support the generalizability of the results (i.e., the sample comes from different geographical locations in each country, is age and country balanced, and there is an equal sex distribution across every age group and country). Additionally, findings obtained from parental questionnaires should be interpreted cautiously, as parents' perceptions are subjective. Nonetheless, parents can provide reliable and valuable information about their child's everyday performance, which is difficult to determine in a clinical evaluation[29]. Additional lifestyle- and play-

related variables were not collected, which may affect internal validity, and therefore further research should explore potential confounding effects. Finally, the diagnosis of definite DCD could not be determined as only one diagnostic criterion was assessed (i.e., criterion B = daily motor performance). In order to minimize the risk of false-positive classification, the 95th and not the 85th percentile cutoff score was used to determine probable DCD in the sample, as it is recommended when addressing the presence of DCD in population-based research studies[50,51].

CONCLUSIONS

This study indicates that daily participation and performance in typically developing children are associated with individual, task, and country constraints and that this relationship is dynamic and varies between contexts. This is the first study to explore the influence of the interrelation between sex, type of activity and geographical background on ADL learning, participation, and performance. These findings may have relevant implications for both the clinical field and research, especially in relation to the role of Dynamic Systems Theory in motor performance. The sex gap in learning, participation, and performance of motor-based daily activities seems to rely on geographical background and type of activity, showing an even more complex interrelation between individual, environmental, and task constraints. It is necessary to develop population-adjusted cutoff scores to prevent a cultural bias when addressing the diagnosis of DCD in different countries, regardless of the instrument of evaluation.

APPENDIX

Table A1. Illustrative item of the DCDDaily-Q.

Item 1. Activity: Buttering a sandwich	**Correct performance:** The right amount of butter is neatly and evenly spread, at a normal pace, without making a mess and without dangerous situations involving the knife	
Participation *My child does this…* 1. Regularly 2. Sometimes 3. Seldom 4. Not yet / never	**Performance** *My child can do this…* 1. Well 2. Sometimes well and sometimes not as well 3. Not very well (or badly) most of the time	**Learning** *My child…* 1. Is taking or has taken longer to learn this skill than his/her age peers

Table A2. Sociodemographic characteristics of the sample (n = 300).

	Spanish	**Dutch**
Sociodemographic characteristics	**N (%)**	**N (%)**
5 years old	36 (24.0)	36 (24.0)
Boys	18 (50.0)	18 (50.0)
Girls	18 (50.0)	18 (50.0)
6 years old	38 (25.3)	38 (25.3)
Boys	19 (50.0)	19 (50.0)
Girls	19 (50.0)	19 (50.0)
7 years old	38 (25.3)	38 (25.3)
Boys	19 (50.0)	19 (50.0)
Girls	19 (50.0)	19 (50.0)
8 years old	38 (25.3)	38 (25.3)
Boys	19 (50.0)	19 (50.0)
Girls	19 (50.0)	19 (50.0)
Total	150 (50.0)	150 (50.0)

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CHAPTER 5

THE MEDIATING ROLE OF MOTOR PERFORMANCE IN DAILY PARTICIPATION IN CHILDREN WITH AND WITHOUT PROBABLE DEVELOPMENTAL COORDINATION DISORDER

Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Hartman E, Schoemaker MM. Motor performance and daily participation in children with and without probable developmental coordination disorder. Dev Med Child Neurol. 2021;10.1111/dmcn.15036.

ABSTRACT

The aim of this study was to test the mediating role of motor performance in the relationship between individual and environmental constraints, delayed learning of activities of daily living (ADL) and daily participation in typically developing children (TD) and children with probable DCD (p-DCD). Parents of 370 randomly selected children aged 5 to 10 years disorder (194 females; mean age [SD] 7y 5mo [1y 10mo]) were included in the study (321 typically developing, 49 probable DCD). Motor performance, ADL learning, and participation were assessed using the DCDDaily-Questionnaire. Individual variables included child's age and sex, and environmental variables included family and mother educational level, presence of siblings, and area of residence. Direct, indirect, and mediating effects were tested using a partial least squares structural equation modelling approach. The model explained 44.5% of the variance of daily participation. Motor performance significantly mediated the effect of individual and environmental constraints and ADL learning on daily participation. These findings suggest that the effect of individual and environmental constraints and delayed learning of ADL on daily participation is mediated by motor performance in typically developing children and children with probable DCD. These findings provide further evidence that interventions to promote participation in children with probable DCD should adopt ecological, task-oriented approaches. Further studies should evaluate model generalizability with clinical samples.

INTRODUCTION

About 5% to 6% children of school-age present with developmental coordination disorder (DCD)[1], and as many as 12% to 25% of children are at risk of motor coordination issues[2-5]. In children with DCD, the execution of motor coordination skills is substantially below age-matched typically developing peers, which cannot be explained by any intellectual impairment, neurological, or developmental condition[1]. The deficits in motor skills are usually expressed in slower learning of motor skills and less accurate motor performance, and these difficulties are more significant in complex daily living activities[6]. So far, the etiology of DCD is unclear, but several hypotheses have been developed to contribute to the understanding of this disorder[1].

The activity deficit hypothesis[7] proposes that children with low motor proficiency usually avoid engaging in motor activities, which eventually widens the motor skill gap between these children and typically developing children as they grow older. Research shows that delayed learning of motor skills and motor-based activities of daily living (ADL) is associated with poorer execution[6,8], which in turn predicts reduced participation both in children with and without DCD[9].

Satisfactory participation is defined as active engagement in meaningful ADL[10]. Participation in daily contexts is considered a major component of health and well-being[11]. Therefore, the impact of DCD and poor motor skills transcends motor performance. Literature has widely reported that deficits in motor ability reduce participation in children with DCD[1,6]. Consequently, recommendations have been made to pay special attention to how motor performance difficulties impact daily participation in children with DCD[1,12]. According to the results of a systematic review, children with DCD participate less than typically developing children in self-care and self-maintenance ADL, social and motor-based leisure ADL, school-related ADL, and instrumental ADL[12].

During the last decade, new studies have explored participation in DCD, further supporting the influence of motor performance on daily participation[9,13,14], but evidence regarding which sociodemographic factors are associated with both motor performance and daily participation is scarce.

Newell's constraints model is a useful to investigate which factors account for motor performance deficits and reduced participation[1,15]. According to this model, both individual and environmental constraints impact motor performance. This is in line with the International Classification of Functioning, Disability, and Health for Children and Youth, which argues that children's ADL performance and participation in daily contexts are influenced by environmental and personal factors[11]. This theoretical framework is further supported by research showing that both motor performance and participation are influenced by individual (i.e. neurological factors, age, sex)[2,4,5,16] and environmental constraints (i.e. family-related factors, like family socioeconomic and educational level, having siblings, area of residence, and cultural background)[3,5,16,17-20]. Although previous research showed that individual and environmental constraints influence motor performance and participation, it is unknown whether these constraints have a direct influence on participation or whether motor performance plays a mediating role in this relationship, as suggested by the activity deficit hypothesis.

Therefore, the aims of this study are: (1) to explore a model to test the influence of environmental and individual constraints on motor performance and daily participation in children with and without probable DCD; (2) to examine the mediating role of motor performance on the relationship between individual and environmental constraints and daily participation; and (3) to examine the mediating role of motor performance on the relationship between ADL learning and daily participation.

The hypotheses of this study are as follows: (1) motor performance will have a significant influence on daily participation. (2) Environmental (a) and individual (b) constraints will have a significant influence on motor performance. (3) Environmental (a) and individual (b) constraints will have a significant influence on daily participation. (4) Motor performance mediates the relationship between environmental (a) and individual (b) constraints and daily participation. (5) Learning of daily activities will have a significant influence on motor performance. (6) Motor performance mediates the relationship between learning of daily activities and daily participation.

METHODS

Procedures and Participants

Children were eligible if they were aged 5 to 10 years, in mainstream education, and did not have a diagnosis of a neurodevelopmental disorder, learning disability, or medical condition affecting movement. Participants were parents of children from 15 randomly selected mainstream preprimary and primary schools from seven regions in Spain. Parents received a dossier containing the DCDDaily-Questionnaire (DCDDaily-Q), a sociodemographic ad hoc questionnaire, and an informative letter explaining the aims of the study through school intermediation. Only those parents who gave informed consent filled in the questionnaires at home. To keep the identity of the patients anonymous, we did not ask for additional written consent. This study received ethical clearance from the Autonomic Research Ethics Committee of Galicia (code 2018-606). The final sample comprised 370 children without a previous reported diagnosis of neurodevelopmental disorder (194 females; mean age [SD] 7y 5mo [1y 10mo], age range 5–10y). For a more detailed description of the sample size estimation and selection see Appendix S1 (online supporting information).

DCDDaily-Questionnaire (DCDDaily-Q)

Parents completed the Spanish version of the DCDDaily-Q, which explores 23 ADL in children aged 5 to 10 years. It includes motor performance (how well the child performs the activity), daily participation (the extent to which the child participates in the activity), and ADL learning (if the child took longer to learn the activity in comparison to their peers)[21,22]. Motor performance is rated from 1 to 3 (1=good performance, 2=medium performance, 3=poor performance), while participation is rated from 1 to 4 (1=the child does the activity regularly [every day], 2=the child does the activity sometimes [every now and then], 3=the child seldom or rarely does the activity, 4=the child never does the activity), meaning that higher scores show poorer performance and lower participation respectively. The total score of the learning subscale indicates the number of activities the child took longer to learn, ranging from 0 (the child did not take longer to learn any activity) to 23 (the child took longer to learn every activity). The 23 items are subdivided in self-care and self-maintenance activities (10 items), fine motor activities (seven items), and gross motor playing activities (six items).

The DCDDaily-Q has good discriminant capacity to identify children with DCD (sensitivity=88%; specificity=92%)[21]. A cross-cultural adaptation and validation study in Spanish children showed that this measure has good internal consistency (Cronbach's alpha=0.7–0.8) and good criterion validity with the DCD Questionnaire (r=0.406, $p<0.001$)[22,23]. Additionally, the structure of the factors proposed for the Dutch DCDDaily-Q (i.e., how items are organized within the questionnaire) was confirmed in Spanish children, providing further evidence of its construct validity (Satorra $\chi 2$ [227]=405.86, $p<0.05$; Satorra $\chi 2$/degrees of freedom=1.79; comparative fit index=0.940; non-normed fit index=0.933; root mean square error of approximation=0.054, 90% confidence interval=0.045–0.062)[21,22]. Reliability of the participation and learning scales in this sample was also good (Cronbach's alpha for participation=0.7–0.8; learning=0.7–0.8). Children were identified as having probable DCD according to the total score of

the DCDDaily-Q motor performance scale (total score >85th centile; criterion B of the DSM-5 DCD diagnosis)[1,23-25]. For a more detailed description of the identification of probable DCD see Appendix S2 (online supporting information).

Sociodemographic variables

Environmental and individual constraints of the children were measured using an ad hoc questionnaire. Variables regarding social and physical environment of the children included presence of siblings (only child/has siblings), education level of each parent (first or second level studies/university studies), family educational level (the highest level of one parent), type of school (public school/semi-private or private school), and area of residence (urban [>10 000 population]/semi-rural or rural [≤10 000 population]). Individual constraints evaluated were age group (ages 5–6y/7–10y) and sex (male/female).

Data analysis

Descriptive and bivariate analyses of the variables were calculated using SPSS v.24 (IBM Corp., Armonk, NY, USA). To test the hypotheses, two main statistics strategies were used. First, the independent two-sample *t*-test analyses were conducted to identify significant differences in motor performance and daily participation according to environmental and individual variables. Because of the sufficient sample sizes in all of the subgroups that were examined, *t*-tests relying on the central limit theorem were used. Differences in performance and participation between the probable DCD and typically developing group were also examined. Second, the environmental and individual variables that showed independent significant differences in at least one subarea of daily motor performance and participation were entered alongside the scores on the three subscales of the DCDDaily-Q (motor performance, daily participation, and ADL learning), into the hypothesized model of this study (Fig. 1). The model was tested with a partial least squares based structural equation modelling (PLS-SEM) approach using Smart PLS v3.2.9 (Ringle, Wende, and Becker, Bönningstedt, Germany).

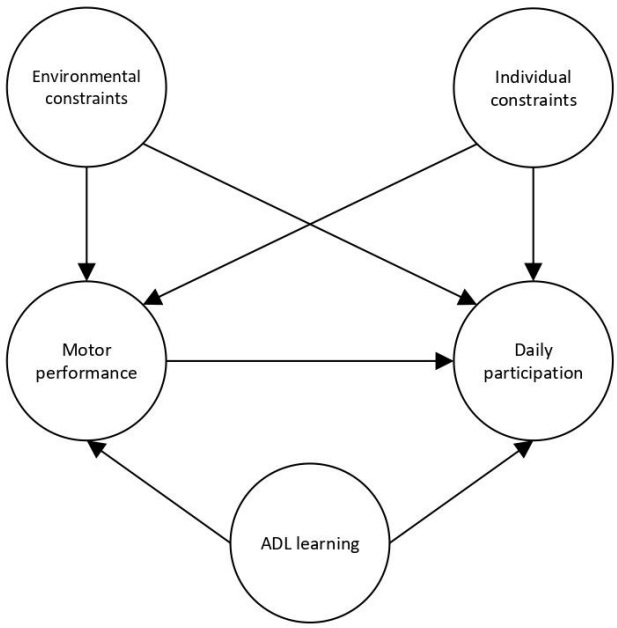

Figure 1. Conceptual framework of the mediating effects of motor performance on daily participation. ADL, activities of daily living.

The PLS-SEM analysis was conducted using a two-step procedure[26]. First, we explored the measurement model in order to analyse the relationships between the observable variables (i.e. indicators) and the underlying constructs (i.e. latent variables) and to ensure that the estimation was technically valid. Second, we explored the structural model to analyse the relationships among the latent variables and to test the hypotheses of the study. Finally, we examined the mediating effect of motor performance in the relationship between individual and environmental constraints, ADL learning, and daily participation using the guidelines of Zhao et al. as reported by Hair et al.[26]. For a detailed description of the PLS-SEM analysis see Appendix S3 (online supporting information).

RESULTS

Descriptive analysis

Individual and environmental variables of the participants are presented in Table 1 alongside the mean scores on the motor performance, daily participation, and ADL learning subscales for self-care, fine motor, and gross motor activities. A total of 49 children (13.2%) were identified as having probable DCD according to the total score on the motor performance scale of the DCDDaily-Q. Differences in performance and participation between both groups are shown in Table S1 (online supporting information; effect sizes=0.8–2.3).

Table 1. Individual and environmental constraints and means, standard deviations, and score range on the DCDDaily-Q subscales.

	N	%	M (SD)	Range
Individual constraints				
Age	370		7.4 (1.8)	5 – 10
5 – 6 years	137	37.0		
7 – 10 years	233	63.0		
Sex	369			
Boys	175	47.4		
Girls	194	52.6		
Environmental constraints				
Siblings	368			
Only child	110	29.9		
Has siblings	258	70.1		
Father education level	324			
First or second level studies	199	61.4		
University studies	125	38.6		
Mother education level	358			
First or second level studies	177	49.4		
University studies	181	50.6		
Family education level	369			
First or second level studies	154	41.7		
University studies	215	58.3		
Area of residence	370			
Urban (> 10 000 population)	296	80.0		
Semi-rural or rural (≤ 10 000 population)	74	20.0		

DCDDaily-Q=DCDDaily-Questionnaire; ADL=activities of daily living.

Table 1 (cont). Individual and environmental constraints and means, standard deviations and score range on the DCDDaily-Q subscales (n = 370).

	N	%	M (SD)	Range
Type of school	370			
Public school	197	53.2		
Semi-private or private school	173	46.8		
Daily performance, participation and learning				
Motor performance	370		31.3 (6.0)	23 – 57
Self-care	370		13.1 (2.8)	10 – 25
Fine motor	370		8.9 (2.1)	7 – 18
Gross motor	370		9.3 (2.4)	4 – 16
Daily participation	370		36.2 (6.8)	23 – 71
Self-care	370		14.6 (3.3)	10 – 35
Fine motor	370		9.3 (2.3)	7 – 18
Gross motor	370		12.3 (2.9)	6 – 21
ADL learning	370		0.6 (1.6)	0 – 17
Self-care	370		0.2 (0.7)	0 – 7
Fine motor	370		0.2 (0.7)	0 – 5
Gross motor	370		0.2 (0.7)	0 – 6

DCDDaily-Q=DCDDaily-Questionnaire; ADL=activities of daily living.

Differences in mean motor performance and daily participation scores between environmental and individual variables are shown in Tables S2 and S3 (online supporting information). The two individual variables (age group and sex) showed significant differences between mean scores of at least one subarea of motor performance and daily participation (p<0.05). Regarding environmental variables, mother and family education level, presence of siblings, and area of residence had significant differences between mean scores of at least one subarea of motor performance and daily participation (p<0.05), and therefore were included in the PLS-SEM model. Age, being female, having siblings, coming from families in which at least one parent had a university degree, and living in semi-rural or rural areas led to significantly lower mean scores (p<0.05) on at least one subarea of daily motor performance and participation (i.e. better performance and more participation).

PLS-SEM analysis

Assessment of the measurement model

The assessment of the measurement model indicated that the hypothesized model had good reliability and validity, as all indicators of reflective constructs and most indicators of formative constructs met the recommended criteria. See Appendix S4 and Table S4 (online supporting information) for a detailed description of the assessment of the measurement model.

Assessment of the structural model

Figure 2 shows the path coefficients and measures of the explained variance in the structural model including the standardized parameter estimates. Environmental constraints, individual constraints, and ADL learning together explained 31.4% of the variance in motor performance, while the overall model explained 44.5% of the variance in daily participation. The Q2 values for motor performance and daily participation were 0.203 and 0.262 respectively, indicating that the hypothesized model had a significant medium predictive capacity for daily participation.

Mediating effect of motor performance

Environmental constraints, individual constraints, and ADL learning had a significant direct effect on motor-based activities performance (p<0.01; Fig. 2). As shown in Table 2, environmental constraints, individual constraints, and ADL learning also had a significant indirect effect on daily participation through motor performance, but only environmental constraints had a significant direct effect on daily participation.

These findings indicate an indirect-only (full) mediation of motor performance on the effect of individual constraints and ADL learning over daily participation. Conversely, the effect of environmental constraints on daily participation was partially complementary mediated through motor performance (Table 2). Motor performance was the latent construct with the larger effect size on daily participation (f^2=0.498). Individual constraints had a large effect on motor performance (f^2=0.285), while ADL learning and environmental constraints had a small effect size on motor performance (f^2=0.028–0.138).

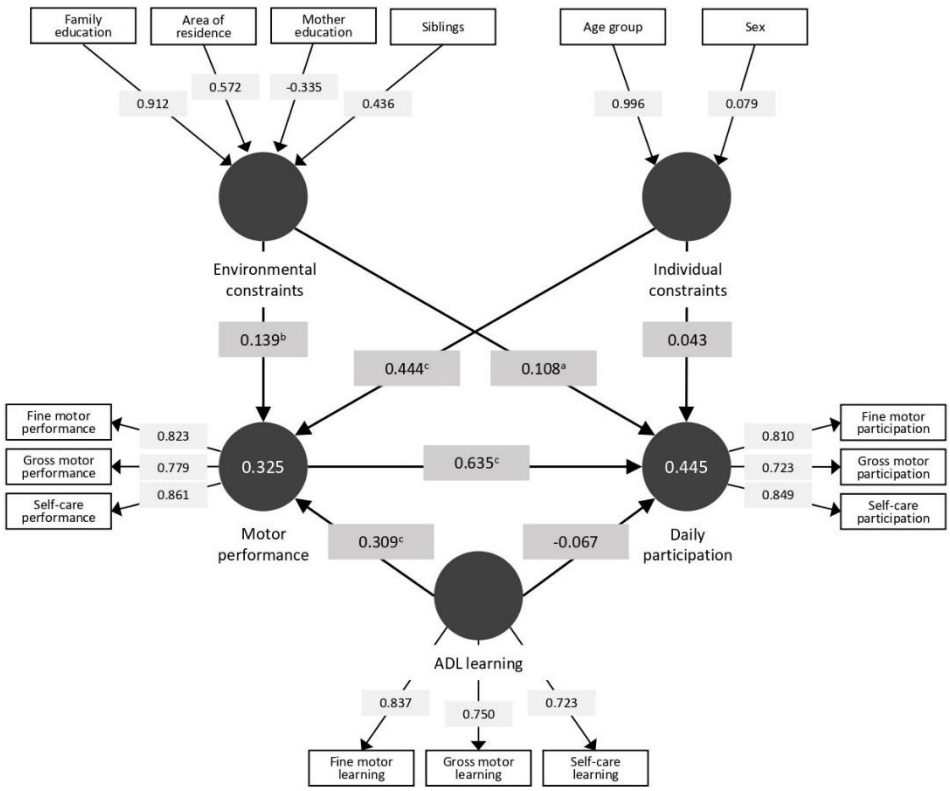

Figure 2. Path analysis of the mediating role of motor performance. In light grey (rectangles) standardized parameter estimates; in medium grey (rectangles) path coefficients; in dark grey (circles) explained variance. [a]=p<0.05; [b]=p<0.01; [c]=p<0.001.

Table 2. Hypotheses testing for direct and mediated relationships

Hypotheses	Path coeffs		*p*	f^2	Mediation type	Supported
(H1) MP → DP	Direct	0.635	< 0.001	0.498	-	Yes
(H2a) EC → MP	Direct	0.139	0.002	0.028	-	Yes
(H2b) IC → MP	Direct	0.444	< 0.001	0.285	-	Yes
(H3a) EC → DP	Direct	0.108	0.023	0.020		Yes
(H3b) IC → DP	Direct	0.043	0.351	0.003	-	No
(H4a) EC → MP → DP	Direct	0.108	0.023	0.020	Complementary (partial mediation)	Yes
	Indirect	0.088	0.003			
	Total	0.196	< 0.001			
(H4b) IC → MP → DP	Direct	0.043	0.351	0.003	Indirect-only (full mediation)	Yes
	Indirect	0.282	< 0.001			
	Total	0.325	< 0.001			
(H5) AL → MP	Direct	0.309	< 0.001	0.138	-	Yes
(H6) AL → MP → DP	Direct	-0.067	0.144	0.007	Indirect-only (full mediation)	Yes
	Indirect	0.196	< 0.001			
	Total	0.128	0.015			

Note. EC = environmental constraints; IC = individual constraints; MP = motor performance; AL = ADL learning; DP = daily participation.

DISCUSSION

The current study showed that environmental and individual constraints played a role in both motor performance and daily participation in typically developing children and children with probable DCD but without other neurodevelopmental disorders (such as attention-deficit/hyperactivity disorder or autism spectrum disorder). First, it was assessed whether motor performance and daily participation differed for several individual and environmental variables, including family and environmental factors. In line with findings from previous studies[2-5,16-20,27], older children were more proficient in motor activities and more frequently engaged in ADL, and males performed better and participated more frequently than females in gross motor activities, while females outperformed males in fine motor activities and participated more in self-care and overall activities[2,4,5,16,23,28]. In addition, children from families with higher education levels showed better motor skills and participated more in certain daily domains[3-5,16,17,27], and children living in rural settings tended to engage in a broader range of activities and did so more frequently than children living in urban areas[18]. Lastly, having siblings was associated with better motor skills and with more daily participation in some areas in both typically developing children and children with neurodevelopmental disorders[20,27].

Next, we investigated the mediating role of motor performance in the relationship between individual and environmental constraints and daily participation. Both individual and environmental constraints showed a significant direct effect on motor performance and a significant indirect effect on daily participation. The influence of environmental constraints on daily participation was partially complementary mediated by motor performance, indicating that some but not all the influence of environmental constraints on daily participation can be explained by motor performance. As stated in the literature, environmental constraints, and particularly family-related factors, are associated with daily participation in both typically developing children and children with disabilities[14,27,28]. Our findings

suggest that, though family-related environmental factors can directly affect participation in daily activities, this relationship may be even more significant if the child has motor coordination issues. Conversely, motor performance was found to fully mediate the relationship between age and sex and daily participation. This finding may suggest that some individual constraints, like age and sex, influence daily participation through motor performance.

Results from our model showed that delayed learning of ADL did not directly influence daily participation but had a full indirect effect through motor performance, meaning that motor performance accounts for all the effects that delayed learning may have on daily participation. Children with DCD do not have a learning deficit as such, as they are able to acquire and retain new motor skills[6]. However, when learning complex activities, children with DCD take longer, use less efficient strategies, and need more practice and tailored feedback[8,29], which gradually leads to less participation in motor-based activities, preventing these children from improving their motor skills[6]. Van der Linde et al.[9] explored the relationships between learning of ADL, performance, and participation in children with and without DCD. Similar to findings of the present study, the authors found that delays in motor learning predicted poor motor performance in children with DCD, which in turn predicted less daily participation in both groups[9]. It can be concluded that delayed motor learning may be partially responsible for the deficits in motor performance present in DCD and probable DCD, which will reduce the child's active and motivated involvement in motor-based activities, beginning a negative cycle that persists and widens during childhood[29,30].

Overall, this study suggests that motor performance plays a crucial role in the participation of children with and without probable DCD, as it significantly mediated the effect of individual and environmental constraints and delayed ADL learning on daily participation in ADL. Moreover, results support the influence of both individual and environmental constraints on performance and

participation of children. This is not only in line with the International Classification of Functioning, Disability and Health and Newell's model[11,15], but also with other theoretical frameworks such as the Person-Environment-Occupation and the Ecology of Human Performance models[31]. Therefore, this further emphasizes that motor coordination issues and daily participation should be assessed within the personal, family, and cultural context of the child.

Altogether, these findings have several implications for future research and clinical practice. Researchers can further explore this model by including environmental and individual constraints that were not assessed in the present study (i.e., findings from neuroimaging studies on brain structure and connectivity, or deficits in executive functioning). As for the clinical practice implications, clinicians can use our findings to design comprehensive assessment protocols that evaluate the variables that may influence both motor performance and daily participation in children with coordination difficulties. In addition, this research raises awareness for possible participation restrictions in children with and without probable DCD because of motor performance difficulties. Moreover, this model may provide further evidence for individually tailored interventions, and family-centred, activity-oriented approaches aimed to support participation in meaningful daily contexts in children with DCD[1].

Strengths and Limitations

The main strengths of the study are the large and representative sample of children, and the use of a mediating analysis to explore the relationships between the variables. However, only particular individual and environmental constraints were evaluated, which could explain the medium explanatory power and predictive capacity of the model. In addition, this study did not establish causality between variables. Moreover, it is possible that motor performance and daily participation share a bidirectional relationship, which could not be tested in the present study because of limitations of the statistical analysis. Finally, this study relied on parental information, so the findings should be interpreted with caution.

Although parents are able to provide accurate information regarding daily participation and motor performance of the child, future studies would benefit from using motor batteries to objectively measure motor performance. In addition, future research should individually assess all DSM-5 DCD diagnosis criteria. More studies are needed to test the construct validity of the DCDDaily-Q participation subscale.

WHAT THIS PAPER ADDS?

- Individual and environmental constraints influence motor performance and daily participation.
- Motor performance mediates the relationship between individual and environmental constraints, ADL learning, and daily participation.
- Individual and environmental constraints, ADL learning and motor performance help explain daily participation.

CONCLUSIONS

The present study showed that motor performance had a direct effect on daily participation, and that it mediated the influence of individual and environmental constraints and delayed learning of ADL in children with and without probable DCD. While both individual and environmental constraints and ADL learning had a direct effect on motor performance, only environmental variables retained a direct effect on daily participation as well. These findings suggest that motor performance plays a crucial role in the influence of individual and environmental variables on daily participation. Hence, individually tailored task-oriented interventions should be used to promote functioning in children with probable DCD.

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APPENDIX

Appendix S1. Detailed description of sample size estimation and selection.

Sample size estimation was made based on several criteria and requirements. First, we estimated a sample size large enough to estimate the prevalence of expected probable DCD in Spanish school-age children (i.e., ≈12.2%)[4] assuming a 99% confidence interval and a margin of sampling error <5%. For that, we used the formula proposed by Daniel[31] (n=z^2*P(1-P)/d^2). The resulting minimum sample size was 296. Thus, a sample size bigger than 296 would further improve the precision of the estimation. Second, we followed the recommendations of Hair et al.[25] who summarizes the guidelines proposed by several authors regarding sample size calculation in PLS-SEM analyses. According to these authors, the required sample size in this statistical technique should be determined by means of power analyses based on the part of the model with the largest number of predictors, which in this work was "daily participation" as it had four predictors (e.g., motor performance, ADL learning, environmental constraints and individual constraints). In accordance to these authors, a sample size of 41 participants is enough to achieve a statistical power of 80% for detecting R^2 values of at least 0.25 (i.e., 25% of variance of the dependent construct is explained by the model) with a 95% confidence interval, but larger samples sizes are recommended as they increase the precision (i.e., consistency) of PLS-SEM estimations.

Parents of all the children who were enrolled in the sixth (last grade) grade of pre-primary education, and in the first to sixth grades of primary education in the participating schools received a dossier and an informative letter explaining the aims of the study through school intermediation. The dossier included the Spanish version of the DCDDaily-Q (DCDDaily-Q-ES) and an ad-hoc questionnaire regarding sociodemographic variables. Only those parents who gave informed consent to the research and to publication of the results anonymously filled in the questionnaires at home and then sent them to the schools within a week, from where they were retrieved by the two first authors.

A total of 519 parents returned the questionnaires, of which 111 were discarded due to being younger than 5 years (n = 46) or older than 10 years (n = 65). Twenty-nine more children were excluded as they had a diagnosis of neurodevelopmental disorders, learning disabilities or developmental conditions affecting movement (not DCD) as reported by parents (Attention Deficit and Hyperactivity Disorder (ADHD), n = 14, Autism Spectrum Disorders (ASD), n = 6, co-occurring ADHD-ASD, n = 1, sensory processing disorder, n = 2, dyslexia, n = 2, cancer, n = 2, acquired brain injury, n = 1, other, n = 1). Of the 379 remaining children, nine were excluded due to too many missing data on the DCDDaily-Q. Therefore, the final valid sample (n = 370) met the two requirements of sample estimation for this study.

Appendix S2. Detailed description of the identification of probable Developmental Coordination Disorder.

Children were identified as having probable DCD (p-DCD) according to the total score of the DCDDaily-Q motor performance scale (criterion B of the DSM-5 DCD diagnosis)[3]. The age group-adjusted Spanish 85th percentile cut-off was used to determine the presence of p-DCD (total score > 85th)[23,24]. Criterion D (the motor skills deficits are not better explained by intellectual disability or by medical conditions affecting movement) was validated by only including those who were attending mainstream schools full time (i.e., without intellectual

disabilities) and excluding those children who had any known medical diagnosis of learning or intellectual disability, neurodevelopmental disorder or medical condition affecting movement as reported by parents. Criterion A (deficits in acquisition and execution of motor skills) and criterion C (onset of symptoms is in the early developmental period) were not specifically evaluated, and therefore children were classified as having p-DCD instead of a formal diagnosis of DCD.

Appendix S3. Detailed description of the PLS-SEM analysis.

Partial least squares equation modelling (PLS-SEM) is a statistical approach for complex multivariable relationships between observed and latent variables that can be used with unnormal or unknown distributed data and with both reflective and formative models. As PLS-SEM does not assume that the data is normally distributed, it uses bootstrapping, a nonparametric procedure, to test the statistical significance of path coefficients, R^2 values, and the rest of the assessment indicators.

Assessment of the measurement model

The path weighting scheme was run using a maximum of 300 iterations and a stop criterion of 1*10^-7 to test the measurement model[32]. Reflective measurement constructs (motor performance, daily participation and ADL learning), where causality flows from the latent construct to the indicator, were assessed by examining their reliability and validity. On the other hand, collinearity and weights' significance were evaluated for the formative measurement constructs (environmental constraints and individual constraints), where causality flows from the indicator to the construct[25].

Reliability of reflective constructs was first evaluated by checking that the outer loadings of their indicators were above 0.7 following Hair et al. criteria[25]. Cronbach's alpha, Dijkstra and Henseler's ρA and Jöreskog's composite reliability were used to assess internal consistency reliability, with values between 0.70 and 0.95 being considered as indicators of good internal

consistency[25]. While composite reliability is the preferred method for PLS-SEM, Cronbach's alpha and ρA can be used as a more conservative approach[25,33].

Convergent validity and discriminant validity of the reflective models were evaluated through Average Variance Extracted (AVE) and the heterotrait-monotrait (HTMT) ratio of the correlations, respectively[25,34]. The generally recommended AVE value is 0.50 or higher, which would indicate that the construct explains at least 50% of the variance of its indicators[25]. Regarding HTMT, the threshold value of 0.90 is the recommended criteria to consider that discriminant validity is adequate[34].

For formative measurement constructs (i.e., environmental constraints and individual constraints), collinearity and statistical significance of the indicators' weights must be evaluated. Collinearity was explored with the variance inflation factor (VIF), which indicates critical collinearity issues among the indicators of the formative construct at values ≥ 5[25]. Yet, multicollinearity can also occur at lower VIF values, which highly depends of the field of study, so ideally the VIF values should be close to 3. Indicators with VIF values between 3 and 5 need to be individually revised to decide whether to delete or to them. Finally, indicators with non-significant weights should be revised as well, especially if the loading is also not significant[25]. However, deletion of formative indicators is seldom recommended as it will reduce the measurement model's content validity, and therefore it is the researcher's decision to keep an indicator with non-significant weight and loading to preserve the construct's content validity[25,35].

As shown in Figure 1 (main text), environmental constraints (indicators: family education level (first or second level studies / university studies), mother education level (first or second level studies / university studies), living area (urban, <10,000 population / semi-rural or rural, ≤ 10,000 population) and presence of siblings (only child / has siblings)), individual constraints (indicators: age group (ages 5 or 6 / ages 7 to 10) and sex (boy / girl)) and ADL learning

(indicators: self-care learning score (0 to 10), fine motor learning score (0 to 7) and gross-motor learning score (0 to 6)) were entered as predictor latent variables of motor performance (indicators: self-care performance score (10 to 30), fine motor performance score (7 to 21) and gross motor performance score (6 to 18)) and daily participation scores (indicators: self-care participation score (10 to 40), fine motor participation score (7 to 28) and gross motor participation score (6 to 24)), that were entered as dependent latent variables. Motor performance was also entered as a predictor latent variable of daily participation, as well as a mediating variable for environmental and individual constraints and ADL learning over daily participation.

Assessment of the structural model

A total of 5,000 subsamples were used in the bootstrapping analysis. Assessment of the structural model included the model's explanatory power by using the coefficient of determination (R^2), the predictive accuracy of the model by calculating the Q^2 value, and the statistical significance and practical relevance of the path coefficients for the hypothesized relationships included in the model.

Significant R^2 values give the share of variance explained in a dependent construct by the model, with higher values indicating a greater explanatory power[25]. On the other hand, the Q^2 is used to examine the predictive relevance of accuracy of the hypothesized model[25]. Q^2 values > 0 indicate predictive accuracy of the structural model for the examined construct, with higher values indicating a higher predictive accuracy. Generally, Q^2 values > 0, > 0.25 and > 0.50 represent small, medium and large predictive relevance of the path model[25]. Finally, the path coefficient estimates for the hypothesized relationships were considered statistically significant when its p-value was below 0.05. The practical relevance of the significant effects was estimated by considering the effect sizes of the relationships between the latent constructs using the f^2 value[25]. The higher the f^2 value the greater the effect size, with values > 0.02, > 0.15 and ≥ 0.35 depicting small, medium or large effect sizes, respectively[36].

Mediating analysis

The mediating role of motor performance in the relationship between environmental constraints, individual constraints, ADL learning and daily participation was explored by examining the direct, indirect and total effects of the independent variables over daily participation through motor performance. The mediation effect was interpreted following the guidelines of Zhao et al.[25,37] who propose a classification of five types of potential mediation or non-mediation.

For mediation effects, they identify three types of possible mediation: complementary (partial) mediation, if indirect effect and direct effect both exist and point at the same direction; competitive (partial) mediation, if indirect effect and direct effect both exist and point in opposite directions; and indirect-only (full) mediation, if the indirect effect is significant but the direct effect is non-significant[25,37]. Conversely, they categorize two types of non-mediation: direct-only non-mediation, if direct effect exists, but no indirect effect; and no-effect non-mediation, if neither direct effect nor indirect effect exists[25,37].

Appendix S4. Results from the assessment of the measurement model.

The tested model had three reflective constructs (motor performance, daily participation and ADL learning) and two formative constructs (environmental constraints and individual constraints) (supplementary table S3). Outer loading values, Cronbach's alpha, ρA, composite reliability and AVE values met the recommended criteria for the reflective constructs. HTMT values were all below 0.9 (0.185 – 0.864). Regarding formative constructs, all indicators had VIF values below 5, with only mother education level and family education level showing a VIF slightly above 3, indicating that there were not any critical collinearity issues. Weights of mother educational level and sex were non-significant, but the decision was to keep both indicators to preserve the constructs' content validity. Overall, the results from the assessment of the measurement model indicated that the hypothesized model had good reliability and validity.

Table S2. Independent samples t-tests between environmental and child-related factors and daily participation

	Self-care participation Mean (SD)	T value	Fine motor participation Mean (SD)	T value	Gross motor participation Mean (SD)	T value	Total ADL participation Mean (SD)	T value
Total sample								
Age group		9.362***		3.431***		2.346*		6.589***
5 – 6 years	16.5 (3.7)		9.8 (2.5)		12.7 (2.7)		39.1 (7.2)	
7 – 10 years	13.5 (2.5)		9.0 (2.1)		12.0 (3.0)		34.5 (6.0)	
Sex		1.437		0.268		2.178*		0.142
Boys	14.9 (3.5)		9.3 (2.4)		11.9 (3.0)		36.1 (7.2)	
Girls	14.4 (3.1)		9.3 (2.1)		12.6 (2.8)		36.2 (6.4)	
Siblings		2.120*		0.672		2.672**		2.400*
Only child	15.2 (3.3)		9.4 (2.2)		12.9 (2.9)		37.5 (6.4)	
Has siblings	14.4 (3.3)		9.3 (2.3)		12.0 (2.9)		35.7 (6.9)	
Father education level [1]		0.445		2.744**		1.068		1.578
First or second level studies	14.8 (3.2)		9.6 (2.1)		12.4 (2.7)		36.8 (6.3)	
University studies	14.6 (3.6)		8.9 (2.5)		12.0 (3.2)		35.6 (7.7)	
Mother education level [2]		0.403		2.053*		0.960		1.293
First or second level studies	14.7 (3.4)		9.6 (2.3)		12.4 (3.0)		36.7 (6.7)	
University studies	14.5 (3.4)		9.1 (2.3)		12.1 (3.0)		35.7 (6.9)	
Family education level [3]		1.359		3.457***		1.583		2.497*
First or second level studies	14.9 (3.3)		9.8 (2.2)		12.5 (2.8)		37.3 (6.5)	
University studies	14.4 (3.3)		9.0 (2.3)		12.1 (3.0)		35.5 (6.9)	
Living area		1.935[a]		1.699		2.476*		2.579*
Urban (> 10,000 population)	14.8 (3.4)		9.4 (2.3)		12.5 (2.8)		36.7 (6.9)	
Semi-rural or rural (≤ 10,000 population)	14.0 (2.9)		8.9 (2.0)		11.5 (3.1)		34.4 (6.1)	
Type of school		1.089		0.761		1.192		1.297
Public school	14.5 (3.1)		9.2 (2.3)		12.1 (2.8)		35.8 (6.5)	
Semi-private or private school	14.8 (3.5)		9.4 (2.3)		12.5 (3.0)		36.7 (7.1)	

Note. [1]n=324; [2]n=358; [3]n=369; [a]p=0.054; *p<0.05; **p<0.01; ***p<0.001.

Table S3. Independent samples t-tests between environmental and child-related factors and motor performance.

	Self-care performance Mean (SD)	T value	Fine motor performance Mean (SD)	T value	Gross motor performance Mean (SD)	T value	Total ADL performance Mean (SD)	T value
Total sample								
Age group		9.120***		7.062***		6.026***		9.389***
5 – 6 years	14.7 (3.0)		9.3 (2.3)		10.3 (2.4)		34.8 (6.2)	
7 – 10 years	12.2 (2.1)		8.3 (1.8)		8.8 (2.3)		29.3 (4.9)	
Sex		1.197		3.079**		1.892		0.856
Boys	13.3 (2.8)		9.2 (2.3)		9.1 (2.4)		31.6 (6.2)	
Girls	12.9 (2.7)		8.5 (1.9)		9.6 (2.5)		31.1 (5.9)	
Siblings		1.311		0.227		2.356*		1.631
Only child	13.4 (2.8)		8.9 (2.1)		9.8 (2.6)		32.1 (6.1)	
Has siblings	13.0 (2.8)		8.8 (2.1)		9.1 (2.3)		31.0 (6.0)	
Father education level [1]		0.318		1.239		0.070		0.606
First or second level studies	13.2 (2.7)		9.0 (2.1)		9.3 (2.5)		31.6 (6.1)	
University studies	13.1 (2.9)		8.7 (2.2)		9.3 (2.5)		31.1 (6.4)	
Mother education level [2]		1.640		2.563*		2.176*		2.548*
First or second level studies	13.3 (2.8)		9.1 (2.3)		9.6 (2.5)		32.1 (6.2)	
University studies	12.9 (2.7)		8.6 (1.9)		9.1 (2.4)		30.5 (5.7)	
Family education level [3]		1.570		3.094**		2.558*		2.850**
First or second level studies	13.4 (2.8)		9.3 (2.3)		9.7 (2.5)		32.4 (6.2)	
University studies	12.9 (2.8)		8.6 (2.0)		9.1 (2.3)		30.6 (5.9)	
Living area		1.627		1.318		1.793		1.937[a]
Urban (> 10,000 population)	13.2 (2.8)		8.9 (2.1)		9.5 (2.5)		31.7 (6.0)	
Semi-rural or rural (≤ 10,000 population)	12.7 (2.7)		8.6 (2.1)		8.9 (2.5)		30.1 (6.1)	
Type of school		0.585		0.927		0.518		0.804
Public school	13.1 (2.6)		8.8 (2.2)		9.3 (2.4)		31.1 (6.0)	
Semi-private or private school	13.2 (2.9)		9.0 (2.1)		9.4 (2.5)		31.6 (6.2)	

Note. [1]n=324; [2]n=358; [3]n=369; [a]p=0.053; *p<0.05; **p<0.01; ***p<0.001.

Table S1. Differences in motor performance and daily participation between the p-DCD and TD groups.

	TD group M (SD)	p-DCD M (SD)	T value	Effect size
Motor performance	29.9 (4.6)	41.2 (5.1)	15.771***	2.3
Self-care performance	12.6 (2.2)	16.8 (3.2)	11.787***	1.5
Fine motor performance	8.4 (1.7)	11.8 (2.3)	11.956***	1.7
Gross motor performance	8.9 (2.1)	12.6 (2.0)	11.574***	1.8
Daily participation	35.2 (6.1)	43.1 (7.4)	8.271***	1.2
Self-care participation	14.2 (2.9)	17.7 (4.3)	7.411***	1.0
Fine motor participation	9.0 (2.1)	11.3 (2.6)	6.822***	1.0
Gross motor participation	12.0 (2.9)	14.1 (2.3)	4.995***	0.8

Notes: *** = $p < 0.001$; TD = typically developing children; p-DCD = probable Developmental Coordination Disorder; effect size according to Cohen's *d*.

Table S4. Assessment of the measurement model (reflective and formative constructs).

Construct	Indicator	LV	α	ρA	CR	AVE	VIF	WV
Motor performance			0.76	0.77	0.86	0.68		
	Self-care performance	0.861*					-	0.446*
	Fine motor performance	0.823*					-	0.396*
	Gross motor performance	0.779*					-	0.372*
Daily participation			0.72	0.74	0.84	0.63		
	Self-care participation	0.849*					-	0.506*
	Fine motor participation	0.810*					-	0.417*
	Gross motor participation	0.723*					-	0.322*
ADL learning			0.67	0.69	0.82	0.60		
	Self-care learning	0.723*					-	0.328*
	Fine motor learning	0.837*					-	0.530*
	Gross motor learning	0.750*					-	0.426*
Environmental constraints								
	Mother education level	0.479*	-	-	-	-	3.207	-0.335
	Family education level	0.689*	-	-	-	-	3.210	0.912*
	Presence of siblings	0.483*	-	-	-	-	1.014	0.436*
	Living area	0.562*	-	-	-	-	1.002	0.572*
Individual constraints								
	Age group	0.997*	-	-	-	-	1.000	0.996*
	Sex	0.085	-	-	-	-	1.000	0.079

Note. * = $p < 0.05$; LV = outer loading value; α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted; VIF = collinearity statistics (variable inflation factors); WV = outer weight value.

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CHAPTER 6
GENERAL DISCUSSION

BACKGROUND AND AIMS OF THE THESIS

Developmental Coordination Disorder (DCD) affects 5%-6% of school-aged children[1,2], while prevalence rates of general motor coordination difficulties or risk of DCD ranges from 12% to more than 20%[3-6], making it one of the most frequent neurodevelopmental conditions. DCD is a chronic disorder with significant consequences on daily functioning for children, adolescents and adults. Epidemiology of DCD is complex, and it is yet unclear how individual, environmental and activity factors interrelate with both performance and participation in motor-based daily activities in children with and without DCD.

Newell's constraints model offers an interesting theoretical framework to explore daily performance through individual, environmental and tasks constraints[7]. This approach is in line with other functioning models such as the World Health Organization's International Classification of Functioning (ICF)[8] and classic transactive Occupational Therapy models like the Person-Environment-Occupation and the Ecology of Human Performance models[9,10].

Therefore, the aims of this thesis were: (1) to examine the prevalence and related sociodemographic factors of DCD in Spanish school-aged children; (2) to identify how sensory processing patterns present in children with DCD in comparison to typically developing children and children with Attention Deficit and Hyperactivity Disorder (ADHD); and (3) to explore the role of individual, environmental and activity factors on performance and participation in motor-based daily activities in children with and without motor coordination difficulties.

SUMMARY OF THE MAIN FINDINGS

Chapter 2 showed that prevalence of probable DCD (p-DCD) in Spanish children was 12.2%. After the multivariate analyses, age, sex, family education level and out-of-school physical activity were associated with p-DCD and motor performance.

In *Chapter 3* it was found that children with p-DCD display higher rates of atypical sensory processing than typically developing peers. In addition, sensory processing were significant predictors of motor performance alongside with age, sex and family educational level. Children with p-DCD showed significant different sensory processing patterns in comparison to children with ADHD and children with co-occurrent symptoms.

Chapter 4 describes the differences in performance and participation of motor-based activities of daily living (ADL) between Spanish and Dutch children. The interaction of sex and country significantly predicted daily performance and participation, with a focus on self-care functioning.

In *Chapter 5*, the direct and indirect effect of individual, environmental and ADL learning related factors on motor performance and daily participation was studied. Findings show that motor performance plays a significant mediating role on daily participation in children with and without p-DCD.

GENERAL DISCUSSION

Epidemiology of Developmental Coordination Disorder in Spain

According to the findings of the four population-based studies compiled in this thesis, prevalence rates of p-DCD in Spain ranged from 8% to 13% of school-aged children without a previous existing neurodevelopmental condition or disability. Presence of p-DCD was more frequent across boys, preterm born children and those who came from families with lower educational level. Overall, more than one hundred Spanish children were identified as having p-DCD, but none of them had a clinical diagnosis of DCD according to parent reports.

The prevalence rates of p-DCD found in this thesis are similar to those reported by other authors in Europe, America, Asia and Africa[3-6,11-20]. Indication of DCD in European children ranges from 4.9% to 19%, with higher rates persistently reported for southern European countries such as Greece, Italy or Portugal (Figure 1).

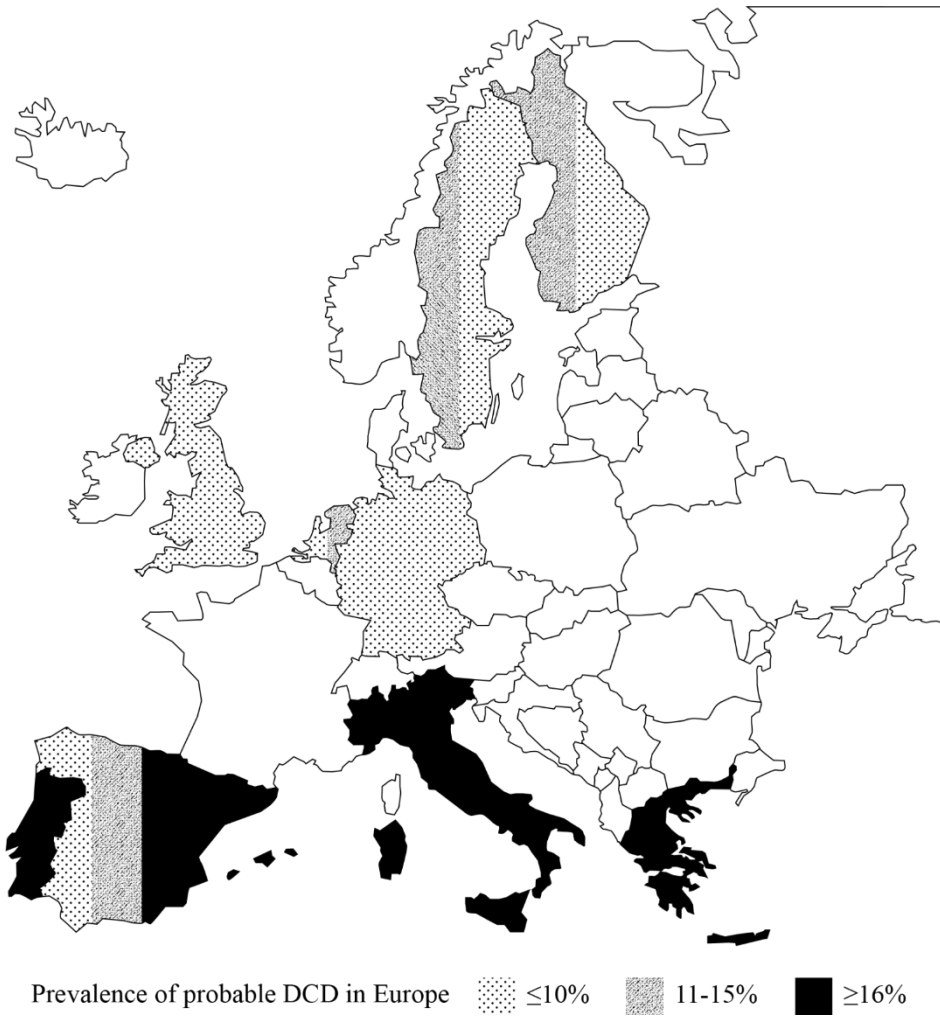

Figure 1. Prevalence of p-DCD or risk of DCD in Europe. Rates reported by Kadesjö & Gillberg[19], Tsiotra et al.[3], Lingam et al.[11], Kantomaa et al.[12], Seelaender et al.[13], Freitas et al.[14], Niemeijer et al.[15], Amador-Ruiz et al.[6], Bolk et al.[16], Caravale et al.[17], Delgado-Lobete et al.[21,22].

Interestingly, reported prevalence of p-DCD in Spain or Italy is higher than in northern countries even using population-adjusted cut-offs[6,17]. The prevalence rates of p-DCD in Spanish school-aged children reported in this thesis were similar when using either the DCDQ or the DCDDaily-Q. In the same line, the work conducted by Tsiotra et al.[3], Amador-Ruiz et al.[6], Freitas et al.[14] and Caravale et al.[17] suggests that Greek, Spanish, Portuguese and Italian children

report more frequency of p-DCD regardless of the use of objective motor tests or parent screening questionnaires. Interestingly, in *Chapter 4* it was shown that sex- and aged-matched Spanish and Dutch children displayed an statistically similar prevalence of pDCD using the same assessment tool and country-adjusted cut-off scores. Thus, findings from this thesis contribute to the understanding of how DCD and motor coordination difficulties present across Europe.

Overall, prevalence of p-DCD in Spanish school-aged children is high but similar to that reported in other southern European countries. Between two and three children in each Spain mainstream elementary classroom show motor coordination issues that significantly interfere with their daily performance. Given that only 1.09% of Spanish school-aged children with motor coordination deficits are identified in Paediatric Primary Care[23], our findings show that most children with DCD are likely going under-diagnosed in Spain.

Individual Factors Associated with Daily Performance

Age as an Individual Factor of Daily Performance

Older children reported better motor performance and were more frequently engaged in ADL, while simultaneously having a higher prevalence rate of p-DCD. This finding is in line with previous studies in America and Europe, which have found that middle-aged children display significant better motor competence and performance and increased participation[4,5,24-26]. For instance, Saraiva et al.[27] found that age was a main predictor of motor performance in Portuguese pre-school children. Motor competence improves as the child grows, and therefore the child's independent performance and participation in a broad range of ADL increases. Complementarily, motor deficits may become more evident and easily detected in older children as they have a greater impact on the child's everyday functioning, as the gap widens from typically developing peers.

Sex as an Individual Factor of Daily Performance

Sex was persistently associated with presence of p-DCD and with different outcomes regarding performance and participation of ADL, which is consistent with existing research[2,6,27]. Prevalence of p-DCD was significantly higher in boys using the DCDQ as reported in *Chapter 2*, and it was twice in boys compared to girls using the DCDDaily-Q as reported in *Chapter 4*, although the former outcome was non-significant, probably due to low statistical power of the sample size. Evidence on this regard is inconclusive, as DCD is usually more frequently identified in boys than in girls[2], while some authors like Lingam et al.[11] and Silva & Beltrame[28] have found a similar prevalence rate between these two groups. It is possible that cultural environment and assessment instrument for DCD can partially account for these different outcomes. For instance, boys have been repeatedly reported to score higher than girls in gross motor tasks, so motor assessment batteries that mainly focus on those skills may result in different prevalence rates than those instruments including a broader range of motor tasks.

On this regard, it must be noted that Spanish school-aged girls repeatedly showed better performance in fine motor performance than boys regardless of country or other individual and environmental factors. Similar findings were reported by Amador-Ruiz et al.[6], Navarro-Patón et al.[29] and Saraiva et al.[27] for Spanish and Portuguese pre-schoolers, and by Psotta et al.[30] and Valentini et al.[31] for British, Czech, North-American and Brazilian school-aged children. By contrast, we found that Spanish girls participated less in gross motor activities in comparison to Spanish boys. It has been argued that girls usually get fewer opportunities than boys to engage in gross motor activities, and they also receive less encouragement and reinforcement when doing so. On the contrary, they tend to participate more frequently in fine motor activities such as drawing, which results in different opportunities for motor learning and mastery[32].

Similarly, Spanish school-aged girls reported better performance and more frequent participation in self-care ADL than Spanish boys, while Dutch boys and girls showed similar levels of performance and participation in self-care ADL. Self-care activities are oriented toward taking care of one's own body and to support daily life within the home and community, such as bathing, dressing or meal preparation and home management[33]. These activities are extremely important for children's successful functioning, but the findings of Magalhães et al.[34], Van der Linde et al.[35] and Zwicker et al.[36] show these activities are highly compromised in children with DCD. In addition, findings from previous research suggest that girls are encouraged to take part in self-care and instrumental activities earlier and more frequently than boys regardless of country, socioeconomic and cultural backgrounds[37-40]. Thus, it may be possible that motor-related functional impairment on self-care ADL is more visible in boys than in girls with motor coordination issues.

Sensory Processing as an Individual Factor of Daily Performance

Previous research shows that children with DCD present with atypical sensory processing[41,42]. To our knowledge, the study described in *Chapter 3* is the first that evaluates differences in sensory processing patterns between typically developing children and children with p-DCD. In addition, we explored differences between children with p-DCD and children with p-ADHD. In this dissertation, children with p-DCD displayed atypical sensory processing in sensory sensitivity, avoiding and low registration. This is consistent with previous studies by Allen & Cassey[42] and by Elbasan et al.[43] which report deficits in sensorimotor processing of visual-spatial information, proprioceptive and tactile stimuli have been previously reported in children with DCD. Co-occurring sensory processing issues in children with DCD may be significantly contributing to their daily performance restrictions, as sensory processing difficulties have a negative impact on daily functioning in children with and without neurodevelopmental disorders[42,44-51].

In addition, low registration and sensory sensitivity were significantly correlated with overall motor performance, which may contribute to the internal modelling deficit in children with DCD[42,43,52]. Thus, findings of this thesis complement the results of previous studies which shows that sensory processing plays a relevant role in the display of DCD and in daily performance. Moreover, they provide new insight on sensory processing variability across DCD and ADHD, which adds to the evidence of these two neurodevelopmental disorders being two frequently overlapping but distinct conditions.

Environmental Factors Associated with Daily Performance

Motor performance and daily participation were associated to several sociocultural and family environmental factors. For instance, findings from *Chapter 4* indicate that Spanish children showed poorer performance in self-care, gross motor and overall motor-based ADL than Dutch children, and they also reported significantly less participation in self-care ADL. As it has been previously discussed in this thesis, there seems to be a trend for southern European and American children to score poorer on both motor tests and daily motor performance questionnaires[3,31,53], which may partially explain some of the unexpected higher rates of DCD in these regions. In addition, children living in semi-rural or rural areas reported increased participation in self-care, gross motor and overall motor-based ADL than children who lived in urban areas, which is consistent with the findings of Brown et al.[54]. Opportunities for motor learning and practice differ across country and living area even within the same region. For instance, Dutch children tend to learn how to ride a bike during early childhood, as cycling is the most frequent mode of commuting to school in The Netherlands. On the contrary, Spanish children rarely cycle to school[55]. Thus, Dutch children are exposed to significantly higher opportunities to practice this motor pattern than Spanish children, which also contribute to improve their motor performance. Overall, these findings further support the influence of cultural environment on motor performance and participation.

Family-related environmental factors associated to daily functioning included family educational level and presence of siblings. Children from highly educated families and those who had siblings showed better performance and higher participation in several motor-based activities. Previous research conducted in Brazil by Valentini et al.[5] and Barba et al.[25], in United Kingdom by Lingam et al.[11] and in Denmark by Faebo Larsen et al.[24] consistently shows that family educational level is associated with motor competence and daily participation, and thus it is possible that children coming from highly educated families are exposed to a richer environment to practice motor skills and to participate in a broader range of activities. Likewise, those children who have siblings may have more opportunities to engage in motor-related play activities[26,56]. Overall, both child's immediate and near socio-cultural environment seems to play a relevant role on motor-based functioning of children with and without p-DCD.

Activity Factors Associated with Daily Performance

Findings from this dissertation show that motor-based daily functioning may be influenced by some activity-related factors such as type of activity and ADL delayed learning. Thus, a considerable percentage of Spanish school-aged children (10.7% to 14.7%) reported delayed learning of self-care, fine motor and gross motor activities in comparison to other age-similar peers. This has relevant implications for both performance and participation in children with and without DCD or motor coordination issues, as delayed learning of daily activities has been reported to eventually predict poorer motor performance and reduced daily participation[35,57,58]. Furthermore, delayed learning of motor-based ADL may contribute to the motor skill gap in children with low motor proficiency as proposed by Wall's activity deficit hypothesis[59].

In addition, Spanish school-aged children showed more performance restrictions and reduced participation in gross motor activities in comparison to self-care or fine motor activities. It has been recurrently alerted that Spanish school-aged boys and girls engage in reduced sport and physical activities and they do not

usually meet physical activity recommendations for health[60-62]. Self-care, academic-related fine motor and play-related gross motor activities are relevant occupations for children's optimal development during early, middle and older childhood. It is important to promote satisfactory functioning in those areas through tailored, activity-oriented approaches, moreover in children with DCD and motor coordination difficulties who have been found to frequently struggle with these daily activities[2,34-36].

Interrelation of Factors

Once the independent relationships between individual, environmental, activity factors and motor-based daily functioning have been discussed, it is relevant to explore and discuss the different interrelationships among these variables.

One of the aims of this thesis was to expand on previous research on the influence of the interrelation of individual, environmental and activity-related factors on motor performance and daily participation, which have been assessed in the four studies compiled in this dissertation in an accumulative manner. Thus, in *Chapter 2* we found that age, sex and family educational (but not occupational) background altogether had an influence on daily motor performance in school-aged children. Based on those findings, in *Chapter 3* we examined how sensory processing interrelated with those individual and environmental variables to predict motor performance. Interestingly, even though all sensory quadrants (i.e., low registration, seeking, sensitivity and avoiding) were significantly correlated with motor coordination according to the bivariate analyses, only low registration and sensory sensitivity remained as predictors once age, sex and family education level were entered into the regression model. It was already expected that atypical sensory processing would be associated with daily motor performance, because children with DCD show sensory processing issues[2,41,42]. In addition, other authors like Nielsen et al.[63] and Román-Oyola et al.[64] have found that atypical sensory processing may be associated with age, sex and family socio-educational background.

Thus, our findings complement previous research and provide preliminary evidence for how sensory processing in childhood may interrelate with sociodemographic factors and daily performance in children with and without motor coordination difficulties. Although it cannot be established that these relationships reflect causation given the cross-sectional nature of the studies, it can be hypothesized that sensory processing has different impact on motor-based daily performance according to the child's socio-demographic background.

The interrelated influence of sex and country factors on daily performance and participation of children with and without p-DCD was comprehensively assessed in *Chapter 4*. Findings show that interaction of sex and country exists for overall daily performance, self-care performance and self-care participation. For instance, Spanish girls showed more proficiency and higher participation than in self-care activities than Spanish boys, but Dutch boys and girls reported similar participation in those activities while simultaneously showing significant differences in other areas, such as fine motor activities. Conversely, Spanish girls and Dutch girls showed similar outcomes of daily performance and participation except for performance in gross motor activities and participation of self-care ADL, while differences were higher for Spanish and Dutch boys. In addition, effect of country and sex on performance and participation slightly differed regarding the type of daily activity evaluated. Previous literature has shown that the sex gap in daily functioning present across countries[37-39], although it may be wider in the Spanish context[38,40]. Overall, it can be hypothesized that differences in self-care, fine motor and gross motor performance and participation are due to sex stereotyping related factors, instead of actual sex differences in motor capacity to perform specific daily activities. Given that self-care and instrumental ADL are two key areas of daily functioning in children with and without DCD, this interaction may have country-specific implications for clinical manifestation of DCD in boys and girls.

A New Insight: Mediating Role of Motor Performance on Participation

To get a better understanding of whether motor performance interceded the influence of individual constraints, environmental constraints and ADL learning on daily participation in motor-based activities, a mediating study was conducted with both typically developing children and children with p-DCD. The findings described in *Chapter 5* revealed a complex relationship between these factors, where motor performance mediated the effect of individual variables (i.e., age and sex), environmental variables (i.e., living area, family and mother education level and presence of siblings) and ADL learning on daily participation. Overall, this model explained almost half the variance in daily participation of children, being motor performance the construct with the larger effect.

Based on previous studies, a significant direct effect of individual and environmental constraints on both motor performance and daily participation was expected, but only environmental constraints had a direct effect over both constructs. For example, children from families with high education level tend to display better motor skills and increased participation in ADL[5,11,24,26], and living area has been reported to influence activity preferences and participation of school-aged children[54]. In this thesis, age and sex showed a direct effect on motor performance but an indirect effect on daily participation through motor performance, which suggests that the later factor may play a key role regarding the influence of individual constraints. In addition, motor performance accounted for all the effect that ADL learning had over daily participation, which confirms and expand the interesting starting point found by Van der Linde et al.[35] in children with and without DCD. Available evidence indicates that children with DCD do not apparently display a deficit in motor learning as such, but they do show different patterns in this process in comparison to typically developing peers[57,58]. Overall, these findings provide new insight about the pivotal effect of motor performance in this complex model (Figure 2).

Thus, it is possible that influence of environmental constraints on participation becomes particularly relevant if the child has motor coordination issues, while motor performance simultaneously plays an even more decisive role on the influence of individual constraints and ADL learning on daily participation in motor-based activities.

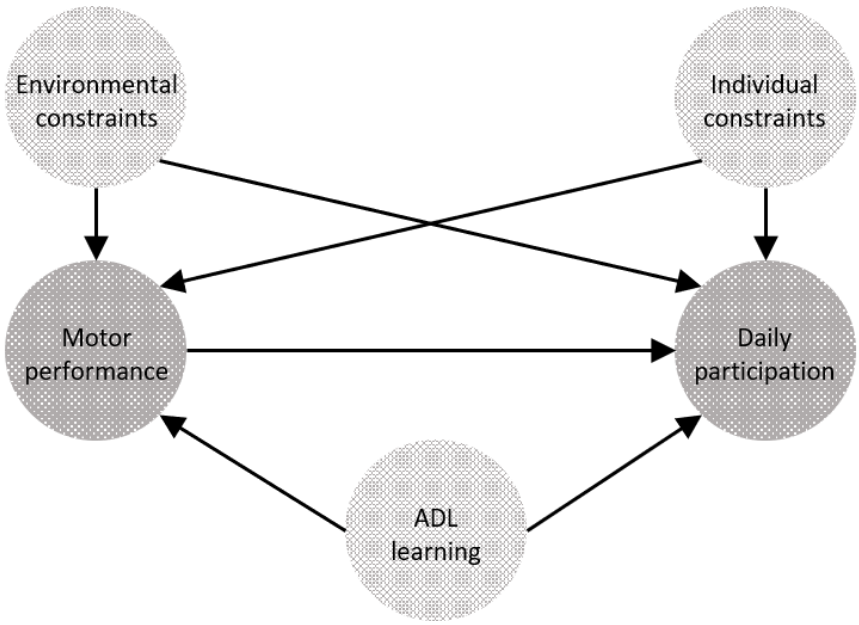

Figure 2. Conceptual framework of the mediating effects of motor performance on participation in motor-based daily activities.

The relationships found in this thesis between individual factors, environmental factors and activity performance and participation in children with and without motor coordination difficulties expand on existing framework like the ICF and Newell's constraints model[7,8], and other classic Occupational Therapy theoretical frameworks as well, such as the Person-Environment-Occupation and the Ecology of Human Performance models[9,10]. Consistently with these models, our findings suggest that motor performance may be a bridge between the person, the environment, and daily participation. It can be concluded that motor-based functioning needs to be comprehensively evaluated within the personal, family and cultural context of the child.

Practical Implications and Future Research Recommendations

The present dissertation has several implications for health professionals working with children with DCD and children with motor-based functioning issues as well as for policy-makers and researchers. First, health professionals involved in the diagnostic and therapeutic assessment of children with motor coordination issues will be aware that this population is a heterogeneous group in terms of individual and sociocultural background, and that they may display different clinical manifestation in self-care, academic fine motor and play-related motor activities. The multicausal nature of DCD further supports an Occupational Therapy intervention, which considers every aspect that influences the child's daily participation. Occupational therapists could take this variability into account to design precise, effective activity-oriented intervention approaches which specifically adjust the child's needs and their individual and family features.

Second, health-related policy-makers should consider implementing systematic screening strategies in Primary Care to identify children at risk of DCD, as it is highly probable that this population is being under-diagnosed in the Spanish context. Furthermore, mainstream elementary schools are the ideal settings for quickly identifying children at risk of DCD, as motor deficits are more likely to be detected when they have a significant impact on relevant daily functioning, such as academic performance. Therefore, it is recommended for regional and central government to include occupational therapists in the Spanish mainstream elementary education system to contribute to the diagnostic and therapeutic assessment of children with DCD in the Spanish context.

Third, findings of this thesis are an interesting starting point to explore daily participation in motor-based activities from a constraints model perspective, which can be expanded in future research by including additional individual, environmental and activity variables. To further understand how these constraints interrelate, longitudinal and neuroimage studies should be conducted with larger samples of clinical diagnosed children with DCD.

CONCLUSIONS

After studying the epidemiology of p-DCD in school-aged children and the interrelation of personal, environmental and activity-related factors on daily performance of children with and without motor coordination difficulties, the following conclusions can be drawn:

- Regarding the first aim of this thesis, it is concluded that prevalence of p-DCD in Spanish school-aged children is significant, but consistent with the prevalence rates previously reported in other European populations. In addition, presence of p-DCD in this population is not evenly distributed, but it is associated with age, sex and family educational level. This supports the need to developing specific strategies to identify and comprehensively assess DCD in those children at higher risk.

- Regarding the second aim of this thesis, it is concluded that children with p-DCD show higher prevalence of atypical sensory processing patterns, which significantly differ from typically developing children and children with ADHD. Moreover, sensory processing interrelates with individual and environmental factors to predict motor performance in both typically developing children and children with p-DCD.

- Regarding the third aim of this thesis, it is concluded that individual, environmental and activity-related factors have a direct effect on motor performance in children with and without p-DCD, and an indirect effect on daily participation through motor performance. This highlights the potential mediating role of motor performance on the influence of personal and environmental variables over participation, supporting the current recommendations regarding the use of activity-oriented approaches to promote functioning in school-aged children with motor coordination difficulties.

Overall, it is concluded that DCD is present in Spanish school-aged children more frequently than currently reported, and there are specific sociodemographic groups more likely to display motor coordination issues. There is a complex relationship between individual factors, sociocultural factors, activity-related factors and motor-based functioning in both typically developing children and in children with p-DCD, in which motor performance plays a decisive role. The model proposed in this dissertation complements and expands the understanding of the dynamic interaction between person, environment and occupation-related factors, especially in those motor-based activities that are relevant for both typically developing and p-DCD children's performance.

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RESUMEN EXTENDIDO EN CASTELLANO

ANTECEDENTES Y OBJETIVOS DE ESTA TESIS

El Trastorno del Desarrollo de la Coordinación (TDC) es uno de los trastornos del neurodesarrollo más frecuentes, afectando al 5%-6% de los escolares[1,2], aunque la prevalencia de dificultades generales de la coordinación o riesgo de TDC llega a alcanzar el 12% y 20% de esta población[3-6]. El TDC es una condición crónica con consecuencias significativas en el funcionamiento diario de la población escolar, adolescente y adulta. La epidemiología del TDC es compleja, y no hay consenso en cuanto a la interrelación de los factores individuales, del entorno y de la actividad y su influencia en el desempeño y participación en actividades motoras de la vida diaria en escolares con y sin TDC.

El modelo de constricciones de Newell[7], propuesto inicialmente para explicar el desarrollo motor a través de la interacción entre constricciones individuales, del entorno y la tarea, ofrece un marco teórico interesante para explorar el desempeño diario. Este planteamiento es consistente con otros modelos de funcionamiento, incluyendo la Clasificación Internacional del Funcionamiento (CIF) de la Organización Mundial de la Salud[8] y otros modelos clásicos transactivos de Terapia Ocupacional, como el modelo Persona-Entorno-Ocupación de Law et al.[9] y el modelo de Ecología del Desempeño Humano desarrollado por Dunn et al[10].

Por tanto, los objetivos de esta tesis fueron: (1) examinar la prevalencia de TDC y los factores sociodemográficos asociados en escolares españoles; (2) identificar los patrones de procesamiento sensorial presentes en TDC en comparación con el desempeño típico y el Trastorno por Déficit de Atención e Hiperactividad (TDAH); y (3) explorar el papel de los factores individuales, del entorno y de la actividad en el desempeño y participación en actividades motoras de la vida diaria en población escolar con y sin dificultades de coordinación motriz.

SÍNTESIS DE RESULTADOS PRINCIPALES

El estudio descrito en el *Capítulo 2* reveló una prevalencia de probable TDC (p-TDC) en escolares españoles del 12,2%. Tras los análisis multivariantes de regresión, la presencia de p-TDC y el desempeño diario se asociaron con la edad, el sexo, el nivel educativo familiar y la participación en actividades físicas extracurriculares de los escolares.

Los hallazgos del *Capítulo 3* mostraron que los escolares con p-TDC presentan mayor prevalencia de procesamiento sensorial atípico que sus compañeros con desarrollo típico. Además, el procesamiento sensorial, la edad, el sexo y el nivel educativo familiar predijeron significativamente el desempeño motor. Las niñas y los niños con p-TDC mostraron patrones de procesamiento sensorial diferentes que aquellos con síntomas de TDAH o con síntomas concurrentes.

El estudio del *Capítulo 4* describe las diferencias en el desempeño y la participación de actividades motoras de la vida diaria (AVD) entre niñas y niños españoles y holandeses. La interacción del sexo y país de los escolares predijeron significativamente el desempeño y participación diarios, especialmente en cuanto al funcionamiento relacionado con el autocuidado.

Finalmente, en el *Capítulo 5* se exploraron los efectos directos e indirectos de los factores individuales, del entorno y de adquisición de AVD. Los hallazgos ponen de manifiesto el papel mediador del desempeño motor sobre la participación diaria de escolares con y sin p-TDC.

DISCUSIÓN GENERAL

Epidemiología del Trastorno del Desarrollo de la Coordinación

Basándose en los hallazgos de los cuatro estudios compilados en esta tesis, la prevalencia de p-TDC se sitúa entre el 8% y el 13% de los escolares españoles sin diagnóstico previo de trastorno del neurodesarrollo o discapacidad.

La presencia de p-TDC fue más frecuente en niños varones, prematuros y aquellos provenientes de familias con bajo nivel educativo. Sin embargo, cabe destacar que ninguno de los más de cien escolares que fueron identificados con p-TDC tenían un diagnóstico clínico de TDC según lo reportado por los padres.

Las cifras de prevalencia de p-TDC encontradas en esta tesis son similares a las reportadas por otros autores en Europa, América, Asia y África[3-6,11-20]. Concretamente, la indicación de TDC en escolares europeos varía entre 4,9% y 19%, siendo persistentemente má elevada en países del sur de Europa como Grecia, Italia o Portugal (Figura 1).

Es interesante resaltar que la prevalencia de p-TDC reportada en España o Italia es mayor que en otros países del norte de Europa, incluso en aquellos casos en los que se han empleado puntos de corte ajustados a la población de estudio[6,17]. Las cifras de p-TDC en escolares españoles encontradas en esta tesis fueron similares utilizando los cuestionarios DCDQ y DCDDaily-Q. En la misma línea, las investigaciones realizadas por Tsiotra et al.[3], Amador-Ruiz et al.[6], Freitas et al.[14] y Caravale et al.[17] sugieren que la prevalencia de p-TDC en niñas y niños griegos, españoles, portugueses e italianos son mayores independientemente del uso de baterías objetivas de competencia motora o de cuestionarios de desempeño dirigidos a padres. Asimismo, en el tercer estudio de la tesis se observó que la presencia de p-TDC en escolares españoles y holandeses pareados por sexo y edad, era estadísticamente similar al emplear la misma herramienta con los puntos de corte ajustados a cada población. De esta forma, los hallazgos de esta tesis contribuyen a entender cómo el TDC y las dificultades de coordinación motora en la infancia se distribuyen en nuestro entorno.

Figura 1. Prevalencia de p-TDC o riesgo de TDC en Europa. Cifras reportadas por Kadesjö & Gillberg[19], Tsiotra et al.[3], Lingam et al.[11], Kantomaa et al.[12], Seelaender et al.[13], Freitas et al.[14], Niemeijer et al.[15], Amador-Ruiz et al.[6], Bolk et al.[16], Caravale et al.[17], Delgado-Lobete et al.[21,22].

En conjunto, la prevalencia de p-TDC en escolares españoles es elevada pero similar a la reportada en otros países del sur de Europa. Entre dos y tres estudiantes en cada clase española de Educación Primaria muestran dificultades motoras que interfieren significativamente con el desempeño diario.

Considerando que tan solo el 1,09% de los españoles en edad escolar con dificultades de coordinación motriz son diagnosticados en los servicios de Atención Primaria[23], estos hallazgos ponen de manifiesto que la mayor parte de niñas y niños con TDC no están siendo diagnosticados en nuestro país.

Factores individuales asociados al desempeño diario

La edad como factor individual del desempeño diario

Los escolares en los grupos de mayor edad reportaron un mejor desempeño motor y una participación más frecuente en las AVD, aunque también mostraron mayor prevalencia de p-TDC. Esto coincide con lo encontrado en estudios previos realizados en América y Europa sobre competencia mejora y aumento de la participación diaria en niñez media y tardía[4,5,24-26]. Por ejemplo, Saraiva et al.[27] encontraron que la edad era un predictor principal de la competencia motora en preescolares portugueses. El desempeño motor mejora a medida que los niños crecen, y por lo tanto aumenta su participación independiente y autónoma en un mayor rango de ocupaciones. Al mismo tiempo, los déficits en las habilidades motoras pueden resultar más evidentes y fácilmente detectables en aquellos escolares más mayores ya que pueden ocasionar un mayor impacto en el funcionamiento diario de los mismos, especialmente en casos de p-TDC.

El sexo como factor individual del desempeño diario

Acorde a la evidencia actual[2,6,27], el sexo se asoció repetidamente con la presencia de p-TDC y con diferentes consecuencias en el desempeño y participación en AVD. Como se señala en el primer estudio de esta compilación, la prevalencia de p-TDC fue significativamente mayor en niños varones según el DCDQ, y tal y como se describe en el tercer estudio, fue del doble respecto a la encontrada en niñas según el DCDDaily-Q, aunque esta última diferencia fue no significativa, probablemente por limitaciones relacionadas con la potencia estadística del tamaño muestral. Las conclusiones de la literatura a este respecto no son concluyentes dado que, generalmente, el TDC se diagnostica con mayor frecuencia en varones que en niñas[2], aunque algunos autores como Lingam et

al.[11] y Silva & Beltrame[28] han encontrado cifras similares entre ambos grupos. Es posible que el entorno cultural y el instrumento de evaluación del TDC puedan explicar en parte las diferencias reportadas en la literatura. Por ejemplo, los niños varones suelen obtener puntuaciones mejores en tareas motoras gruesas, por lo que aquellas baterías de competencia motora compuestas principalmente por este tipo de pruebas pueden arrojar diferentes conclusiones sobre la presencia de p-TDC en comparación con aquellos instrumentos que incluyan un rango más amplio de actividades motoras.

En este sentido, cabe señalar que las niñas en edad escolar han reportado un mejor desempeño en actividades motoras finas independientemente del país y de otros factores individuales y del entorno. Resultados similares han sido previamente reportados por Amador-Ruiz et al.[6], Navarro-Patón et al.[29] y Saraiva et al.[27] en preescolares españoles y portugueses, y por Psotta et al.[30] y Valentini et al.[31] en escolares británicos, checos, estadounidenses y brasileños. En cambio, nuestros estudios indican que las escolares españolas participan con menor frecuencia en actividades motoras gruesas en comparación con sus compañeros varones. Otros autores han alertado que las niñas frecuentemente reciben menos oportunidades, estímulos y refuerzos que los niños para participar en actividades motoras gruesas. Por el contrario, las niñas son alentadas a participar más en actividades motoras finas como el dibujo, lo que resulta en diferentes oportunidades de aprendizaje y dominio motor en función del sexo[32].

Igualmente, las niñas españolas mostraron mejor desempeño y más grado de participación en actividades diarias de autocuidado que los niños españoles, aunque esta diferencia no se encontró en la población holandesa examinada en el tercer estudio de la tesis. Estas ocupaciones se dirigen al cuidado del propio cuerpo y al apoyo de la vida diaria en el hogar y la comunidad, e incluyen actividades como la higiene, el vestido o la preparación de comidas y manejo del hogar[33]. Estas actividades tienen una importancia crucial para el funcionamiento satisfactorio de los escolares, pero los estudios de Magalhães et al.[34], Van der

Linde et al.[35] y Zwicker et al[36] demuestran que están significativamente afectadas en población con TDC. Asimismo, los hallazgos de investigaciones previas sugieren que a las niñas se les anima y refuerza a participar en las actividades de autocuidado e instrumentales antes y con mayor frecuencia que a los varones independientemente del país y del entorno socioeconómico y cultural[37-40]. Por tanto, es posible que los déficits motores en el funcionamiento de actividades básicas e instrumentales de la vida diaria sean más visibles en aquellos niños con dificultades del movimiento que en niñas con la misma condición.

El procesamiento sensorial como factor individual del desempeño diario

Estudios previos han mostrado que la población con TDC suele presentar procesamiento sensorial atípico[41,42]. Sin embargo, hasta donde se ha revisado, el segundo estudio de esta tesis es el primero en evaluar diferencias en los patrones de procesamiento sensorial entre p-TDC y desarrollo típico en edad escolar. Asimismo, hemos hallado diferencias entre escolares con p-TDC y con p-TDAH. Un considerable porcentaje de escolares con p-TDC mostró patrones atípicos de sensibilidad, evitación sensorial y de bajo registro, lo que coincide con lo reportado por Allen & Casey[42] y Elbasan et al.[43] con relación a la presencia de déficits en el procesamiento sensoriomotor de información visuoespacial, propioceptiva y táctil en esta población. Los problemas concurrentes de procesamiento sensorial en TDC pueden estar contribuyendo significativamente a sus restricciones en el desempeño diario, dado que estas dificultades tienen un impacto negativo en el funcionamiento de niñas y niños con desarrollo típico y con otros trastornos del neurodesarrollo[42,44-51].

Por otra parte, el bajo registro y la sensibilidad sensorial se correlacionaron significativamente con el desempeño motor general, lo que puede estar estrechamente relacionado con los déficits en los modelos internos de control motor presentes en el TDC[42,43,52]. De esta manera, los hallazgos de esta tesis complementan las conclusiones de estudios previos que sugieren que el procesamiento sensorial tiene un papel relevante en la etiología y desempeño

diario del TDC. Además, proporcionan nueva evidencia sobre la variabilidad en el procesamiento sensorial entre el TDC y el TDAH, lo que contribuye a entender la distinción entre estas dos condiciones tan prevalentes y que se presentan de manera frecuentemente concurrente durante la infancia.

Factores del entorno asociados al desempeño diario

El desempeño motor y la participación diaria se encontraron asociados a diferentes factores del entorno sociocultural y familiar. Así, los hallazgos del tercer estudio de la tesis indican que los escolares españoles muestran peor desempeño en actividades de autocuidado, de motricidad gruesa y de funcionamiento general que los escolares holandeses, y del mismo modo reportan menor grado de participación en las actividades de autocuidado. Tal y como se ha discutido previamente en esta tesis, parece existir una tendencia de peores puntuaciones en las baterías motoras y en los cuestionarios de desempeño diario entre la población escolar del sur de Europa y América[3,31,53], lo que puede explicar en parte las cifras inesperadamente altas de TDC en estas regiones. Por otra parte, aquellos escolares que residen en entornos rurales o semirrurales reportaron mayor participación en actividades motoras diarias de autocuidado, actividades motoras gruesas y de funcionamiento general que aquellos que residen en entorno urbano, lo que continúa la línea abierta por otros autores como Brown et al.[54]. Las oportunidades de aprendizaje y práctica motora difieren entre países y entorno de residencia, incluso dentro de una misma región. Por ejemplo, la población infantil holandesa aprende a montar en bicicleta desde edades muy tempranas, ya que es el principal modo de transporte en los Países Bajos. Por el contrario, los escolares españoles raramente se desplazan a la escuela en bicicleta[55]. Así, las niñas y niños holandeses disfrutan de más oportunidades para practicar este patrón motor que la población escolar española, lo que también puede tener consecuencias beneficiosas para su desempeño motor general.

Los factores del entorno familiar relevantes en el funcionamiento diario fueron el nivel educativo familiar y la presencia de hermanos. Aquellos escolares de familias con alto nivel educativo y aquellos que tenían al menos un hermano mostraron mejor desempeño y mayor participación en diferentes áreas ocupacionales. Basándonos en investigaciones previas que también han encontrado una asociación en la competencia motora, la participación diaria y el entorno educativo familiar, como las realizadas por Valentini et al.[5] y Barba et al.[25] en Brasil, por Lingam et al.[11] en Reino Unido y por Faebo Larsen et al. en Dinamarca[24], es posible resolver que los escolares que se crían en familias con alto nivel educativo están expuestos a un entorno más enriquecedor para practicar habilidades motoras y para participar en un abanico más amplio de actividades. En la misma línea, aquellos que tienen hermanos pueden disfrutar de más oportunidades para participar en actividades de juego motoras que los hijos únicos[26,56]. En suma, el entorno sociocultural inmediato y cercano parece tener un papel relevante en el funcionamiento motor de escolares con y sin p-TDC.

Factores de la actividad asociados al desempeño diario

Según los hallazgos de esta tesis, el funcionamiento motor diario puede estar influido por factores relacionados con la actividad, como el tipo de actividad o los retrasos en el aprendizaje de ciertas AVD. Un considerable porcentaje de escolares españoles, entre 10,7% y 14,7%, reportaron un retraso en la adquisición de actividades de autocuidado, motoras finas y motoras gruesas en comparación con otros compañeros de la misma edad. Esto tiene implicaciones notables tanto para el desempeño como para la participación de niñas y niños con y sin TDC o dificultades de coordinación motora, ya que el retraso en la adquisición de actividades motoras se ha relacionado previamente con posteriores limitaciones en el desempeño y restricciones en la participación[35,57,58]. De esta manera, el retraso en estas ocupaciones puede contribuir a la brecha en las habilidades motoras en aquellos escolares con baja competencia motora tal y como propone Wall en su planteamiento sobre la hipótesis de déficit de la actividad[59].

Adicionalmente, los escolares españoles mostraron más limitaciones en el desempeño motor y menor participación en actividades motoras gruesas que en actividades de autocuidado o de motricidad fina. Se ha alertado en numerosas ocasiones de la poca participación de las niñas y niños españoles en actividades físicas y deportivas, y de la falta de cumplimentación de las recomendaciones sanitarias sobre la cantidad de actividad física beneficiosa para la salud en población escolar en nuestro país[60-62]. Las actividades motoras de autocuidado, académicas motoras finas y de juego motor grueso son ocupaciones fundamentales para el desarrollo óptimo en la niñez temprana, media y tardía. Es importante promover un funcionamiento satisfactorio en estas áreas mediante estrategias individuales y orientadas a la actividad, con mayor énfasis cuando exista TDC o dificultades de coordinación motora, ya que se asocian con mayores problemas en estas ocupaciones[2,34-36].

Interrelación de factores

Una vez discutidas las relaciones independientes entre los diferentes factores y el funcionamiento en actividades motoras de la vida diaria, es relevante explorar, contrastar y discutir las diferentes interrelaciones entre estas variables.

Uno de los objetivos de esta tesis doctoral era expandir el estudio de la influencia de la interrelación de factores individuales, del entorno y de la actividad sobre el desempeño motor y la participación diaria, que ha sido examinado en los cuatro estudios compilados de forma acumulativa. Así, en el primer estudio se encontró que la edad, el sexo y el nivel educativo familiar, pero no el nivel ocupacional, tenían una influencia compuesta sobre el desempeño motor diario en los escolares. Continuando con estos hallazgos, en el segundo estudio se examinó cómo el procesamiento sensorial se interrelaciona con estas variables individuales y del entorno para predecir en conjunto el desempeño motor. Cabe destacar que, aunque todos los cuadrantes sensoriales (bajo registro, búsqueda, sensibilidad y evitación) se correlacionaban significativamente con la coordinación en los análisis bivariantes, sólo el bajo registro y la sensibilidad

sensorial se mantuvieron como predictores una vez que la edad, el sexo y el nivel educativo familiar se introdujeron en el modelo multivariante. Atendiendo a la literatura, era de esperar que el procesamiento sensorial atípico se asociara al desempeño motor, ya que el TDC se caracteriza por déficits en el procesamiento de los estímulos sensoriales[2,41,42]. Otros autores como Nielsen et al.[63] y Román-Oyola et al.[64] han encontrado que los trastornos del procesamiento sensorial pueden estar asociados a la edad, el sexo y el entorno socioeducativo familiar. Así, estos hallazgos complementan la investigación existente y aportan evidencia preliminar sobre cómo el procesamiento sensorial en la infancia puede interrelacionarse con los factores sociodemográficos y el desempeño diario en escolares con y sin dificultades de coordinación motora. Aunque no es posible establecer que estas relaciones sean causales debido a la naturaleza transversal de los estudios compilados en la tesis, se puede hipotetizar que el procesamiento sensorial tiene un impacto diferente en el funcionamiento motor diario dependiendo del perfil sociodemográfico de las niñas y los niños.

La influencia conjunta del sexo y el país sobre el desempeño y la participación de población escolar con y sin p-TDC fue examinada en profundidad en el tercer estudio de la tesis. Los hallazgos muestran una interacción entre estos dos factores sobre el desempeño diario, el desempeño en actividades de autocuidado y la participación de actividades de autocuidado. De esta manera, las niñas españolas mostraron mayor competencia y participación en actividades de autocuidado en comparación con los niños españoles, pero las niñas y niños holandeses reportaron un funcionamiento similar en estas actividades y, a su vez, diferencias significativas en otras áreas, como las actividades de motricidad fina. Por el contrario, las niñas españolas y holandesas mostraron efectos similares en el funcionamiento diario excepto en el desempeño motor grueso y la participación en actividades de autocuidado, mientras que las diferencias fueron mayores entre los niños varones españoles y holandeses. Estas discrepancias se suman a la discusión previamente argumentada en esta tesis, y coinciden con lo reportado en

la literatura, que muestra que la brecha de sexo en el funcionamiento diario durante la infancia se presenta en diferentes países y regiones[37-39], aunque puede que sea más grande en el contexto español[38,39]. En conjunto, es posible que las diferencias entre niñas y niños en el desempeño y participación en actividades de autocuidado, motoras finas y motoras gruesas se deban más a los estereotipos sexistas que a una diferencia real en la capacidad motora para ejecutar actividades diarias específicas en función del sexo. Dado que las actividades básicas e instrumentales de la vida diaria son dos ocupaciones clave para el desarrollo de escolares con y sin TDC, esta interacción puede conllevar implicaciones específicas para cada país con relación a las manifestaciones clínicas del TDC en niñas y niños.

Una nueva mirada: el rol mediador del desempeño motor en la participación

Para comprender mejor si el desempeño motor intercedía en la influencia de los factores individuales y del entorno y el aprendizaje de las AVD sobre la participación diaria en actividades motoras, en el cuarto estudio se realizó un análisis de mediación incluyendo a escolares con desarrollo típico y con p-TDC. Los hallazgos revelaron una relación compleja entre estos factores, donde el desempeño motor medió el efecto de las variables individuales (edad y sexo), las variables del entorno (entorno de residencia, nivel educativo familiar y materno, y la presencia de hermanos) y el aprendizaje de AVD sobre la participación diaria. En conjunto, este modelo fue capaz de explicar casi la mitad de la varianza de la participación, siendo el desempeño motor el constructo que mostró mayor efecto.

Considerando investigaciones previas, se esperaba encontrar un efecto directo significativo de las variables individuales y del entorno tanto sobre el desempeño motor como sobre la participación diaria, pero tan solo el entorno tuvo efecto directo sobre ambos constructos. En este sentido, las niñas y niños cuyos padres tienen elevado nivel educativo suelen reportar más habilidades motoras y una

mayor participación en las AVD[5,11,24,26], y el entorno de residencia parece influir sobre las preferencias y participación en actividades en población escolar[54]. Por el contrario, el sexo y la edad tuvieron un efecto directo sobre el desempeño motor y un efecto indirecto sobre la participación diaria a través del desempeño, lo que indica que este factor puede jugar un papel clave en cuanto a la influencia de los factores individuales. Por otro lado, el desempeño motor medió la totalidad del efecto del retraso en la adquisición de AVD sobre la participación diaria, lo que corrobora y expande la línea iniciada por Van Der Linde et al.[35] en población holandesa con y sin TDC. La evidencia sugiere que el TDC no implica un déficit en el aprendizaje motor por sí mismo, pero sí la manifestación de diferentes patrones en este proceso en comparación con el desarrollo típico[57,58]. En conjunto, estos hallazgos ofrecen una nueva perspectiva sobre el efecto crítico del desempeño motor en el complejo modelo del funcionamiento diario (Figura 2). Así, es posible que la influencia de las constricciones individuales y del entorno sobre la participación se signifique si la niña o el niño presenta problemas de coordinación motora, mientras que el desempeño motor simultáneamente influya aún más en el efecto de las constricciones individuales y el aprendizaje de AVD sobre la participación de actividades motoras de la vida diaria.

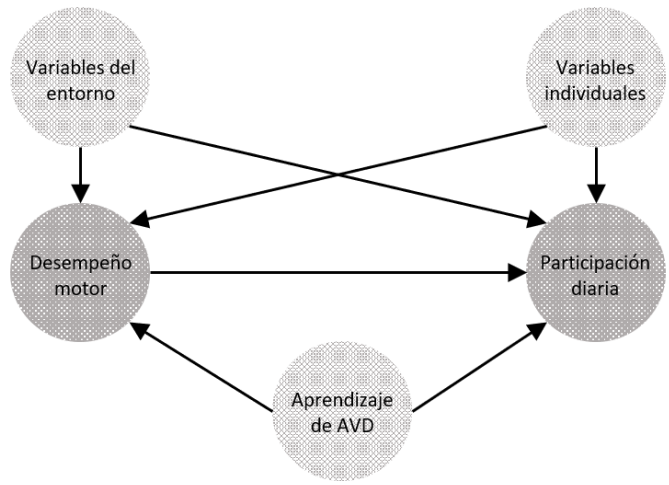

Figura 2. Marco conceptual del efecto mediador del desempeño motor sobre la participación en actividades motoras de la vida diaria.

Las relaciones encontradas en esta tesis entre los factores individuales, los factores del entorno y la participación y desempeño de población escolar con y sin dificultades de coordinación motora contribuyen a expandir la CIF y el modelo de constricciones de Newell[7,8], y también otros modelos teóricos de la Terapia Ocupacional, como el modelo Persona-Entorno-Ocupación y el modelo de la Ecología del Desempeño Humano[9,10]. Así, estos hallazgos sugieren que el desempeño motor puede constituir un puente entre la persona, el entorno y la participación diaria en población escolar con y sin p-TDC. Reflexionando lo encontrado en esta tesis, el funcionamiento motor diario debe ser evaluado considerando el contexto individual, familiar y cultural de las niñas y los niños.

Implicaciones prácticas y recomendaciones para futura investigación

La presente tesis doctoral tiene una serie de implicaciones tanto para los profesionales sociosanitarios que trabajan con escolares con TDC o con problemas de funcionamiento de base motora, como para los responsables implicados en políticas sanitarias y de promoción de la infancia e investigación.

En primer lugar, los profesionales sanitarios involucrados en el manejo diagnóstico y terapéutico de niñas y niños con problemas de coordinación motora pueden disponer de más información sobre la heterogeneidad de esta población en términos de perfil individual y sociocultural, y sobre las diferentes manifestaciones clínicas en las actividades de autocuidado, de motricidad fina y de motricidad gruesa. La multifactorialidad del TDC contribuye a justificar la intervención desde Terapia Ocupacional, que toma en consideración todos los aspectos que influyen en la participación de la niña o niño. Los terapeutas ocupacionales pueden incluir esta variabilidad en el proceso terapéutico, diseñando enfoques de intervención específicos, efectivos y orientados a la actividad, que se ajusten a las necesidades particulares de la niña o el niño y a sus características individuales y familiares.

En segundo lugar, los responsables de las políticas sociosanitarias deberían considerar implementar estrategias sistemáticas para identificar niñas y niños en riesgo de TDC en los servicios de Atención Primaria, dada la alta probabilidad de que esta población esté actualmente siendo infradiagnosticada en España. En esta línea, las escuelas de educación ordinaria suponen un escenario propicio para identificar rápidamente a escolares en riesgo de TDC, ya que los déficits motores son más fácilmente detectados cuando tienen un impacto significativo en el funcionamiento diario relevante, como el desempeño académico. Así, se recomienda que los órganos legislativos pertinentes consideren incluir a terapeutas ocupacionales en el sistema educativo ordinario español, lo que contribuirá al manejo diagnóstico y terapéutico de escolares con TDC.

En tercer lugar, los hallazgos de esta tesis constituyen un interesante punto de partida para explorar la participación diaria en actividades motoras desde la perspectiva de un modelo de constricciones dinámicas, que puede ser expandida en investigaciones futuras incluyendo nuevas variables individuales, del entorno y de la actividad. Para aumentar nuestro entendimiento sobre la interrelación de estos factores, es necesario realizar estudios longitudinales y de neuroimagen con muestras amplias de escolares con diagnóstico clínico de TDC.

CONCLUSIONES

El estudio de la epidemiología del TDC en población escolar española, y la exploración de la interrelación entre los factores personales, del entorno y de la actividad en el desempeño diario, permiten concluir:

- Con relación al primer objetivo de esta tesis, se concluye que la prevalencia de p-TDC en escolares españoles es considerable, aunque similar a las cifras reportadas en otras regiones europeas. La presencia de p-TDC en esta población no se distribuye uniformemente, sino que se asocia a variables sociodemográficas como la edad, el sexo, el procesamiento sensorial y el nivel educativo familiar. Esto resalta la necesidad del desarrollo de estrategias específicas en la identificación y evaluación exhaustiva de TDC en aquellos grupos de riesgo.

- Con relación al segundo objetivo de esta tesis, se concluye que los escolares con p-TDC presentan mayor prevalencia de patrones atípicos de procesamiento sensorial, que difieren significativamente respecto a población con desarrollo típico y con TDAH. Además, se concluye que el procesamiento sensorial interrelaciona con los factores individuales y del entorno como predictores del desempeño motor en escolares.

- Con relación al tercer objetivo de esta tesis, se concluye que los factores individuales, del entorno y de la actividad tienen un efecto directo en el desempeño motor de la población escolar con y sin p-TDC, y un efecto indirecto sobre la participación diaria a través del desempeño motor. Esto pone de relieve el potencial rol mediador del desempeño motor en la influencia que las variables personales y del entorno tienen sobre la participación, y apoya las recomendaciones actuales sobre el empleo de enfoques orientados a la actividad para promover el funcionamiento de escolares con dificultades de coordinación motora.

En conjunto, se concluye que el TDC es una condición que se presenta en población escolar española con mayor frecuencia de la que se está reportando actualmente, y hay grupos sociodemográficos con mayor probabilidad de presentar dificultades de coordinación motora. Existe una compleja relación entre los factores individuales, socioculturales y relacionados con la actividad, y el funcionamiento motor en escolares con desarrollo típico y con dificultades de coordinación motora, en la que el desempeño motor tiene un papel decisivo. El modelo propuesto en esta tesis complementa y expande el conocimiento previo sobre la interacción dinámica entre la persona, el entorno y los elementos relacionados con la actividad, especialmente en las actividades motoras diarias relevantes para el desempeño de niñas y niños con y sin p-TDC.

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APPENDIX

1. OUTPUT

Results of this doctoral thesis were published as articles in peer-reviewed journals, conference presentations and poster presentations.

Articles in peer-reviewed-journals

Delgado-Lobete L, Santos-del-Riego S, Pértega-Díaz S, Montes-Montes R. Prevalence of suspected developmental coordination disorder and associated factors in Spanish classrooms. Res Dev Disabil. 2019;86:31-40.

Delgado-Lobete L, Pértega-Díaz S, Santos-del-Riego S, Montes-Montes R. Sensory Processing Patterns in Developmental Coordination Disorder, Attention Deficit Hyperactivity Disorder and Typical Development. Res Dev Disabil. 2020;100:103608.

Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Cruz-Valiño JM, Schoemaker MM. Interrelation of Individual, Country and Activity Constraints in Motor Activities of Daily Living among Typically Developing Children: A Cross-sectional Comparison of Spanish and Dutch Populations. Int J Environ Res Public Health. 2020;17(5):1705.

Delgado-Lobete L, Montes-Montes R, van der Linde BW, Schoemaker MM. Assessment of Motor Activities of Daily Living: Spanish Cross-Cultural Adaptation, Reliability and Construct Validity of the DCDDaily-Q. Int J Environ Res Public Health. 2020;17(13):4802.

Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Hartman E, Schoemaker MM. Motor performance and daily participation in children with and without probable developmental coordination disorder. Dev Med Child Neurol. 2021; 10.1111/dmcn.15036.

Conference presentations

Delgado-Lobete L, Montes-Montes R, Santos-del-Riego S, Pértega-Díaz S. P Presencia de Trastorno del Desarrollo de la Coordinación en niños españoles de educación primaria. Impacto académico y en la escuela. Research presentation at *I Congreso Mundial de Educación*, 2021, A Coruña, Spain.

Delgado-Lobete L, Montes-Montes R. Asociación entre el procesamiento sensorial y los problemas de inatención e hiperactividad en el Trastorno del Desarrollo de la Coordinación. Research presentation at *I Congreso Virtual Internacional de Terapia Ocupacional*, 2020, Madrid, Spain.

Poster presentations

Delgado-Lobete L, Santos-del-Riego S, Pértega-Díaz S, Montes-Montes R. Restricciones en la participación de niños en riesgo de Trastorno del Desarrollo de la Coordinación. Research presentation at *VI Congreso Internacional en Contextos Clínicos y de la Salud*, 2020, Murcia, Spain.

Delgado-Lobete L, Montes-Montes R, Schoemaker MM. Activities of Daily Living Learning and Participation in Children with Neurodevelopmental Disorders: Results from Spain. *Developmental changes in paediatric neurodisability: from concepts to diagnostics and therapy*, 2019, Groningen, The Netherlands.

Workshops

Delgado-Lobete L. Trastorno del Desarrollo de la Coordinación: factores sociales y de procesamiento sensorial predictores del desempeño motor en población infantil. *V Congreso Internacional en Contextos Clínicos y de la Salud*, 2019, Murcia, Spain.

Delgado-Lobete L. Aportaciones de la Terapia Ocupacional a la investigación sobre el papel de la Teoría de los Sistemas Dinámicos en el Trastorno del Desarrollo de la Coordinación. *OTeca*, 2020, Galicia, Spain

2. ETHICS COMMITTEE APPROVAL

XUNTA DE GALICIA
CONSELLERÍA DE SANIDADE
Secretaría Xeral Técnica

Secretaria Técnica
Comité Autonómico de Ética da Investigación de Galicia
Secretaria Xeral. Consellería de Sanidade
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DICTAMEN DEL COMITÉ DE ÉTICA DE LA INVESTIGACIÓN DE A CORUÑA-FERROL

Carlos Rodríguez Moreno, Secretario del Comité de Ética de la Investigación de A Coruña-Ferrol

CERTIFICA:

Que este Comité evaluó en su reunión del día **21032017** el estudio:

Título: Trastorno del Desarrollo de la Coordinación y procesamiento sensorial en niños de 6 a 10 años y su relación con variables sociodemográficas y clínicas
Promotor: Centro Ocupacional Pascual Veiga
Tipo de estudio: Outros
Version:
Código del Promotor:
Código de Registro: 2017/166

Y, tomando en consideración las siguientes cuestiones:

- La pertinencia del estudio, teniendo en cuenta el conocimiento disponible, así como los requisitos legales aplicables, y en particular la Ley 14/2007, de investigación biomédica, el Real Decreto 1716/2011, de 18 de noviembre, por el que se establecen los requisitos básicos de autorización y funcionamiento de los biobancos con fines de investigación biomédica y del tratamiento de las muestras biológicas de origen humano, y se regula el funcionamiento y organización del Registro Nacional de Biobancos para investigación biomédica, la ORDEN SAS/3470/2009, de 16 de diciembre, por la que se publican las Directrices sobre estudios Posautorización de Tipo Observacional para medicamentos de uso humano, y el la Circular nº 07 / 2004, investigaciones clínicas con productos sanitarios.
- La idoneidad del protocolo en relación con los objetivos del estudio, justificación de los riesgos y molestias previsibles para el sujeto, así como los beneficios esperados.
- Los principios éticos de la Declaración de Helsinki vigente.
- Los Procedimientos Normalizados de Trabajo del Comité.

Emite un **INFORME FAVORABLE** para la realización del estudio **por el/la investigador/a del centro**:

Centros	Investigadores Principales
Centro Ocupacional Pascual Veiga	Laura Delgado Lobete

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Comité Autonómico de Ética da Investigación de Galicia
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Y hace constar que:

31. El Comité Territorial de Ética de la Investigación de A Coruña-Ferrol cumple los requisitos legales vigentes (R.D 223/2004 de ensayos clínicos, y la Ley 14/2007 de Investigación Biomédica).
32. El Comité Territorial de Ética de la Investigación de A Coruña-Ferrol tanto en su composición como en sus PNTs cumple las Normas de Buena Práctica Clínica (CPMP/ICH/135/95).
33. La composición actual del Comité Territorial de Ética de la Investigación de A Coruña-Ferrol es:

Salvador Pita Fernández (Presidente). Médico especialista en Medicina Familiar y Comunitaria. Área de Gestión Integrada A Coruña.
Lucía Fuster Sanjurjo (Vicepresidenta). Farmacéutica. Especialista en Farmacia Hospitalaria. Área de Gestión Integrada Ferrol
Carlos Rodríguez Moreno (Secretario). Médico especialista en Farmacología Clínica. Área de Gestión Integrada Santiago
Natalia Cal Purriños (Vicesecretaria). Licenciada en derecho. Fundación "Profesor Nóvoa Santos". A Coruña
Juana Mª Cruz del Rio. Trabajadora social. Consellería de Sanidad
Begoña Graña Suárez. Médica especialista en Oncología Médica. Área de Gestión Integrada A Coruña
Angel Lopez-Silvarrey Varela. Médico especialista en Pediatría. Área de Gestión Integrada A Coruña
Alejandro Pazos Sierra. Médico. Universidad de A Coruña
Gonzalo Peña Pérez. Médico especialista en Cardiología. Hospital de San Rafael. A Coruña
José Mª Rumbo Prieto. Diplomado en enfermería. Área de Gestión Integrada Ferrol
María Isabel Sastre Gervás. Farmacéutica Atención Primaria. Área de Gestión Integrada A Coruña

Para que conste donde proceda, y a petición del promotor / investigador, en Santiago de Compostela,

El secretario

XUNTA DE GALICIA CONSELLERÍA DE SANIDADE SECRETARÍA XERAL TÉCNICA SECRETARÍA DO COMITÉ DE ÉTICA DA INVESTIGACIÓN DE GALICIA

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Comités de Ética de Investigación de Galicia
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DICTAMEN DEL COMITÉ DE ÉTICA DE LA INVESTIGACIÓN DE A CORUÑA - FERROL

Natalia Cal Purriños, Secretaria del Comité de Ética de la Investigación de A Coruña-Ferrol

CERTIFICA:

Que este Comité evaluó en su reunión del día 18/12/18 el estudio**:**

Título: Evaluación de la coordinación motora en las actividades de la vida diaria y su asociación con el procesamiento sensorial y ejecutivo en niños de 5 a 11 años
Versión:
Promotor/a:Laura Delgado Lobete
Investigador/a: Laura Delgado Lobete
Código de Registro:2018/606

Y que este Comité, tomando en consideración la pertinencia del estudio, el conocimiento disponible, los requisitos éticos, metodológicos y legales exigibles a los estudios de investigación con seres humanos, sus muestras o registro y los Procedimientos Normalizados de Trabajo del Comité, emite un dictamen **FAVORABLE*** para la realización del citado estudio.

NOTA*: Los cuestionarios para recoger los datos del padre y de la madre deben ir por separado, dado que cada uno deberá cumplimentar su información.
Teniendo en consideración que los cuestionarios son anónimos no es necesario indicar información relativa al Delegado de Protección de Datos.

Secretaria Técnica
Comités de Ética de Investigación de Galicia
Secretaria Xeral. Consellería de Sanidade
Edificio Administrativo San Lázaro
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Y HACE CONSTAR QUE:

1. El Comité Territorial de Ética de la Investigación de A Coruña-Ferrol cumple los requisitos legales vigentes

2. La composición actual del Comité Territorial de Ética de la Investigación de A Coruña-Ferrol es:

Lucía Fuster Sanjurjo (Presidenta). Farmacéutica. Especialista en Farmacia Hospitalaria. Área de Gestión Integrada Ferrol
Angel Lopez-Silvarrey Varela. **(Vicepresidente)**.Médico especialista en Pediatría. Área de Gestión Integrada A Coruña
Natalia Cal Purriños. (Secretaria). Licenciada en Derecho. Fundación "Profesor Nóvoa Santos". A Coruña
Sonia Pértega Díaz. (Vicesecretaria). Matemática. Área de Gestión Integrada A Coruña
Juana Mª Cruz del Rio. Trabajadora social. Consellería de Sanidad
Portal González Lorenzo. Médica especialista en Medicina Familiar y Comunitaria. Área de Gestión Integrada Ferrol
Begoña Graña Suárez. Médica especialista en Oncología Médica. Área de Gestión Integrada A Coruña
Carmen Mella Pérez. Médica especialista en Medicina Interna. Área de Gestión Integrada Ferrol
Alejandro Pazos Sierra. Médico. Universidad de A Coruña
Gonzalo Peña Pérez. Médico especialista en Cardiología. Hospital de San Rafael. A Coruña
Carlos Rodríguez Moreno. Médico especialista en Farmacología Clínica. Área de Gestión Integrada Santiago
José Mª Rumbo Prieto. Diplomado en Enfermería. Área de Gestión Integrada Ferrol
María Isabel Sastre Gervás. Farmacéutica Atención Primaria. Área de Gestión Integrada A Coruña

Para que conste donde proceda, y a petición de quien corresponda, en A Coruña,

La Secretaria del Comité Territorial de Ética de la Investigación de A Coruña – Ferrol,

Natalia Cal Purriños

Firmado digitalmente por: CAL PURRIÑOS NATALIA MARIA - 79321490X
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3. QUALITY INDICATORS OF THE PUBLICATIONS

Study 1. Delgado-Lobete L, Santos-del-Riego S, Pértega-Díaz S, Montes-Montes R. Prevalence of suspected developmental coordination disorder and associated factors in Spanish classrooms. Res Dev Disabil. 2019;86:31-40.

AND

Study 2. Delgado-Lobete L, Pértega-Díaz S, Santos-del-Riego S, Montes-Montes R. Sensory processing patterns in developmental coordination disorder, attention deficit hyperactivity disorder and typical development. Res Dev Disabil. 2020;100:103608.

- **Journal:** Research in Developmental Disabilities.
- **Online ISSN:** 1873-3379.
- **Journal Impact Factor (JCR 2019):** 1.836.
- **Journal Impact Factor (JCR 2020):** 3.230.

Category	Quartile (2019)	Ranking (2019)	Quartile (2020)	Ranking (2020)
Rehabilitation (SSCI)	Q1	15/71	Q1	4/74
Education, Special (SSCI)	Q1	7/42	Q1	5/44

Study 3. Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Cruz-Valiño JM, Schoemaker MM. Interrelation of Individual, Country and Activity Constraints in Motor Activities of Daily Living among Typically Developing Children: A Cross-sectional Comparison of Spanish and Dutch Populations. Int J Environ Res Public Health. 2020;17(5):1705.

- **Journal:** International Journal of Environmental Research and Public Health.
- **ISSN:** 1660-4601.
- **Journal Impact Factor (JCR 2020):** 3.390.

Category	Quartile (2020)	Ranking (2020)
Public, Environmental & Occupational Health (SSCI)	Q1	41/176
Public, Environmental & Occupational Health (SCIE)	Q2	68/203
Environmental Sciences (SCIE)	Q2	118/274

Study 4. Delgado-Lobete L, Montes-Montes R, Pértega-Díaz S, Santos-del-Riego S, Hartman E, Schoemaker MM. Motor performance and daily participation in children with and without probable developmental coordination disorder. Dev Med Child Neurol. 2021; 10.1111/dmcn.15036.

- **Journal:** Developmental Medicine and Child Neurology.
- **ISSN:** 0012-1622.
- **Journal Impact Factor (JCR 2020):** 5.449.

Category	**Quartile (2020)**	**Ranking (2020)**
Pediatrics (SCIE)	Q1	7/129
Clinical Neurology (SCIE)	Q1	39/208

5. FIRST AND LAST PAGES OF PUBLISHED PAPERS

Research in Developmental Disabilities 86 (2019) 31–40

Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

Prevalence of suspected developmental coordination disorder and associated factors in Spanish classrooms

Laura Delgado-Lobete*, Sergio Santos-del-Riego, Sonia Pértega-Díaz, Rebeca Montes-Montes

University of A Coruña, Faculty of Health Sciences, Campus de Oza S/N, A Coruña, Spain

ARTICLE INFO

Keywords:
Developmental coordination disorder
Child development
Psychomotor performance
Epidemiology
Prevalence

ABSTRACT

Background: Developmental Coordination Disorder (DCD) is a multifactorial, neurodevelopmental motor disorder that severely affects the activities of a child's daily life and classroom performance. The aim of this study was to determine the prevalence of suspected DCD in a sample of Spanish schoolchildren and its association with socio-demographic factors.
Methods: We conducted a cross-sectional study including a random sample of 460 children attending mainstream schools in northwest Spain in 2017. A Developmental Coordination Disorder Questionnaire-European Spanish was used to evaluate suspected DCD prevalence. We performed multivariate logistic and linear regression analysis to determine the socio-demographic variables associated with suspected DCD and problematic motor coordination performance.
Results: The prevalence of suspected DCD was 12.2%. According to the multivariate analysis, DCD symptoms were significantly associated with males (OR = 3.0), ages above 10 years old (OR = 5.0) and low participation in out-of-school physical activities (OR = 2.3). Preterm birth children were twice as likely to show suspected DCD, although this association was not statistically significant (OR = 2.1).
Conclusions: A high percentage of Spanish schoolchildren are at risk for developing DCD. There is a strong connection between suspected DCD and socio-demographic factors. Protocols aimed to detect DCD and intervention programmes in classrooms designed to promote motor coordination skills need to take these factors into consideration.

What this paper adds?

This is the first study to investigate the epidemiology of suspected Developmental Coordination Disorder (DCD) in a large sample of Spanish schoolchildren aged 6–12 years old. Approximately three children in a general Spanish classroom are at risk for DCD. Boys are three times more likely to show coordination difficulties. Age, premature birth and low participation in out-of-school physical activities are also associated with DCD symptoms. These findings indicate that factors associated with motor coordination difficulties in schoolchildren span across neurological and socio-demographic domains, and should be addressed during early development to promote prompt interventions. Schools offer the best setting to detect learning difficulties due to motor coordination issues, and teachers and health care practitioners working in schools can use this study to design specific strategies to promote full participation according to these children's needs and characteristics.

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Fong, S. S. M., Vackova, D., Choi, A. W. M., Cheng, Y. T. Y., Yam, T. T. T., & Guo, X. (2018). Diversity of activity participation determines bone mineral content in the lower limbs of pre-pubertal children with developmental coordination disorder. *Osteoporosis International, 29*(4), 917–925.
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Sensory processing patterns in developmental coordination disorder, attention deficit hyperactivity disorder and typical development

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ABSTRACT

Background: Sensory processing difficulties (SPD) are present in children with Developmental Coordination Disorder (DCD) and Attention Deficit and Hyperactivity Disorder (ADHD). However, little is known about sensory processing variability in these disorders.
Objective: The purpose of this study was to explore SPD among children with DCD, ADHD and co-occurring symptoms in comparison to children with typical development (TD) and to determine how potential social confounders may influence these associations.
Methods: The study involved 452 children aged 6–12 years. The Short Sensory Profile-2 was used to assess sensory processing patterns. Multiple linear regressions were utilized to investigate the relationship between DCD, ADHD and co-occurring symptoms and sensory processing patterns, adjusting for social covariates.
Results: Children with DCD and ADHD symptoms showed greater variability of atypical sensory processing patterns compared with TD children. Low registration and sensory sensibility issues were more prevalent in the DCD group. ADHD children showed higher rates of low registration, sensory sensibility and sensory seeking, and all children in the co-occurring symptoms group presented sensory sensibility.
Conclusion: This study reports significant variability in sensory processing among children with DCD, ADHD and co-occurring symptoms using a population-based sample. These differences can contribute to understand how neurological and social factors correlates across diagnoses.

What this paper adds?

This is the first study to explore differences in sensory processing patterns among children with DCD, ADHD and co-occurring symptoms in comparison to typically developing children using a population-based sample and adjusting for social covariates. Our results indicate that children with these disorders show more sensory processing difficulties and greater sensory patterns variability than peers without motor coordination or inattention/hyperactivity issues. Children with co-occurring symptoms experienced more sensory processing variability than any other group. Presence of DCD, ADHD or co-occurring symptoms were significantly and independently associated with atypical sensory processing, but social characteristics such as age, sex and family educational level were also significantly related. These findings highlight the need to consider both sensory processing variability and social

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Interrelation of Individual, Country and Activity Constraints in Motor Activities of Daily Living among Typically Developing Children: A Cross-sectional Comparison of Spanish and Dutch Populations

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Abstract: Motor performance is influenced by individual, environmental, and task constraints. Children perform differently according to individual (i.e., sex), environmental (i.e., country), and task (i.e., type of activity) factors. However, little is known about the effect of the interaction between sex and country factors across different activities of daily living (ADL) learning, participation, and performance. The main aim of this study was to examine the relationship between sex, country, and type of activity in motor-based ADL learning, participation, and performance in five-to-eight-year-old, typically developing children. Additionally, we aimed to compare the prevalence of probable Developmental Coordination Disorder (DCD) across sex and country. The DCDDaily-Q was used to assess ADL learning, participation, and performance in 300 age and sex-matched children from Spain and The Netherlands. The prevalence of probable DCD was determined based on the total ADL performance score. Results showed that differences in ADL learning, participation and performance differed across sex and country ($p < 0.05$). Prevalence of probable DCD was statistically similar in both countries. These findings show that daily participation and performance in typically developing children may be influenced by individual, country, and task constraints, and that country and sex may have different influences on particular tasks.

Keywords: developmental coordination disorder; dynamic systems theory; cross-cultural; motor performance; activities of daily living; occupational therapy; DCDDaily-Q

1. Introduction

The Dynamic Systems Theory proposes that motor performance results from the interaction of individual, environmental, and task constraints [1–3]. Previous research has proposed that both motor performance and the presence of Developmental Coordination Disorder (DCD) are influenced by different constraints such as sex, lifestyle, physical activity routines, environmental settings, and participation in activities of daily living (ADL) [4–9]. The influence of these factors varies from one country to another, even within a Western European context, and there is an increasing interest in literature to explore motor performance patterns in children from different regions [4,6,10–13].

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Motor performance and daily participation in children with and without probable developmental coordination disorder

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ABBREVIATIONS

ADL	Activities of daily living
DCD	Developmental coordination disorder
DCDDaily-Q	DCDDaily-Questionnaire
PLS-SEM	Partial least squares-based structural equation modelling

AIM To test the mediating role of motor performance in the relationship between individual and environmental constraints, delayed learning of activities of daily living (ADL), and daily participation in typically developing children and children with probable developmental coordination disorder (DCD).

METHOD Parents of 370 randomly selected children aged 5 to 10 years (194 females; mean age [SD] 7y 5mo [1y 10mo]) were included in the study (321 typically developing, 49 probable DCD). Motor performance, ADL learning, and participation were assessed using the DCDDaily-Questionnaire. Individual variables included child's age and sex, and environmental variables included mother and family educational level, presence of siblings, and area of residence. Direct, indirect, and mediating effects were tested using a partial least squares-based structural equation modelling approach.

RESULTS The model explained 44.5% of the variance of daily participation. Motor performance significantly mediated the effect of individual and environmental constraints, and ADL learning on daily participation.

INTERPRETATION Results suggest that the effect of individual and environmental constraints and delayed learning of ADL on daily participation is mediated by motor performance in typically developing children and children with probable DCD. These findings provide further evidence that interventions to promote participation in children with probable DCD should adopt ecological, task-oriented approaches. Further studies should evaluate model generalizability with clinical samples.

About 5% to 6% children of school-age present with developmental coordination disorder (DCD),[1] and as many as 12% to 25% of children are at risk of motor coordination issues.[2–5] In children with DCD, the execution of motor coordination skills is substantially below age-matched typically developing peers, which cannot be explained by any intellectual impairment, or neurological or developmental condition.[1] The deficits in motor skills are usually expressed in slower learning of motor skills and less accurate motor performance, and these difficulties are more significant in complex ADL.[6] So far, the etiology of DCD is unclear, but several hypotheses have been developed to contribute to the understanding of this disorder.[1]

The activity deficit hypothesis[7] proposes that children with low motor proficiency usually avoid engaging in motor activities, which eventually widens the motor skill gap between these children and typically developing children as they grow older. Research shows that delayed learning of motor skills and motor-based activities of daily living (ADL) is associated with poorer execution,[6,8] which in turn predicts reduced participation both in children with and without DCD.[9]

Satisfactory participation is defined as active engagement in meaningful ADL.[10] Participation in daily contexts is considered a major component of health and well-being.[11] Therefore, the impact of DCD and poor motor skills transcends motor performance. Literature has widely reported that deficits in motor ability reduce participation in children with DCD.[1,6] Consequently, recommendations have been made to pay special attention to how motor performance difficulties impact daily participation in children with DCD.[1,12] According to the results of a systematic review, children with DCD participate less than typically developing children in self-care and self-maintenance ADL, social and motor-based leisure ADL, school-related ADL, and instrumental ADL.[12] During the last decade,

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5. ABOUT THE AUTHOR

Short Curriculum Vitae

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Overview

Laura Delgado-Lobete received her bachelor degree in Occupational Therapy at University of Oviedo (2015), with an interest in the child's psychomotor development and performance. She conducted her master thesis at University of A Coruña, where she then started her PhD research in 2016. She continued working as an occupational therapist while conducting her PhD research on Developmental Coordination Disorder and daily performance until 2018, since when she has worked full-time on research and teaching projects at University of A Coruña.

In 2019 and 2020, Laura completed two research internships at University of Groningen (The Netherlands), where she had the opportunity to expand her research about the interrelated influence of individual, environmental and activity-related factors on motor-based functioning in school-aged children.

Education

2014	Expert degree in Psychomotricity Universidad Pontificia de Salamanca, Spain
2015	Bachelor degree in Occupational Therapy University of Oviedo, Spain
2016	Master's degree in Health Care and Research University of A Coruña, Spain
2016-2021	PhD student in Health Sciences University of A Coruña, Spain

International internships

2019	Center for Human Movement Sciences, University Medical Center Groningen, Universidad de Groningen, Países Bajos
2020	Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, The Netherlands

Supervision

2018	Supervisor for external clinical internships (bachelor in Occupational Therapy, University of A Coruña, Spain).
2018-curr.	Supervisor for bachelor theses (bachelor in Occupational Therapy, bachelor in Nursing and bachelor in Podiatry, University of A Coruña, Spain).
2020-curr.	Supervisor for master theses (master in Occupational Therapy in Adult Neurologic Rehabilitation, Faculty Padre Ossó, Spain).

Publications

First author and co-author of fourteen scientific papers published in international, high impact factor journals.

Communications

First author and co-author of more than thirty conference and poster presentations in scientific congresses and meetings.

Solo te quise decir que no dejé de creer
Pero era grande la sensación
De vertigo constante

Leiva