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Developmental coordination disorder: Case series and literature review

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Abstract

Developmental coordination disorder (DCD) is a clinical condition that manifests in the childhood period by a motor performance that fails to live up to what would be expected given the child's age. Characterized by difficulties in fine and gross motor skills, DCD can lead to children acting in an uncoordinated, awkward and/or slow fashion. It has a high prevalence among the pediatric population (5-6%), with great repercussions performing tasks of daily living, school performance, sports and leisure activities. Despite its high prevalence, DCD remains an underdiagnosed disorder and a subject with reduced awareness. Given these problems, it becomes of major importance to raise awareness for this condition and emphasize the importance of this diagnosis.

Regarding a small series of clinical cases of children with developmental coordination disorder, an extensive review of the literature on the subject was carried out, prioritizing the most recent and relevant articles. This case series was based on the retrieval of pertinent clinical data relevant to this condition that was obtained using clinical records of patients diagnosed with DCD who had a general neuropediatric routine visit during the last semester of 2021.

After comparing our results with the actual literature, the data we obtained was consistent with the current understanding encompassing DCD. We acknowledge that our case series has several limitations, mainly due to the small sample size, lack of funding and the pandemic context, hindering data retrieval. No use of standardized scales was employed. Because we conducted a retrospective study some data was unable to be obtained from patient clinical files. Even so, we believe that this study paved the way for future ones.

Besides reinforcing this topic, this case series serves the purpose of raising awareness and sensitizing to the importance of this diagnosis.

***Key words**: Developmental coordination disorder; DCD; Dyspraxia; Motor clumsiness; Minimal brain dysfunction; DAMP.*

Resumo

A perturbação do desenvolvimento da coordenação motora (PDCM) é uma entidade clínica que se manifesta no período infantil por um desempenho motor que fica aquém do esperado para a idade da criança. É caracterizada por dificuldades na motricidade fina e grosseira, que pode conduzir a que as crianças realizem as ações de uma forma descoordenada, inábil e/ou lenta. Apresenta uma elevada prevalência na população pediátrica (5-6%), com grande repercussão na execução das tarefas da vida diária, desempenho escolar, atividades desportivas e de lazer. Apesar da sua elevada prevalência, continua a ser uma condição subdiagnosticada e um tema com pouco destaque. Face a estes problemas torna-se importante alertar e realçar para a importância deste diagnóstico.

A propósito de uma pequena série de casos clínicos de crianças com o diagnóstico de perturbação do desenvolvimento da coordenação motora, procedeu-se à elaboração de uma revisão extensa da literatura sobre o tema, dando primazia aos artigos mais relevantes e recentes. A série de casos teve por base a recolha de dados clínicos relevantes com a condição, obtidos com recurso a registos clínicos de pacientes com o diagnóstico de PDCM em contexto de consulta de seguimento de neuropediatria durante o último semestre de 2021.

Após confrontados os resultados com a literatura atual, os dados obtidos foram concordantes no que concerne ao panorama global que envolve a PDCM. Reconhecemos que a nossa série de casos apresenta limitações, as quais se devem principalmente à reduzida dimensão da amostra, falta de financiamento e contexto pandémico, dificultando o processo de obtenção de dados. Não foi empregue o uso de escalas padronizadas. Tendo em consideração que foi realizado um estudo retrospectivo, infelizmente, alguns dados não puderam ser obtidos dos registos clínicos dos pacientes. Ainda assim, acreditamos que este estudo abriu caminho para a realização de outros futuros.

Para além de relançar este tema, esta série de casos serve o propósito de ao mesmo tempo alertar e criar sensibilidade para a importância deste diagnóstico.

***Palavras-chave**: Perturbação do desenvolvimento da coordenação motora; PDCM; Dispraxia; Desajeitamento motor; Disfunção cerebral mínima; DAMP.*

Abbreviations and acronyms

ADHD - Attention–deficit / hyperactivity disorder

ASD – Autism spectrum disorder

BOT - Bruininks-Oseretsky Test of Motor Proficiency

BOT-2 - Bruininks-Oseretsky Test of Motor Proficiency-second edition

CO-OP - Cognitive orientation to daily occupational performance

DAMP - Deficits in attention, motor control, and perception

DCD - Developmental coordination disorder

DCDQ - Developmental Coordination Disorder Questionnaire

DCDQ'07 - Developmental Coordination Disorder Questionnaire 2007

DSM - *Diagnostic and Statistical Manual of Mental Disorders*

DSM-5 - *Diagnostic and Statistical Manual of Mental Disorders 5*

DSM-III-R - *Diagnostic and Statistical Manual of Mental Disorders* 3rd *Revised Edition*

DSM-IV - *Diagnostic and Statistical Manual of Mental Disorders IV*

DTI - Diffusion tensor imaging

EOA - Early onset ataxia

FA - Fractional anisotropy

IMD - Internal modeling deficit

LI - Language impairment

MABC - Movement Assessment Battery for Children

MABC-2 - Movement Assessment Battery for Children-second edition

MBD – Minimal brain dysfunction

MNS - Mirror neuron system

NTT – Neuromotor task training

PDCM – Perturbação do desenvolvimento da coordenação motora

PDD - Pervasive developmental disorder

SARA - Scale for Assessment and Rating of Ataxia

SM1 - Somatomotor cortex

TD – Typically developing

Index

Figure index

Table index

Box index

Introduction

Developmental coordination disorder (DCD) is a clinical condition that manifests in the childhood period by a motor performance that fails to live up to what would be expected given the child's age. DCD is characterized by difficulties in fine and gross motor skills, which can lead to children acting in an uncoordinated, awkward and/or slow fashion. Despite remaining an underdiagnosed disorder and a topic with little attention, DCD has a high prevalence among the pediatric population (5-6%), with great repercussions in the performance of tasks of daily living, school performance, sports and leisure activities.

Although it is a non-progressive condition, the diagnosis of DCD has a great impact on the daily lives of children and those around them. Besides the difficulties in motor skills, there remains a significant psychological burden that is not negligible, with frequent exclusion from sports activities by their colleagues, contributing to the lack of motivation to perform group activities and low self-esteem, predisposing to unaccomplishment. It should be noted that these difficulties are of major importance especially in boys due their sociocultural intimate link with sport related activities. Because they are so interwoven with athletics, their diminished physical performance is a center of attention and a focus of great distress, with possible repercussions concerning their mental health. Given the above, it becomes of crucial importance to diagnose and address this condition, so that these children develop in a more typical fashion and at the same time preventing psychological comorbidities, particularly during adolescence.

Language disturbances, learning difficulties and dysgraphia can often be associated, as well as developmental comorbidities such as ADHD and dyslexia. Because these comorbidities are so frequent among children with DCD, once the diagnosis is made, the physician should always be on the lookout for them. Besides ruling them out, it is of utmost importance to care for the patients' mental wellbeing, listening and addressing their psychological complaints. In contrast with other developmental disorders (such as ADHD), DCD is a not much acknowledged entity among the general population (and even within the medical community), thus remaining such a fairly underdiagnosed disorder. Consequently, many cases get diagnosed only during adolescence, with countless never

actually getting diagnosed. Regardless of a late diagnosis, intervention regimens are still important and should not be disregarded, as well as reinforcing patients' self-esteem at such a distinctive age as in the adolescence period.

Methods

Our case series was established on the retrieval of clinical data relevant to the condition, such as social impact, functional impairment, comorbidities, risk factors, treatment regimen, among others, so that a descriptive analysis of the obtained data could be carried out and then compared. Medical records of all 6 patients with an actual or past diagnosis of DCD who resorted to a routine appointment in neuropediatrics in the last semester of 2021, followed in the Northern Lisbon University Hospital Centre were reviewed. Incomplete clinical data parameters were excluded from this review. It is important to emphasize that we only included patients that resorted to a neuropediatrics appointment and not to development pediatrics, increasing the risk of bias. It is expected that due to this fact our cohort might present with more gross motor impairment, while in developmental pediatrics physicians may deal with children with a subtler phenotype (for example with difficulties only in dexterity). Also our cohort is of small dimension (6 patients).

Concerning this literature review, an extensive bibliographic search of articles on the condition was carried out, prioritizing the most relevant and recent articles. The bibliographic search was conducted in August 2021 using the electronic database *PubMed*. The search queries used were: “DCD” and “Developmental coordination disorder”, as well as “Developmental coordination disorder” and “DAMP”, retrieving in total 184 articles, of which 4 were not attainable. All remaining 180 articles yielded by the search were screened for relevance to this review. Applied filters were: Clinical trial, meta-analysis, randomized controlled trial, review, systematic review. No year filter was applied. The publication date was not an exclusion criterion. The eligibility criteria were: English and Portuguese language. Whenever relevant, the bibliographies of the included studies were also consulted and included in this report.

Early descriptions

Developmental coordination disorder (DCD) is a condition that has been known for several years, however, in the past, a wide range of labels have been employed to its designation. Some authors suggest this discrepancy had its basis on the fact that this condition did not have a well-defined physiological basis and diagnostic criteria. Thus physicians would impose their own designation based on their findings and on its presumable etiology (Wilson, 2005), which led to sparse gathering of information on the matter in the past and contributing to the underdiagnosis, despite its high prevalence amongst the pediatric population.

Early descriptions of children exhibiting DCD symptoms retrace as far back as 1911 when French psychiatrist Ernest Dupré reported what he called clumsiness of voluntary movement which he later in 1925 designated as motor debility.

Later in 1937 Dr. Samuel Orton described these children as being abnormally clumsy. And made the analogy between the condition and a right-handed person trying to use their left hand (Polatajko & Cantin, 2005). He noted that these children had difficulty performing tasks that required more skills and complex sequencing, such as playing sports and throwing objects as opposed to simpler tasks like walking and running which are associated with longer phylogenetic ancestry (Orton, 1937).

Minimal brain dysfunction (MBD) was a widely used umbrella diagnosis employed for those manifesting decreased motor control, deficits in attention, language and perception disorders, impulsivity and memory impairment. Hence being one very heterogeneous diagnosis and not specific to DCD.

Developmental dyspraxia was another term used to describe DCD in the past. Proposed by Ayres in 1972, this label arose from the implication that there was an inability to plan and perform a complex motor sequence in a fashioned way, resulting in classic motor features such as slow and/or uncoordinated movements. Ayres believed the motor problems found in these children were caused by a deficit of sensory integration.

In 1975 Dr. Sasson Gubbay restructured literature defining these children as unable to perform skilled movement despite normal intelligence and having a normal neurological exam as prerequisite as he named the condition *clumsy child syndrome* (Missiuna & Polatajko, 1995).

DSM introduction

Developmental coordination disorder was the terminology used when this diagnosis was introduced in the *Diagnostic and Statistical Manual of Mental Disorders* 3rd *Revised Edition* (DSM-III-R*)* in 1987 hence avoiding previous pejorative connotations. DCD was defined as a significant impairment of motor coordination below what would be expected given the child's age and intelligence and causing significant interference in daily life activities and academic performance. The problem being that the DSM criteria did not provide clear cut-offs regarding motor performance and intellectual abilities. Today, although DSM criteria remains fairly the same, physicians can rely on a wide range of diagnostic tools such as questionnaires and specific motor assessment instruments to establish the diagnosis of DCD. Some of the worth mentioning changes in criteria among years were the exclusion of the diagnosis in children meeting pervasive developmental disorder (PDD) when DSM-IV was released (it was later removed in the DSM-V), introduction of the possibility of diagnosing children with "mental retardation" (intellectual disability) when DSM-IV was launched and finally with the actual DSM-V came another criteria that stated that for DCD to be diagnosed the symptom onset had to present in the early developmental period (*Diagnostic and Statistical Manual of Mental Disorders : DSM-5*, 2013). Actual DSM-5 diagnostic criteria (see *Box* 1) will be further discussed under the section *Diagnostics*.

Prevalence

Children with developmental coordination disorder (DCD) constitute a significant portion of school aged children as it is estimated that its prevalence is approximately 5-6% in children whose ages range from 5 to 11 years according to the DSM-5. It is important to keep in mind that DCD's prevalence is affected by how strict the diagnostic criteria are and the population under the scope. The condition affects unequivocally more boys than girls with a ratio ranging from 2:1 to 7:1 (*Diagnostic and Statistical Manual of Mental Disorders : DSM-5*, 2013). It is important to note that some authors warn that the prevalence in girls may be higher, given that girls are easier to escape diagnosis, for example due to less sociocultural demand for physical activities while growing up, thus masking this condition's manifestations.

Using the DSM-IV, a study was conducted to investigate the prevalence of DCD in children aged 7 in the United Kingdom. Using the 5^{th} percentile as cutoff when evaluating motor skills and excluding children whose IQ was less than 70 made the diagnosis stricter. Like so, the results reported a prevalence of 1.8% which is significantly inferior regarding previous studies. However, when increasing the cutoffs to the 15^{th} percentile the same study noted a prevalence of DCD of 5.5% converging to as previously reported. Gender ratio was 1.9:1 males to females (Lingam et al., 2009).

Interestingly when comparing the prevalence of DCD in Greek and Canadian children a significantly higher rate of DCD among the Greek (19% vs 8%) was noted. The authors themselves note that these findings do not necessarily mean that the Greek have increased difficulty acquiring motor skills, instead they warn us about the presence of other variables such as higher body fat percentage and lower cardiorespiratory fitness among the Greek that point out inactivity resulting in underperformance when assessing motor skills (Tsiotra et al., 2006). These results advise us to be mindful of lifestyle differences between samples and how they can alter DCD prevalence, as countries with higher physical activity indexes will typically be associated with better physical performance outcomes.

Another study conducted in 2020 in India using DSM-5 diagnostic criteria with children aged 8-17 years revealed a prevalence of 3,8%, in particular 5% in boys and 2.7% in girls (Sujatha B et al., 2020).

As expected, prevalence varies amidst studies, changes to age-based motor skill acquisition can be attributable to diagnostic definition which can be stricter by, for example, lowering cutoff scores of motor skill tests or broader by allowing lower IQ cutoffs for instance. As demonstrated previously, lifestyle and cultural influence are of great significance.

Clinical features

Developmental coordination disorder (DCD) rather than being perceived as a pure motor control disorder is viewed as a more generalized issue, affecting sensory and sensorimotor integration. Understanding DCD's manifestations is an important but difficult task given that children with the condition are part of a very heterogeneous group (Visser, 2003), therefore being subject to less specificity. For example, while one might struggle more with fine motor control activities such as tool handling, others can have trouble to a higher extent with gross motor control activities such as gait and balance.

Early symptoms might include a delay achieving developmental milestones (crawling, sitting and walking are frequently reported) although some might achieve them fairly easily. Being unspecific of the condition, the diagnosis is most often reserved for children aged 5 or older, allowing children with suboptimal skills to "catch up" and avoiding labeling them with a developmental delay. Beyond this age DCD's manifestations become more pronounced and with great impact on daily life activities, given the increased demand as a child enters primary school. It is estimated that only 1 in 4 children diagnosed with DCD are referred to a specialist before starting school (Gibbs et al., 2007). As said before, different children will exhibit the different symptoms, likewise the diagnosis is made once confirmed that there is a significant impairment of motor coordination using an extensive pool of motor skill elements that will be discussed further.

Children with the diagnosis will experience a delay in motor skill acquisition, particularly the less rudimentary ones. In theory, recent motor sequences that deviate from our older phylogenetic ancestry imply an additional learning effort, which becomes more pronounced in children with DCD as referred early on (Orton, 1937). Once acquired, execution tends to be slow or inaccurate when compared to normally developing peers. The main problem is not only the lack of smoothness in motor control by itself, but mainly its implication on daily life, reason why when describing the condition one needs to be aware of the psychological impact of underperforming.

These children typically exhibit a graceless posture which some authors relate to trunk and member hypotonia. The latter leading to joint fixing as a compensatory mechanism. Since these children have decreased adaptability, they require added effort and commitment when performing tasks, this leads to awkward and “stiff” body postures. For example, fixing joints when reaching for a high object allows these individuals not to fall over and to focus on using their arm and hand with better control in order to attain the wished-for object (Chung et al., n.d.).

It was also noted that these children expressed gait abnormalities, presenting with a shorter temporal and spatial gait cycle and exhibiting the propensity to place the foot flatter at initial contact, which are mechanisms that avoid tripping and are typically seen when starting to walk. Anterior trunk tilt was also noted (Deconinck et al., 2006). When running decreased smoothness of movement and inferior speed when compared to typically developing children has been pointed out.

Deficient balance control and lack of predictive response were noted, presumably associated with diminished sensory integration and feedback mechanisms which is understandable given the fact that DCD is a disorder of process planning and execution. In simpler tasks, adjustments are delayed but still feasible despite increased reaction time, however when performing actions that require complex sensory integration, task completion becomes much harder and might not be achievable (Verbecque et al., 2021).

The lack of coordination makes success in sports activities far less achievable. Getting involved in demanding activities that require superior balance and coordination control like rope skipping, riding a bicycle or skating increase the risk of fall and injury. Typically, children with DCD have a marked trouble with ball associated activities, translating the decreased eye-hand coordination, thus catching, throwing and kicking a ball is subject to inaccuracies. Because a lot of those activities are group sports (like basketball or volleyball for example), when played with normally developing peers, the unfruitful performance leads to frustration, and poor self-esteem. Other children are normally aware of the graceless performance and might not want them on their team, not being unusual that children with DCD are left until last when putting together a team. The feeling of failure contributes to withdrawal from these activities (especially collective

ones), leading to a more sedentary lifestyle and higher incidence of social exclusion and bullying (O'Dea et al., 2021).

The lack of manual dexterity when performing fine motor sequences lead to difficulties handling everyday objects and tools. It has been found that children with DCD present an increased grip force while holding objects when compared to typically developing peers. This increased safety margin force (exerted force – minimal necessary force) and the displayed increase in contact time with the object before holding it, are findings that support the concept that DCD is marked by diminished kinesthetic functioning and these mechanism aims to overcome these deficits in an attempt to dodge accidental slipping or dropping of the object (Pereira, 2001).

Handwriting skills are, as expected, also affected. It is estimated that 1 in 2 children with DCD has dysgraphia even though their writing impairment may vary greatly. When assessing word legibility many variables come into account, such as pen grip force, hand posture and the movement itself (speed, pen lifting, etc.). There is a predisposition for macrographia explained by ample pen movements, leading to difficulty in writing longer sentences within a given space (Biotteau et al., 2019). Dysgraphia severely impacts academic performance since children with DCD require more effort to write than their peers. Writing difficulties contribute to fatigue and the feeling of being unable to keep up with classes, triggering lack of interest in school activities, taking a toll on school grades which are classically lower than their normally developing colleagues. As seen, writing disorders such as dysgraphia are frequent and, as reported, there is an increased chance of language disorders like dyslexia thus it would not be unusual for dysorthographia to be present as well. The inferior ability to handle a pencil also leads to drawing abilities that fall behind the expected for their age and intelligence, resembling a sketch made by a younger child. It becomes important to take into consideration that the below average academic performance found in classic DCD is attributable to the poor writing skills rather than a specific learning disorder. Not forgetting that other comorbidities such as ADHD (attention – deficit / hyperactivity disorder) which is highly reported in children with a diagnosis of DCD may also be responsible for their poor achievement.

In fact, DCD and ADHD overlap so much that some authors such C. Gillberg hypothesized a common etiological basis (still a target of great debate) and proposed the diagnostic label of Deficits in attention, motor control, and perception (DAMP). In order to avoid reiteration, this topic will be dissected under the section *comorbidities*.

The impaired motor control has a marked negative impact on daily life activities such as self-care (showering, hair combing, teeth brushing), getting dressed (buttoning shirts, tying shoelaces, using zippers) and eating with age appropriate cutlery. Adding to the repeated dropping of objects, recurrent falls and the previously referred motor difficulties, it is not hard to realize why it is important to make an early diagnosis and address the issue.

Diagnostic

Currently, developmental coordination disorder can be diagnosed in light with the DSM-5 (*Diagnostic and Statistical Manual of Mental Disorders : DSM-5*, 2013) if the four following criteria are met (*Box* 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 (eg, dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (eg, catching an object, using scissors or cutlery, handwriting, riding a bike or participating in sports).

B. The motor skills deficit in criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (eg, self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure and play.

C. Onset of symptoms is in the early developmental period.

D. The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (eg, cerebral palsy, muscular dystrophy, degenerative disorder).

Box 1 - DSM-5 diagnostic criteria for DCD.

Criterion A concerns the lack of proficiency when executing motor actions regarding the expected for their age and context. To assess such functioning, physicians can employ specific tools to evaluate motor development such as the widely used Movement Assessment Battery for Children (Movement ABC) or Bruininks-Oseretsky Test of Motor Proficiency (BOT).

Criterion B states that for DCD to be diagnosed the stated motor incoordination needs to constantly exert a negative impact on the patient's daily life activities. Underperforming reportedly leads to lack of motivation and frustration, prompting discontinuation of the affected doings, so it is important to inquire about avoided activities.

Criterion C asserts that the first symptoms must initiate in early childhood.

Criterion D is an exclusion one, stating that there must not be another clinical condition who better explains the child's symptoms, hence the need for the physician to undergo a thorough head to toe investigation, discarding other possible medical conditions. For that reason DCD can be seen as a diagnosis of exclusion.

Children with intellectual disabilities can be diagnosed with DCD if found that the motor deficits are in excess of what would be expected given the child's condition. Currently, there is no IQ cut-off beyond which DCD would no longer be diagnosed. Although age is not an exclusion criteria, diagnosing a child who is less than 5 years old is not routinely performed. When doing so, one must not forget that the same child is susceptible to catching up later due to a delay in motor development. The age of acquisition of daily life activities greatly varies among preschoolers and is reliant on a parent's lifestyle. Also, younger children are less cooperative thus exacerbating motor deficits when undertaking the assessment (Blank et al., 2019).

Evaluating a suspected case of DCD

Some factors and features heighten the likelihood of making the diagnosis of DCD, such as late developmental milestones, writing difficulties, attention deficit disorder, concomitant developmental disorder, learning difficulties or behavioral issues. The previous increase the chance of early referral to a physician. Adding to the widely reported lack of awareness of the condition among teachers and caregivers , a study conducted in Canada noted that 91% of primary care physicians had never heard of the condition (Gaines et al., 2008), hence the obstacle of achieving the correct diagnosis.

Obtaining a full history is the foundation of the assessment. It is important to understand when did the parents first perceive something might be off, what made the patient come to the physician (worsening of symptoms, parents' concern, poor academic performance, etc). It is essential to appreciate how the patient perceives their social standing, what difficulties are experienced amid daily life activities and understanding the impact carried by the patient's symptomatology among home, school and leisure settings. If available, it is always valuable to take into consideration reports of teachers

and caregivers, given that some difficulties are more noticeable in other than the home setting.

Getting access to a patient´s detailed past history such as birth and pregnancy history, developmental history and school performance reports will prove helpful supporting the diagnosis. Family history should not be disregarded, for example, the presence of ADHD on a family member, which has a high heritability and very often co-occurs with DCD (about 1 in every 2 children with ADHD has DCD) (Gillberg, 2003), raise the need of exploring the presence of DCD. Simultaneously, if another family member has or has had similar symptomatology and was diagnosed with another disease, such occurrence decreases the likelihood of DCD, shifting the diagnosis toward a genetic cause.

Diagnostic tools in DCD

Succinctly, physicians can rely on two major types of tests when addressing a child with suspected DCD: standardized motor performance tests and questionnaires regarding daily activities impact. The European Guidelines on Coordination Development Disorder recommend the use of MABC-2 or the BOT-2 to assess acquisition and execution of motor skills and the use of DCDQ-R as additional evidence to support the diagnosis of DCD (Blank et al., 2019). The importance of using motor assessment scales cannot be understated. Providing an objective and standardized measure of evaluating the severity of a child's deficits, they are also essential to evaluate its course. These assessment tools play a very important role when it comes to assess whether a given intervention regimen is effective. Allowing, if needed, for the physician, in consultation with the child's occupational therapist, to switch to an intervention regimen of another nature in order to achieve better functional outcomes.

Movement Assessment Battery for Children (M-ABC 2)

After being revised in 2007, the second edition of the Movement Assessment Battery for Children (M-ABC 2) is today one of the most popular and widely used tools to address suspected cases of DCD**.** This collection of tests was designed to evaluate children

between 3 to 16 years and 11 months, assessing manual dexterity, ball skills (aiming and catching) and static and dynamic balance through 8 tasks for each of 3 age ranges: 3 to 6 years; 7 to 10 years and 11 to 16 years and 11 months. Scores are based on the best performance within the limited attempts for each given activity. Based on the child's age and total motor score, performance is then displayed in percentiles. Children falling below the 5th percentile are found to have significant motor difficulties, and would be considered to have DCD if other diagnostic criteria are met. Between the 6th and 15th percentile, minor motor difficulties are noted and a diagnosis of DCD is possible. Depending on research criteria some authors use different cut-offs when establishing DCD children cohorts, knowing that higher cut-offs will be more inclusive and less specific, and lower cut-offs might underdiagnose children with DCD. A child who scores above the 15th percentile (no significant motor difficulties) has a very low likelihood of being diagnosed with DCD. This tool also comprises a checklist to evaluate motor and non-motor skills in children who range between 5 and 11 years old. The previous should be carried out by teachers, in order to put in evidence the limitations that impair the child's daily life (Cancer et al., 2020).

Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)

The revised version of the Bruininks-Oseretsky Test of Motor Proficiency, BOT-2 is another tool that can be used other than the MABC-2, according to the European guidelines on DCD (Blank et al., 2019), to assess fine and gross motor control in children suspected of having DCD. This tool assesses fine manual control, manual coordination, body coordination, and lastly strength and agility through eight sections (fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper-limb coordination and strength). This tool has the advantage of allowing the patient's score to be portrayed not only based on total motor control, but also for gross and fine subset scores. Another advantage of the BOT-2 is that it comes up both on a short and extensive form, allowing better time management within each given patient setting (Cancer et al., 2020).

Developmental Coordination Disorder Questionnaire 2007 (DCDQ'07)

The Developmental Coordination Disorder Questionnaire (DCDQ'07) is a parent developed questionnaire mainly used as a screening tool, which evaluates their child's control during movement, fine motor and handwriting skills and general coordination through a list of 15 questions. Parents should answer the different items trying to compare their child's performance with typically developing children with the same age. The simplicity of the questionnaire makes its completion accessible, and the little amount of elements makes it quick and easily used in any setting (estimated completion time around 10 – 15 minutes). The scoring system evaluates children in 3 distinct age groups, ranging from 5 to 15 years old. After the form is completed two results are possible: "suspected DCD" or "probably not DCD". The authors of this tool warn that its use alone cannot singlehandedly diagnose DCD although it provides a significant contribution to understanding the child's functioning and difficulties, providing support for establishing criterion B of the DSM-5 on developmental coordination disorder.

Differentiating DCD from other clinical conditions

DCD is a diagnosis of exclusion, as such, it is necessary to inquire and discard the possible occurrence of another clinical entity. Any loss of previously acquired motor skills or rapid deterioration in symptoms should always incite complementary investigation.

Signs such as marked spasticity, tiptoeing, scissor gait, ataxia, or dyskinesia might be indicative of cerebral palsy, which presents with non-progressive movement, posture or motor function impairment caused by fetal or infant brain damage. Both cerebral palsy and DCD share common risk factors such as male sex and being born preterm (Hoorn et al., 2021).

Muscular dystrophies with an early onset presentation can initially be misdiagnosed as DCD (Kirby et al., 2014). History of progressive muscle weakness and atrophy, a positive Gower's sign and calf pseudohypertrophy support its diagnosis.

A recent fall or head trauma correlating with symptoms' onset or decline should point towards a structural lesion instead of a developmental disorder. Moreover, an unexplained rapid deterioration of a patient's symptoms should raise suspicion over the presence of a serious entity such as an expansive mass of the posterior fossa or a stroke. The simple act of looking at patient's skin can unveil the diagnosis of a neurocutaneous syndrome able to mimic some motor manifestations of DCD such as ataxia-telangiectasia (presence of conjunctivae telangiectasias) or neurofibromatosis (presence of *café au lait* spots). Visual impairments, fetal alcohol syndrome and genetic syndromes among others, are also conditions which might initially be misdiagnosed as DCD.

DCD or ataxia?

Both dyspraxia and ataxia impair coordination of movement, therefore it is of great importance to be able to distinguish between DCD and ataxia.

For example, early onset ataxia (EOA), an heterogeneous inherited group of disorders manifesting before 25 years of age, are an important cause of pediatric ataxia. Differentiating between DCD and EOA is challenging due to overlapping signs, as children with severe DCD symptoms and children with EOA who exhibit mild ataxic symptoms may initially present in a fairly similar fashion, phenotypically speaking. (Baxter, 2020; Lawerman et al., 2020; Mannini et al., 2017). It was found that when resorting to SARA (Scale for Assessment and Rating of Ataxia), patients with EOA exhibited significantly higher total and subtotal SARA scores when compared to children with DCD. Also, children with EOA tended to be affected in all their SARA domains, as opposed to children with DCD, where most of the impairment was rather seen in only one SARA domain (Lawerman et al., 2020).

The presence of a wide and unsteady gait, dysmetria, intentional tremor, dysdiadochokinesia, dysarthria or nystagmus should always raise suspicion over the presence of ataxia.

Risk factors for developing DCD

Sociodemographic risk factors

Alongside other neurodevelopmental disorders such as attention-deficit / hyperactivity disorder (ADHD) and autism spectrum disorder (ASD), DCD's prevalence is higher among males, supporting the hypothesis that being a boy conveys intrinsic characteristics that increase the risk of developing the condition. Although gender ratios vary within studies, male favoring is the rule and literature is consensual regarding the fact that DCD is more prevalent in males (see *prevalence*), (Lee & Zwicker, 2021; Zwicker, Yoon, et al., 2013). Interestingly, (Hoorn et al., 2021) noted that, gender played a higher influence in term born children, as disparities between both genders regarding DCD's incidence become less evident in preterms.

Prenatal risk factors

There is low to moderate evidence that children whose parents are subfertile are at increased risk of developing developmental coordination disorder (Hoorn et al., 2021), (parental subfertility defined as couples who only managed to conceive after 12 months despite attempting to).

Perinatal risk factors

Gestational age

A systematic review revealed that the risk of developing DCD becomes significant if a child is born before 32 weeks of gestation (very preterm) (Edwards et al., 2011). One can infer that decreased gestation ages are associated with poorer outcomes, as it has been demonstrated that the risk of developing DCD increases as gestational age at birth decreases. Conversely, post-term birth is not a risk factor for developing DCD and there is little evidence that late preterms are at increased risk for DCD (Hoorn et al., 2021).

Birth-weight

Because being born preterm and having a low birth weight go hand-in-hand, as expected, lower birth weights are also a well-known risk factor for the condition. Literature is consensual that similarly to being born preterm, light weighted babies are at a higher risk of developing DCD later in life. Children born with extremely low birth weights (<1000g) are at increased risk of developing developmental coordination disorder when compared to very low birth weight children (<1500g), (Edwards et al., 2011).

Neonatal risk factors

A retrospective study conducted in a very low birthweight born children cohort (weighing less than 1250g), revealed that postnatal exposure to steroids was significantly associated with the risk of developing DCD later in life, although administered postnatal steroid dose and treatment duration were not taken into account and are yet to be explored (Zwicker, Yoon, et al., 2013).

Post-natal administration of steroids decreases the prevalence of chronic lung disease and promotes earlier extubation in children suffering from bronchopulmonary dysplasia. However, early (first week) administration of steroids revealed an increased risk of cerebral palsy and unspecified abnormal central nervous system examination, hence not being routinely recommended by the authors (Halliday, 2017). Findings revealed that later post-natal steroid administration (after the first week) showed minimal increase in neurological impairment outcomes. In opposition to postnatal steroid administration, antenatal use of steroids does not appear to be linked to significant neurological impairment later in life.

Other risk factors

As children with “pure” DCD are the exception rather than the rule quoting Kaplan (Kaplan et al., 1998), the unveiling of another neurodevelopmental disorder namely ADHD, ASD, speech or language disorders in a child raises the probability of a DCD diagnosis being made in comparison to normally developing peers. Although theoretically risk factors for DCD, these entities will be further discussed under the section *comorbidities*.

Comorbidities

DCD constitutes a condition with a highly heterogeneous population, as the typical patient will have another neurodevelopmental disorder. It is still a target of debate whether there is a *continuum* between some of the overlapping conditions and the possibility of shared etiologies. Concomitant medical conditions such as ADHD, dyslexia, specific language impairment and ASD are some of the most frequently reported comorbidity among those with the diagnosis of DCD, with special attention to ADHD, who is estimated to be present in half of the DCD population. The following are a brief review of frequent co-occurring conditions among this specific population.

Attention deficit / Hyperactivity disorder (ADHD)

The most commonly identified comorbidity of children diagnosed with DCD is attention deficit hyperactivity disorder (ADHD). Features of impulsivity, hyperactivity, and inattention are displayed in a heterogeneous fashion, therefore children are divided into different clusters according to their predominant symptoms. The condition severely affects a child's functioning among various settings specifically at school, marked by the typical inferior achievement and difficulties in maintaining focus in task execution. Patients very commonly have other learning disabilities such as dyslexia and dysgraphia, which heightens the already grim school performance prognosis, requiring medical attention. Regarding the ADHD and DCD overlap, studies found this co-morbidity to be more prevalent in children who exhibit an inattentive or mixed subtype of ADHD (Watemberg et al., 2007). In fact, this overlap was found to be so frequent, that it has been for long a target of research for a better understanding of this association, this co-occurrence gave birth to the DAMP concept.

Deficits in attention motor control and perception (DAMP)

Deficits in attention motor control and perception (DAMP) is a concept proposed by Christopher Gillberg which arose on the framework of a follow up series on a large Swedish children cohort, labeled as having what was known as minimal brain dysfunction (MBD). His initial work aimed at establishing the prevalence of different psychiatric and neurological diseases within that population (Gillberg, 1983). Results revealed that children manifesting with deficits in attention very often had difficulties with motor performance. His work restructured literature as subsequent studies supported the fact that ADHD and DCD very often co-occur, he also proposed that a generalized disorder was to be responsible for children's constellation of symptoms rather than simple overlapping of diagnosis as ADHD and DCD.

Today it is known that up to 50% of children diagnosed with ADHD meet the criteria for DCD and vice versa (Gillberg & Kadesjö, 2003). DAMP affects 3-6% of 7 year-olds and, as expected, boys are more frequently affected than girls, in a ratio ranging from 3:1 to 5:1.

The acronym DAMP implies attentional, motor coordination and perceptual dysfunction. It has been proposed for the diagnosis of DAMP to be established when criteria for ADHD and DCD can be met. Concerning the perceptual dysfunction, it seems that, according to literature, virtually all children with DCD have impaired perception, struggling with nonverbal visuospatial tasks. Implying this deficit to be present whenever a DCD diagnosis is made. Gillberg also proposed a subtype of DAMP targeting those with severe features. The severe DAMP affects 1,5% of children and was diagnosed if a child manifested with a combined (inattentive and hyperactive) ADHD comprising all of the hyperactivity criteria plus the DCD diagnosis (Gillberg, 2003).

It was noted that children with DAMP have more pronounced manifestations, than those to be expected as having this comorbidity, strengthening the concept that ADHD and DCD might share a common etiology which is yet to be validated. Specifically regarding motor abilities, those children who bear a DAMP diagnosis will exhibit more prominent difficulties with motor coordination than others who were diagnosed with only DCD, due to this synergistic effect between DCD and ADHD. Concerning co-morbidities in the DAMP population, literature reports a higher prevalence of dyslexia

and autism spectrum disorders (Gillberg, 2003). In adulthood, findings suggest that individuals with DAMP will reveal less marked motor impairment due to acquaintance and optimization of motor control. Regarding ADHD's symptomatology spectrum, hyperactivity and impulsivity symptoms tend to fade while attention deficits are very likely to endure (Gillberg, 2003).

It is controversial if the use of central stimulants, such as methylphenidate, to treat ADHD in DAMP patients improve DCD's manifestations or its course. Being a relatively recent entity, little is known about long term outcomes of those who were diagnosed with DAMP at a young age, urging for more research on this matter.

Developmental dyslexia

Dyslexia constitutes a specific learning disorder that is primarily marked by difficulties with reading and writing. The condition features a problem with the process of word decoding, as patients will have difficulty attributing a phonological aspect to a specific letter or syllable, resulting in word substitutions, suppressions or letter inversions that frequently make produced speech incomprehensible. Dysorthographia is a very frequent finding in this condition, which might result in unreadable produced text, having a pronounced negative impact in learning and school performance.

Dyslexia is more common in children diagnosed with DCD (Biotteau et al., 2017). Concerning this overlap, the automatization deficit hypothesis has been proposed to explain the etiology of dyslexia. This theory asserts that dyslexics, as compared to normal individuals, when executing a motor task and a non-motor task is concomitantly added, there is a significantly decreased outcome on the primary motor task, proposing that there is an intrinsic lack of automatization. This theory, with regard to the motor problems, might prove a bridge between dyslexia and DCD, however further studies are needed to unfold this link (Visser, 2003).

Language impairment (LI)

Children diagnosed with language impairment (LI) exhibit a marked delay or impaired aptitude to understand and/or produce language. Patients can be labeled according to their impairment: receptive, expressive or mixed receptive-expressive language impairment. Given the child's age, a diminished vocabulary, an altered meaning of words and a poor grammatical aspect of language are some of the findings present in those diagnosed with LI.

Roughly 1 in every 3 children diagnosed with LI meet the criteria for DCD (Flapper & Schoemaker, 2013). Given the high prevalence of motor problems in this specific population, it has been suggested that LI is not a specific disorder of only language and that there might be a common etiological factor causing both linguistic and motor problems (Caçola et al., 2017; Hill, 2001). *Praxis* incoordination found in LI patients was comparable to those found in DCD children, as research points that children with LI also struggle with gross and fine movements to some extent when compared to typically developing children (Hill, 2001).

Children with DCD are prone to become socially dysfunctional as there is propensity towards lack of participation in activities and social isolation. When besides DCD, a LI diagnosis is present, this tendency intensifies as the deficit in communication poses another barrier concerning social interaction.

Autism spectrum disorder (ASD)

The designation ASD refers to a complex and heterogeneous group who exhibit a wide range of behavioral symptoms impacting the ability to communicate and interact with others and often displaying stereotyped movement patterns and specific interests. The prevalence of children and adolescents diagnosed with ASD who meet criteria for DCD could be as high as 90% (Green et al., 2009; Miller et al., 2021). There is limited data on the prevalence of ASD in the general DCD population, which might be due to the great motor features overlapping between both conditions.

In previous versions of the DSM manuals, for the diagnosis of DCD to be established one had to rule out pervasive developmental disorder (PDP). In light of the new DSM-5, it is now possible to make a diagnosis of DCD in a child with autism spectrum disorder (ASD).

It is important to take into account that motor symptoms (fine and gross) are impaired in a similar fashion between both conditions phenotypically speaking, being highly prevalent in the ASD population. Gestural performance is impaired in ASD children although that is not typical in DCD and distinct patterns of executive functioning and neural signatures have been pointed out between DCD and ASD (Caçola et al., 2017). Similarities between both conditions exist but the differences are preponderant, supporting the hypothesis that both conditions are distinct and can overlap, making a common etiological basis less likely.

Obesity and decreased overall physical fitness

Children with DCD perceive themselves as clumsy and are unable to keep up with their colleagues in sports activities. This intrinsic decreased ability leads to physical activity avoidance, guiding them into a sedentary lifestyle with described increased incidence of obesity among this population (Tsai et al., 2014) and a higher risk of developing cardiovascular and metabolic diseases later in life. Decreased fitness levels are frequently seen as a result of inactivity (Cairney & Veldhuizen, 2013), namely lower aerobic tolerance, inferior strength and flexibility.

Encouraging physical activity among this population is of major importance, given the fact that inactivity and obesity promote lack of stimulation, taking a dampening effect on development of motor control at young ages. This fact fuels inferior aptitude when performing physical tasks and thus contributes to more inactivity due to avoidance.

Mental health

DCD places children in a vulnerable state from a psychological standpoint. The inferior performance experienced daily takes its toll upon children's mental health and frequently leads to anxiety and/or depression (Draghi et al., 2020).

In pediatric ages, children are often subject to exclusion from activities that demand higher motor control, such as playing collective sports. Being among the last ones to be picked when forming teams in physical education, these children recognize their inability to perform and, as a result, often isolate themselves, withdrawing from activities, avoiding the negative feedback from their peers and consequently, they tend to socialize less. The constant struggle with daily life activities leads to persistent frustration and low self-esteem, decreasing the likelihood of psychological well-being.

During adolescence, children with DCD appear more prone to develop mental health disturbances with regard to their impairment (Zwicker, Harris, et al., 2013) than in early childhood. Evidence also points that adults with the diagnosis tend to present more anxious or depressive traits than normally developing adults (Caçola, 2016).

It is important to note that not all children with DCD will develop emotional problems, although at risk, other factors such as their social skills and intelligence will influence how each child’s emotional response will be (Draghi et al., 2020).

Pathophysiology

Understanding dyspraxia

Dyspraxia is the hallmark of developmental coordination disorder. The words apraxia and dyspraxia derive from the Latin *praxis*, which designates the act of putting an idea into practice. In the medical context, *praxis* refers to the ability to perform complex and purposeful actions. Thus, the two terms apraxia and dyspraxia highlight conditions in which there is a dysfunction of the *continuum* of the act. Dyspraxia can be recognized by difficulties in learning and acquiring motor sequences, action planning and underperformance in execution, in the absence of other conditions or gross deficits that could explain such impairment. In dyspraxia, the planning and execution deficit is due to a learning disability, whereas in apraxia, there is a loss of execution capacity which occurs for processes that had already been previously acquired. The underlying etiology of dyspraxia can either be primary or secondary, with DCD constituting a primary cause, thus being also referred to as developmental dyspraxia.

In contrast to dyspraxia, apraxia is a more well-described and consensual subject given the fact that a great part of cases are secondary with structural lesions, providing useful material in order to pinpoint specific affected brain areas.

Acknowledging that motor coordination is a complex process that requires harmonious integrity and functioning amongst various brain structures, unnoticeable changes in the gross brain structure can easily be recognized in a clinical perspective.

DCD'S neural basis

Regarding DCD's pathophysiology, there is limited evidence concerning the underlying neural abnormalities present in these children, as opposed to ADHD, for example, which has been thoroughly a target of great research. However, in the later years, an increasing

number of studies have been conducted in the attempt of unveiling DCD's etiology and pathogenesis, therefore a brief review of relevant development is herewith presented.

Functional connectivity

Using resting-state functional magnetic resonance imaging (fMRI) it was found that the left thalamus and the right lobule V of the cerebellum had higher functional connectivity with the left SM1 (primary motor and somatosensory cortex) than with right SM1 in DCD and ADHD children cohorts when compared to typically developing (TD) children, which the authors attribute to an increased effort in optimizing right (dominant) hand dexterity (McLeod et al., 2016).

In DCD children, the right putamen did not display intrahemispheric dominance (in TD children, the right putamen displayed higher connectivity with the right somatomotor cortex when compared with the left SM1). Given the significant role of this structure in learning, action planning, initiation and automatization, these findings are hypothesized to explain the existing motor deficits found in DCD cohorts (McLeod et al., 2016). Interestingly, other authors had already suggested as well that DCD could arise due to atypical brain hemispheric specialization, where DCD patients had propensity towards recruiting left-lateralized networks in executive functioning as opposed to the right-lateralized networks typical in TD children (Querne et al., 2008).

In DAMP patients, higher functional connectivity between visuospatial processing areas (bilateral precuneus, bilateral middle frontal gyri and bilateral inferior lateral occipital cortices) and the left SM1 were displayed. The decreased connectivity between these cerebral areas and the right SM1 might be able to provide an underpinning for the existing visuospatial and sensorial processing deficits found in children diagnosed with DAMP, given the crucial role of the right hemisphere in visuospatial processing. Expectedly, children with higher functional connectivity between right SM1 and visuospatial processing areas had higher motor performances. This study asserts that children with DCD have abnormal functional connections among cortical, subcortical

and cerebellar pathways. Further studies are necessary to clarify which neural findings are specific to DCD (McLeod et al., 2016).

White matter arrangement

A pilot study conducted in children with DCD using diffusion tensor imaging (DTI) revealed lower mean axial diffusivity of motor and sensory tracts compared to TD children. Early results point that the DCD cohort had lower mean axial diffusivity in the corticospinal tract and posterior thalamic radiation. Moreover, overall lower axial diffusivities of these tracts were strongly associated with inferior motor performances (assessed using MABC-2 tool). Decreased axial diffusivity suggests underlying altered axonal, extra-axonal properties or diminished water content, yet similar radial diffusivities found in these tracts between DCD and TD cohorts indicate normal myelination (Zwicker et al., 2012). Being the main voluntary movement control tract, the pyramidal tract plays a crucial role in action execution. It is possible that the lower mean axial diffusivity found in these fibers contribute to the inferior dexterity characteristic of DCD. Similarly to the corticospinal tract findings, further studies are required to endorse if in fact the perceptual deficits can be in part attributable to the proposed impairment of the posterior thalamic radiation. Decreased fractional anisotropy (FA) values were noted in the left retrolenticular limb of the internal capsule in children with DCD and were associated with poorer visuomotor tracing outcomes (Debrabant et al., 2016). Connecting the lateral geniculate nucleus to the calcarine fissure, these optic radiation fibers have a major role in visual perception and microstructural abnormalities could lead to some of the perceptual difficulties perceived by DCD patients.

Psychological theories

Mirror neuron system (MNS) deficit hypothesis

Stimulated when observing a person performing an act and when trying to enact it, the mirror neuron system (MNS) constitutes an essential behavioral network for action learning, understanding and prospective modeling. The fronto-parietal network, involved in "cool" executive functioning, besides comprising the ability to focus and reject distractors also plays an important role in inhibitory control, working memory and ability to conceive and correct action planning.

Believed to be located in the posterior inferior frontal gyrus and adjacent ventral premotor cortex and in the rostral inferior parietal lobule, children diagnosed with DCD revealed hypoactivation and decreased overall functional connectivity between temporal, parietal and frontal cortices (Wilson et al., 2017). Less activation in the inferior frontal gyrus (IFG), namely in pars opercularis, in DCD children has been reported when performing imitation actions, supporting dysfunction of the MNS network (Reynolds et al., 2015).

Internal modeling deficit (IMD) hypothesis

The internal modeling allows for a fast action correction. Whenever a motor plan is put into action, signaling is conducted from the motor cortex through corticospinal tracts in order to execute the planned action. In order to maintain smoothness and achievement of the proposed act, incongruences between the actual action and the projected one are taken into account by effective reciprocal exchange between the cerebellum and visuospatial integration areas, allowing for a faster than sensorimotor (online) feedback action correction (Adams et al., 2014; Kawato, 1999).

Children with DCD have difficulties generating accurate forward predictions regarding their movement, thus their ability to perform skillful rapid corrections is decreased. The IMD theory implies that there is a deficit in this process causing overall below average

movement planning (suggested by impairment in motor imagery and by the inferior ability to generate effective anticipatory postural adjustments). It has been argued that the development of compensatory mechanisms results from the observed inferior predictive control.

Treatment of DCD

Even though indications for intervention depend essentially on the exerted influence of the diagnosis of DCD on activities of everyday living, in accordance with international clinical practice recommendations, it is suggested that all children diagnosed with DCD be offered an intervention plan (Blank et al., 2019). In a similar fashion, children who have difficulties with everyday tasks should be considered for intervention even if criteria for DCD are not met.

There is limited evidence regarding frequency, intensity and duration of interventions (although short course interventions exert positive results). This complicates goal setting for each given intervention type. Also, no studies have reported a training regimen on which a state of no further improvement was reached for DCD cohorts (Blank et al., 2019). It is also unknown if concomitant disorders have influence on the outcome of an intervention (B. Smits-Engelsman et al., 2018).

Choosing an intervention

According to current developments, mechanisms of transfer in DCD remain unclear, making the act of opting for a particular treatment regimen a challenging task. To facilitate this task, it is recommended to take into consideration individual qualities and everyday settings in order to propose a specific intervention program and to manage expectations. Classically, two major intervention options can be recognized: activity oriented and body function oriented, addressed below.

Activity oriented interventions (task oriented)

Activity-oriented interventions are focused on specific goals, based on the individual's context (typically focusing on daily life activities). This treatment has its backing on the principle that systematically and methodically exposing a child to certain specific

activities under a controlled environment can improve internal modeling mechanisms thus being a “top-down” intervention, this is, focused on improving the cognitive aspect of motor control through the principles of motor learning.

Activity oriented approaches have been shown to improve functional performance outcomes, with some studies claiming a faster and better functional improvement in children diagnosed with DCD (B. C. M. Smits-Engelsman et al., 2013), which might explain the increasing trend of activity oriented studies.

It is important to highlight the importance of practice and generalization, as encouraging completion of specific tasks without trying to support generalization will result in improved performance for that particular task without significant repercussions in other daily life activities. As such, it is of major importance that important relatives to the child (parents, siblings, teachers and others) stand able to get involved in these activities in order to promote continuous repetition (increasing opportunities for improvement) of these acts in everyday tasks, enabling generalization of transfer mechanisms to other daily activities.

Some subtypes of this modality of this intervention are worth mentioning such as neuromotor task training (NTT) and cognitive orientation to daily occupational performance (CO-OP) intervention which are the most commonly used effective examples of this intervention. Other less used interventions include motor imagery training and active video gaming.

Neuromotor Task Training (NTT) is a modality of context and activity oriented approach that takes into consideration besides the proposed task, the interaction between the child and the environment. The aim of this approach is to recognize and posteriorly address existing issues within this complex interaction. The interaction in the proposed activities are therefore dependent on the characteristics of the child (strength, arm length, weight, etc.), as well as the environment (display, physical properties and function of an object).

In order to execute the planned task (for example climbing up a set of stairs or climbing onto a step), issues with execution must be identified. Then, the child can be subject to

a series of specific therapy sessions which provide opportunity to learn and to practice increasing challenging tasks in order to overcome previously identified difficulties by adapting the environment and the proposed task (Niemeijer et al., 2007).

Cognitive orientation to daily occupational performance (CO-OP) intervention uses cognitive-based strategies to improve performance of specific tasks based on child chosen goals. Through goal setting, planning, execution and posterior assessment, the child can evaluate whether the employed strategies were successful or not, thus developing new means of overcoming their weaknesses, towards achieving the proposed goal.

More than focusing on motor control, this intervention aims, to a greater extent, to improve the child's action planning, demanding the development of new strategies. It was shown that both the children who took part in a 10 week CO-OP intervention and their parents revealed higher satisfaction levels at the end of the treatment. This therapy also, interestingly, appears to reduce motor overflow on the inactive limb and proximal segments of the body that do not play a role in action execution (Thornton et al., 2016).

The architecture of this approach aims at central planning difficulties of children diagnosed with DCD and explains why there were gains with this intervention on tasks previously handled with limited effectiveness.

Body function oriented interventions (process or deficit oriented)

In contrast with the aforementioned interventions, body function oriented approaches deliver a "bottom up" treatment method, this is, focusing on the perception of movement (kinaesthesia). These interventions are centered on improving sensory perception associated with motor performance rather than on the cognitive aspect of goal accomplishment (characteristic of activity oriented approaches), (Polatajko & Cantin, 2005). The intent of this training is to reinforce motor performance itself through stimulation of motor reworking (Missiuna, 2013).

Sensory integration therapy was a very popular “bottom up” approach in DCD’s earlier days. Developed in the 1960s it aimed to improve disorders of the sensory processing and was used as a treatment in children who had DCD, considering that improving the processing of sensory inputs would improve body functioning and coordination.

Some authors claim that process oriented approaches are grounded on old-fashioned neuromaturational theories (Missiuna, 2013), with inconclusive evidence with regard to their efficacy (Wilson, 2005), leading to some authors recommending a shift from process oriented to task oriented approaches (Polatajko & Cantin, 2005). Also, a recent meta-analysis regarding the efficacy of interventions revealed weak efficacy of process oriented interventions (B. C. M. Smits-Engelsman et al., 2013).

Traditional physical therapy and occupational therapy

Broad and classic interventions such as physical and occupational therapy have been shown to improve perceptual-motor control in individuals with DCD and remain an effective option in improving the quality of life in patients with DCD, as shown by various research studies (B. C. M. Smits-Engelsman et al., 2013). These approaches are designed to improve the fundamental gross motor skills (trunk stability, balance, throwing, catching, kicking, jumping, etc.), fine motor skills (cutting, lacing, buttoning, etc.) and body awareness activities (pointing, tracking, moving). By combining underlying process-oriented with activity-oriented approaches this intervention plan constitutes a broader and encompassing therapy.

Group intervention

While both individual and group therapies are related to improvement in outcomes regarding improvement of motor control in daily life activities, it is still uncertain whether group intervention is superior to the individual intervention or the other way around. Nevertheless both treatments appear to be associated with favorable progress towards everyday tasks (de Hóra & Larkin, 2019).

Group interventions appear to greatly improve children's participation in activities and self-esteem (McWilliams, 2005). Given the major issue with these children's self-esteem and increased effort in engaging with others, group intervention may serve as a dual purpose treatment. Designed to also be participation oriented, as opposite to primarily focusing on improving the child's motor performance.

While group interventions can be very useful in improving social functioning, large groups may also have a negative impact by exacerbating anxiety among children. This can be explained by their fear to underachieve among their peers and the inevitable judgment of their performance based on their colleagues (Caçola et al., 2016). As such, it should be noted that children who perform very poorly may benefit from individual or small group intervention as well as those with established anxiety disorders

Although ideal group size could not, not so far, be determined (based on the little existing evidence on this matter), groups of four to six people appear to show promising results (Blank et al., 2019).

Targeting handwriting

Despite the lack of unanimity regarding which intervention provides the most effective results in improving handwriting and penmanship, the combined targeting of motor and graphic components of handwriting, appears to be the core of the majority of treatments put up at the present time (Biotteau et al., 2019).

Children with dysgraphia must be taught about the importance of writing. One must be mindful that dysgraphic children have a severe dislike for writing, as such, children must be offered simple tasks that focus on the fundamentals of writing and steadily progress to more demanding ones in an attempt to overcome writing avoidance.

Occupational therapy can and should be carried on and off the school setting with the purpose of heightening motor and perceptual awareness of one's penmanship, so that the child gains fluency and can improve the legibility of the written trace. It appears,

according to studies of handwriting interventions, that improvements in children's handwriting legibility are more achievable than enhancing the rate of written text (Feder & Majnemer, 2007).

Given the rapid development of modern technology we can expect to see a growth of resources and electronic tools, such as new applications, virtual reality and tablets designed to improve handwriting skills, even though pencil and paper tools are irreplaceable.

Pharmacological approaches

Individuals diagnosed with ADHD and DCD (DAMP) benefit in a great extent from stimulants (such as methylphenidate) with regard to improvement of their behavioral issues and handwriting, however more studies are needed to recommend its use on children diagnosed with DCD without ADHD. So far, due to the lack of evidence, international clinical practice guidelines do not recommend the use of any medication or supplement (Blank et al., 2019).

Prognosis

Early research on developmental coordination disorder claimed that the motor difficulties present in those diagnosed were transient, with children outgrowing motor deficits. Current investigation revealed that the motor problems affecting these children do not cease to exist, with persistence through adolescence and adulthood (Cantell et al., 1994; Cousins & Smyth, 2003), in a fairly similar fashion to what is seen in other developmental disorders such as ADHD (Rasmussen & Gillberg, 2000). It is estimated that more than half of the children diagnosed with DCD have persistent motor difficulties through adolescence (Blank et al., 2019).

In adulthood, coping mechanisms and avoidance of certain activities may conceal present deficits and, although affected to a lesser extent than children, learning new activities can still be challenging. It can be noted that some of the main concerns of children with DCD are impermanent, as in childhood, difficulties with playing will develop into peer interaction barriers by their teenage years and originating emotional and self-centered issues into early adulthood.

Timing of the diagnosis, severity of symptoms, type of intervention received and co-morbidities can significantly influence the prognosis of DCD (Biotteau et al., 2019; Bo & Lee, 2013), hence the need for interventional approaches early on.

In addition to the formerly addressed concomitant frequent developmental disorders, particular focus should be given to the highly prevalent comorbid ADHD among patients. Children who met criteria for both DCD and ADHD at a young age showed a particularly poor prognosis when evaluated in adulthood, in terms of academic achievement, occupational functioning and psychosocial fittingness (withdrawal from participation, increased risk of depressive disorders and anxiety) when compared to those with only DCD, as demonstrated by longitudinal studies (Gillberg & Kadesjö, 2003; Rasmussen & Gillberg, 2000).

Besides educational, behavioral and motor issues, these children are at increased risk for noteworthy maladies such as obesity and coronary vascular disease.

Given the current poor understanding on the prognosis of DCD further research should include more longitudinal studies in order to be able to further expand our current knowledge and ability to tackle difficulties in a more specific course.

Case series results

Identification	Patient ID (initials)	AL	PD	JS	JR	LM	TM
	Gender	Male	Male	Male	Male	Male	Female
	Age (years)	7	5	10	6	13	10
Diagnosis	Age at which first symptoms were noted	3	4	4	3	5	5
	School year at noticed first symptoms	Preschool	Primary	Primary	Preschool	Primary	Primary
	Who noticed the symptoms first	Preschool teacher	Classroom teacher	Preschool teacher	Healthcare professional	Physical education teacher	Classroom teacher
	Age at diagnosis (years)	5	6	5	3	9	8
	Reason for referral to neuropediatrician	Difficulty cutting and drawing	Dysgraphia	Difficulty cutting and drawing	Motor clumsiness	Motor clumsiness	Dysgraphia
	Diagnostic delay (years)	2	2	1	0	4	3
	Family history of neurodevelopmental disorders	Absent	Absent	**Dyslexia**	**ADHD**	Absent	Absent
School setting	Scholastic difficulties	**Present**	**Present**	**Present**	**Present**	Absent	**Present**
	Dysgraphia	**Present**	**Present**	**Present**	**Present**	**Present**	**Present**
	Dysorthographia	Absent	**Present**	**Present**	**Present**	**Present**	Absent
	Has failed a grade at least once	No	No	No	**Yes**	No	No
Developmental milestones	Object transfer (Normal: 6-8 months)	Normal	Normal	Normal	Normal	Normal	Normal
	Pincer grasp (Normal: 9-12 months)	Normal	Normal	**Delayed**	Normal	Normal	**Delayed**
	Sitting without support (Normal: 6-9 months)	Normal	**Delayed**	Normal	**Delayed**	Normal	**Delayed**
	Crawling (Normal: 6-12 months)	Normal	Normal	Normal	**Delayed**	Normal	Normal
	Walking without support (Normal: 15-18 months)	**Early**	**Delayed**	Normal	**Delayed**	Normal	**Delayed**
	First words (Normal: 12-18 months)	Normal	Normal	Normal	Normal	Normal	Normal
Comorbidities	ADHD (DAMP)	**Present**	**Present**	**Present**	**Present**	Absent	**Present**
	Autism spectrum disorder (ASD)	Absent	Absent	Absent	Absent	Absent	Absent
	Language impairment (LI)	Absent	Absent	**Present**	**Present**	Absent	**Present**
	Dyslexia	**Present**	Absent	Absent	**Present**	Absent	**Present**
	History of depressive disorder	Absent	Absent	Absent	Absent	Absent	Absent
	History of anxiety disorder	Absent	Absent	Absent	Absent	Absent	Absent

Table 1 – Summary of patients' profiles.

Age

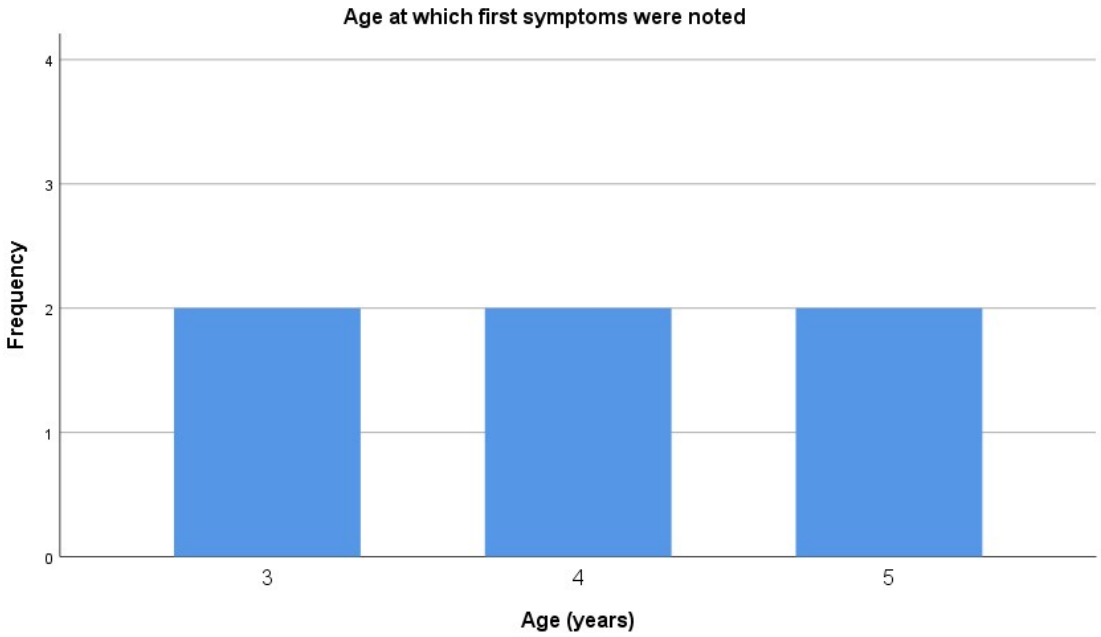

Figure 1 – Age at which first symptoms were noted.

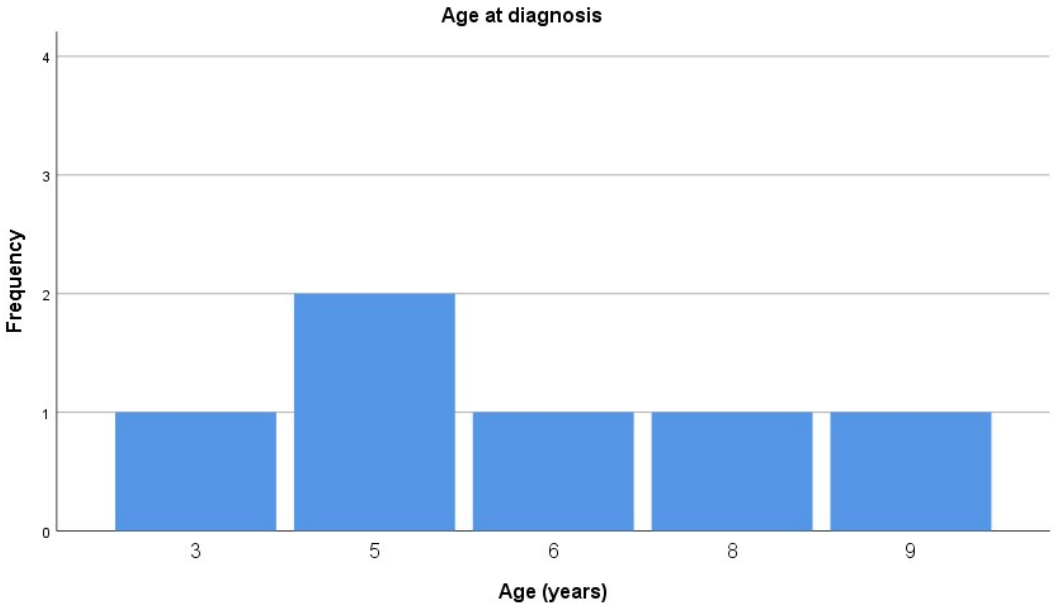

Figure 2 - Age at diagnosis.

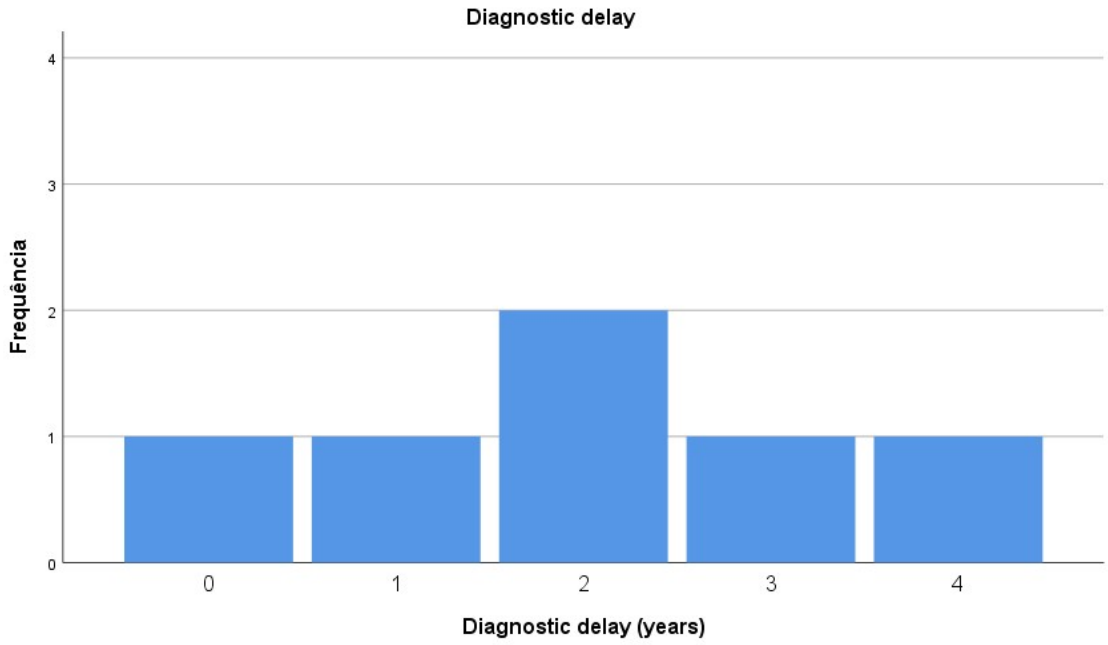

Figure 3 – Diagnostic delay.

Diagnostic delay was on average 2 years, with values ranging from less than 1 year to 4 years after first symptoms (*Figure* 3 and *Table* 2).

Age summary

		Age at which first symptoms were noted (years)	Age at diagnosis (years)	Diagnostic delay (years)
N	Valid	6	6	6
	Missing	0	0	0
Mean		4	6	2
Range		2	6	4
Minimum		3	3	0
Maximum		5	9	4

Table 2 – Age summary.

Early manifestations of DCD were noted between 3 and 5 years in all children of our case series, Figure 1 – Age at which first symptoms were noted.*Figure* 1 and *Table* 2.

Diagnosis was established at five years old or above with the exception of 1 child who was diagnosed at 3. Of all 6 children, only 2 patients were diagnosed before entering primary school, *Table* 1.

Gender

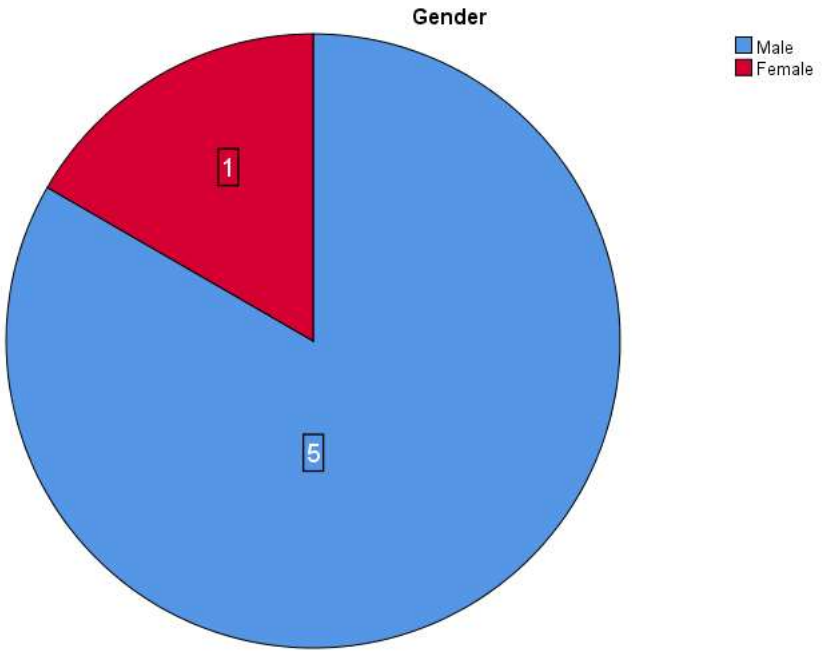

Figure 4 - Gender distribution.

Our case series was composed of 5 males and 1 female, *Figure* 4.

Perinatal

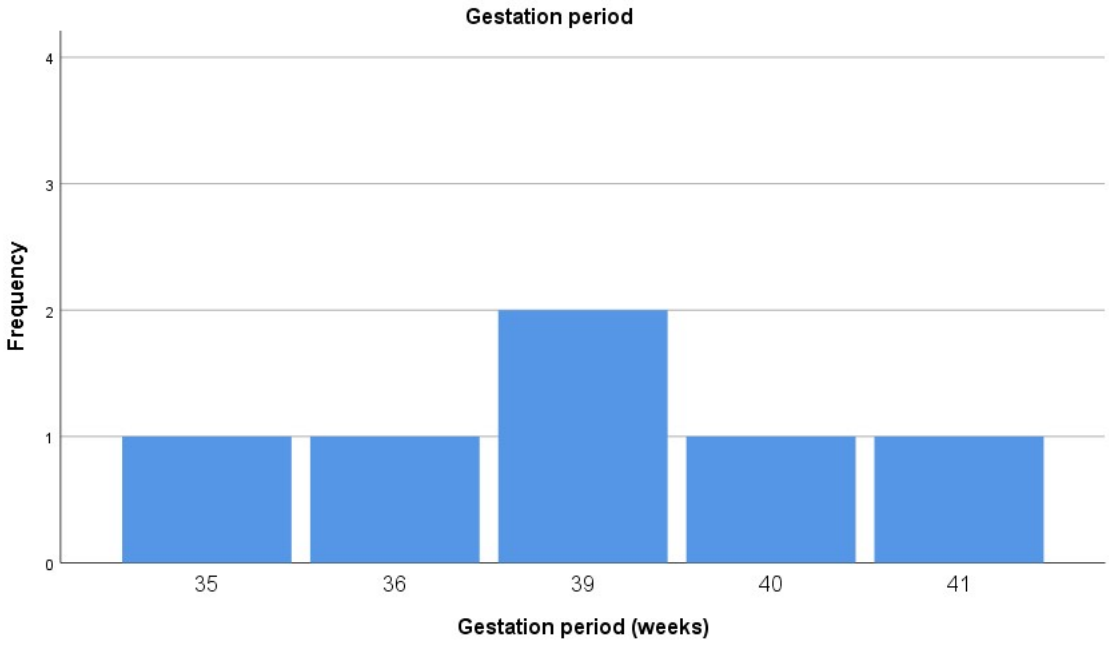

Figure 5 – Gestation period.

Statistics		
Gestation period (weeks)		
N	Valid	6
	Missing	0
Mean		38,33
Range		6
Minimum		35
Maximum		41

Table 3 – Gestation period statistics.

Gestation period ranged from 35 to 41 weeks with an average value of 38,3 weeks, with 4 children being born at term and 2 classified as late preterms. None of the children in our case series was born post-term, as shown in *Figure* 5 and *Table* 3.

Perinatal exposure to corticosteroids					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	5	83,3	83,3	83,3
	Yes	1	16,7	16,7	100,0
	Total	6	100,0	100,0	

Table 4 – Perinatal exposure to corticosteroids.

In *Table* 4 it is shown that 1 patient received corticosteroids during the perinatal period, which corresponds to the patient with the shortest gestation period of our case series (35 weeks). The motive for the use of corticosteroids in this patient was not specified, as well as the cause for his preterm birth.

Developmental milestones

Object transfer					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal (6 - 8 months)	6	100,0	100,0	100,0

Table 5 - Object transfer.

Object transfer was achieved by all children in the standard period of acquisition for this motor skill (6 – 8 months) as seen in *Table* 5.

Pincer grasp					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal (9 - 12 months)	4	66,7	66,7	66,7
	Delay	2	33,3	33,3	100,0
	Total	6	100,0	100,0	

Table 6 – Pincer grasp.

Regarding the pincer grasp milestone, 2 patients were late achievers, while the other 4 were able to attain this skill within the normal period (9 – 12 months), shown in *Table* 6.

Sitting without support					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal (6 - 9 months)	3	50,0	50,0	50,0
	Delay	3	50,0	50,0	100,0
	Total	6	100,0	100,0	

Table 7 – Sitting without support.

In *Table* 7 it can be observed that half (3) of the children in our cohort reported late sitting without support, while the other half revealed a normal achievement (6 – 9 months).

Crawling					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal (6 - 12 months)	5	83,3	83,3	83,3
	Delay	1	16,7	16,7	100,0
	Total	6	100,0	100,0	

Table 8 – Crawling.

Only 1 patient was a late achiever with regard to crawling, with the other 5 reaching this milestone in the expected timespan (6 – 12 months), see *Table* 8.

Walking without support					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Early	1	16,7	16,7	16,7
	Normal (15 - 18 months)	2	33,3	33,3	50,0
	Delay	3	50,0	50,0	100,0
	Total	6	100,0	100,0	

Table 9 – Walking without support.

Table 9 exhibits that half (3) of the patients caught up with walking without support late, 2 acquired it within the normal range (15 – 18 months) and 1 child earlier than the expected.

First words					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal (12 - 18 months)	6	100,0	100,0	100,0

Table 10 – First words.

All (6) children of our cohort articulated their first words in the normal timespan (12 – 18 months), *Table* 10.Even though most of our cohort (4 children) had LI and/or dyslexia, none exhibited a delayed articulation of their first words, with all falling in the normal acquisition period (12 – 18 months), as seen in *Table* 10.

Comorbidities

ADHD (DAMP)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	1	16,7	16,7	16,7
	Yes	5	83,3	83,3	100,0
	Total	6	100,0	100,0	

Table 11 – Prevalence of ADHD.

In *Table* 11 we can see that 5 of our DCD patients have been diagnosed with ADHD and only 1 did not display this diagnosis.

Language impairment (LI)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	3	50,0	50,0	50,0
	Yes	3	50,0	50,0	100,0
	Total	6	100,0	100,0	

Table 12 – Prevalence of LI.

Table 12 – Half of our cohort (3 children) had a previous diagnosis of specific language impairment and the other half did not.

Dyslexia					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	3	50,0	50,0	50,0
	Yes	3	50,0	50,0	100,0
	Total	6	100,0	100,0	

Table 13 – Prevalence of dyslexia.

In *Table* 13 we see that half of the children (3) had already been diagnosed with dyslexia.

It should be noted that no patient had previous history of depressive or anxiety disorders, nor had previously been diagnosed with ASD, see *Table* 1.

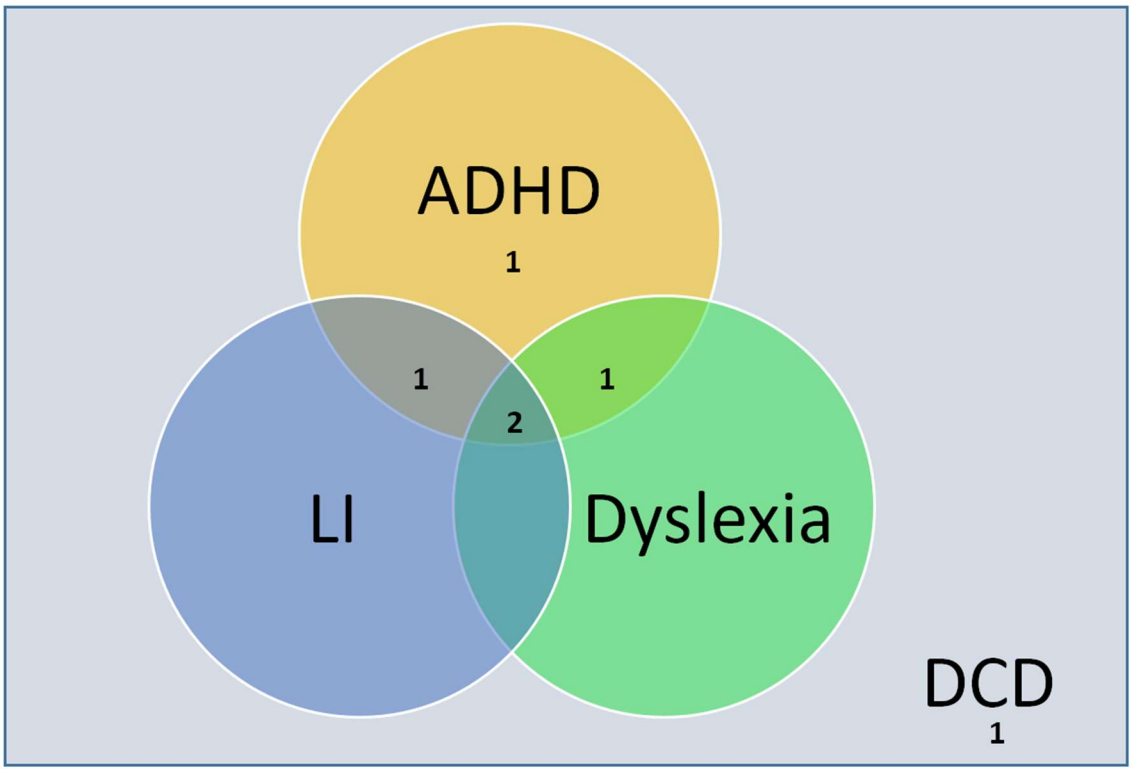

Figure 6 – Overlapping comorbidities among our DCD cohort.

In *Figure* 6 we are able to see the intricate overlap among the various developmental disorders present in our cohort. Besides DCD (present in all patients), 1 patient had concomitant ADHD, 1 had ADHD and LI, 1 had ADHD and dyslexia and 2 had ADHD, LI and dyslexia. Only 1 patient presented with DCD without further comorbidities.

Academic impact

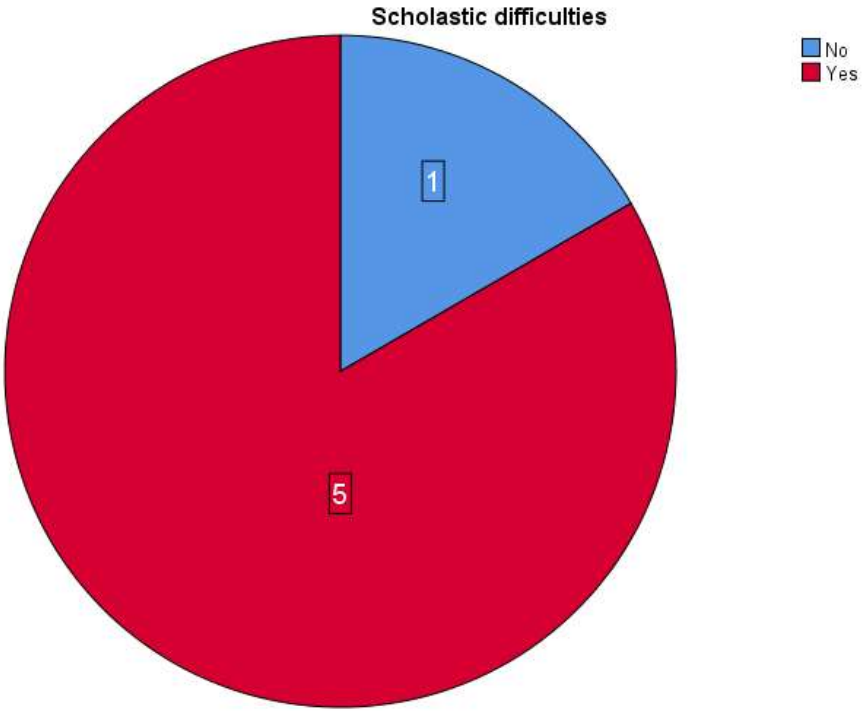

Figure 7 – Stated academic difficulties.

When asked if the child experienced constant difficulties with their academic performance 5 responded favorably and 1 denied, see *Figure* 7.

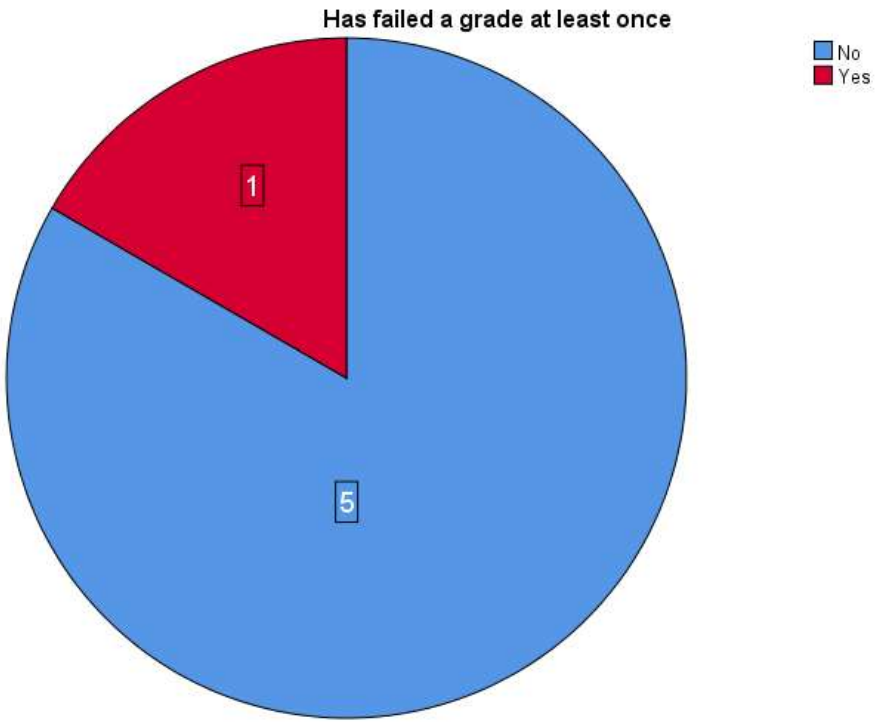

Figure 8 – Grade retention.

Despite the high proportion of patients reporting educational difficulties, only 1 patient had previously flunked (*Figure* 8), however it is important to emphasize that reasons behind this occurrence have not been gone into.

Dysgraphia

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100,0	100,0	100,0

Table 14 - Presence of dysgraphia.

All (6) patients in our case series had dysgraphia, see *Table* 14.

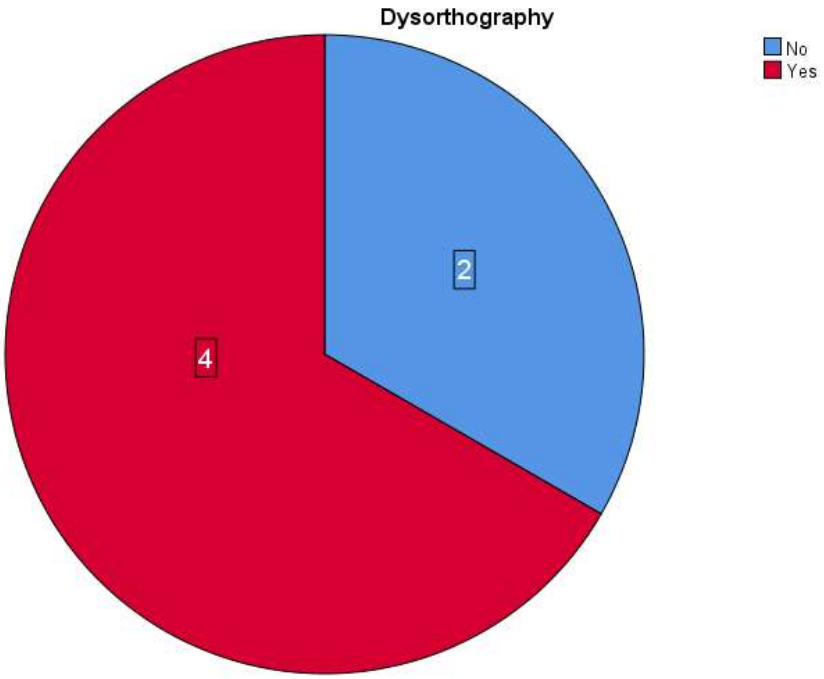

Figure 9 – Presence of dysorthography.

Dysorthography was exhibited by 4 patients and 2 did not *Figure* 9.

Diagnostics

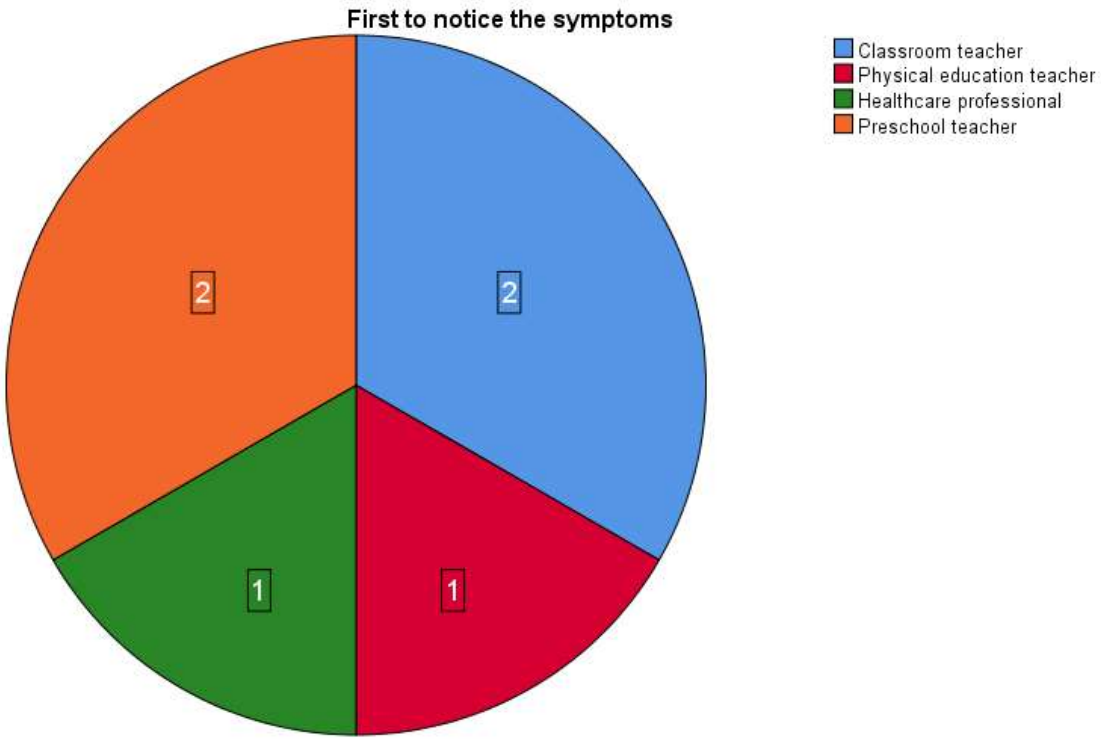

Figure 10 – Person who first noticed patient's symptoms.

In *Figure* 10 we see that classroom teachers were the ones who first detected uncharacteristic symptoms in 2 students. Physical education teachers also first noticed these signs in 2 other patients. A preschool teacher was responsible for noticing alterations in 1 child. With regard to the last child, their healthcare professional was the one who noticed (and also promptly diagnosed) early manifestations in 1 patient.

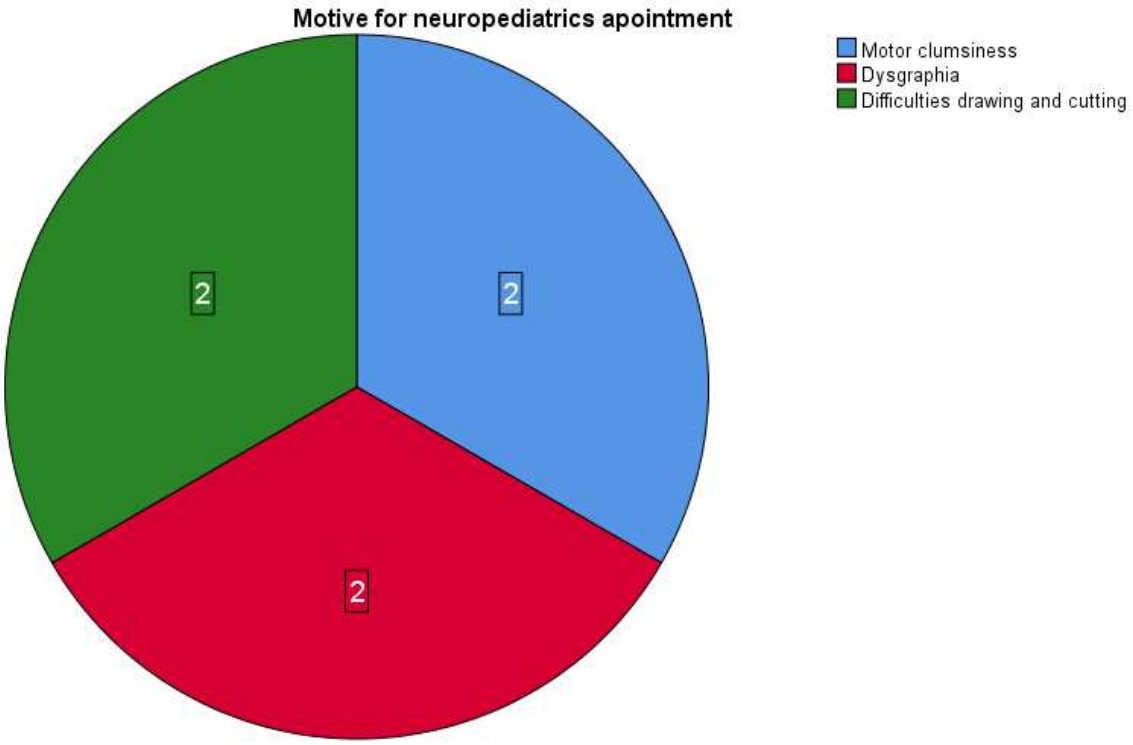

Figure 11 – Symptoms which lead to a physician assessment.

Figure 11 reveals the different motives for referral to a physician. Results were distributed equally among patients, with 2 reporting motor "clumsiness", 2 with dysgraphia and the other 2 with difficulties drawing and cutting.

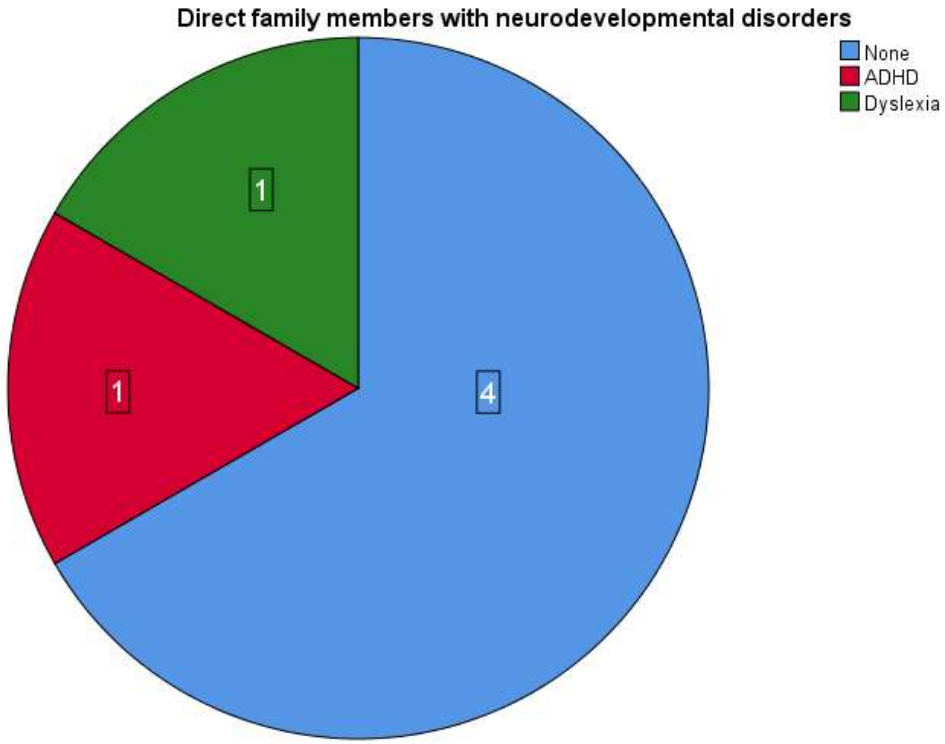

Figure 12 – History of neurodevelopmental disorders among direct family members.

Figure 12 shows that 1 patient had a direct family member with previous history of ADHD, 1 patient had a direct family member with dyslexia and the rest of the children had no familial history of neurodevelopmental disorders.

Developmental coordination disorder questionnaire (DCDQ) results

Statistics				
		DCDQ score before treatment (points)	DCDQ score after treatment (points)	DCDQ total score improvement (points)
N	Valid	6	6	6
	Missing	0	0	0
Mean		32	47,5	15,5
Range		17	13	14
Minimum		22	41	9
Maximum		39	54	23

Table 15 – DCDQ score summary

In *Table* 15 we can see that before treatment our cohort had a mean DCDQ score of 32 points, which after treatment increased to 47,5 points (average improvement of 15,5 points). This questionnaire was conducted by the parents.

DCDQ results (in accordance with age) before treatment					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Indication of DCD or suspect DCD	6	100,0	100,0	100,0

Table 16 - DCDQ result (in accordance with age) before treatment

Table 16 indicates that, according to the DCDQ, all the patients (6) had indication of DCD or suspect DCD (note that the overall sensitivity of this questionnaire is 84,6% and the specificity is 70,8%).

DCDQ results (in accordance with age) after treatment					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Indication of DCD or suspect DCD	4	66,7	66,7	66,7
	Probably not DCD	2	33,3	33,3	100,0
	Total	6	100,0	100,0	

Table 17 - DCDQ result (in accordance with age) after treatment

After treatment, as seen in *Table* 17, 2 children managed to improve their functioning so that they would no longer be labeled as suspected cases of DCD. The remaining 4 children kept their label of suspect DCD as in before treatment.

Treatment

Type of treatment conducted					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Occupational therapy	6	100,0	100,0	100,0

Table 18 - Type of treatment conducted.

Table 18 – All (6) patients underwent intervention regimens. Curiously, every one of them underwent an occupational therapy based intervention. We were not able to get access to the specifics of their interventions such as time and specific tasks and techniques used.

Improvement of symptoms after treatment					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	100,0	100,0	100,0

Table 19 – Improvement of symptoms after treatment.

Table 19 - When inquired on the effects of their intervention, all patients stated that they experienced an improvement of their symptoms after their treatment regimen.

Pharmacotherapy

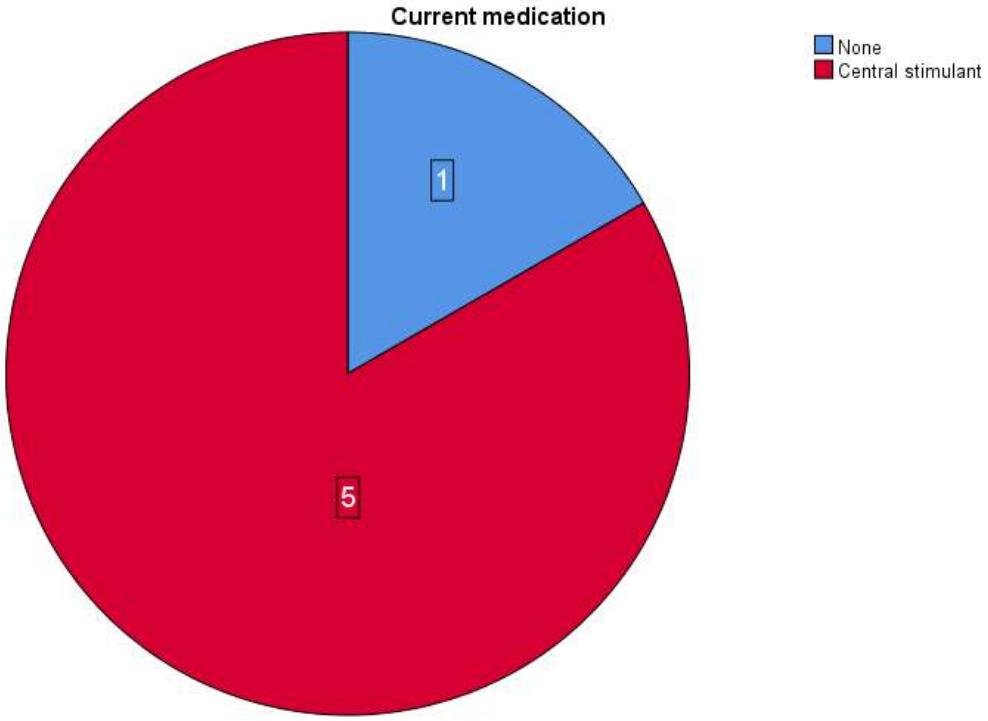

Figure 13 – Current medication.

In (*Figure* 13) we can note that 5 patients were on a central stimulant at time of inclusion in this case series and only 1 was not (*Figure* 13). All 5 children on a central stimulant had previously been diagnosed with ADHD. The one patient not receiving any stimulant drug did not have ADHD. Because central stimulants have no evidence of improving DCD's manifestations, its prescription is not recommended with respect to DCD.

Discussion

Regarding the 2 patients that were diagnosed before entering primary school, these results approximately converge with literature's proportion of 1 in 4 (Gibbs et al., 2007). Because most children in our cohort were diagnosed at 5 or above, our findings are in accordance with the standard practice of not routinely diagnosing DCD in children less than 5 years old due to diminished cooperation and a possible later "catch up" phenomenon, even though age is not an exclusion criteria, *Figure* 2 and *Table* 2.

Concerning diagnostic delay, it is difficult to parallel these results with literature data because of the small dimension of our cohort and the fact that the oldest child was only 9 years of age when the diagnosis was made, leaving a gap on diagnostic delay in older children. Due to this feature of our cohort, it is expected for the real diagnostic delay of DCD to be higher than what we have found. Also, the social environment was not explored, whereas it is known that ease of access to healthcare and higher sociocultural statuses will be associated with less diagnostic delay.

Going alongside the tendency for male predisposition for neurodevelopmental disorders, our DCD case series was composed by 5 boys and 1 girl, as seen in *Figure* 4, resulting in a 5:1 male to female ratio, thus, falling between the DSM reports with regard to gender distribution (stated as ranging from 2:1 to 7:1), (*Diagnostic and Statistical Manual of Mental Disorders : DSM-5*, 2013).

Gestation period findings revealed a slight tendency towards prematurity as literature states, however we should again warn of the heterogeneity of our results and the small dimension of our sample. Regarding the one patient who was administered perinatal corticosteroids, it would be of interest if we were able to get access to the specific drug used, dose, administration timing and duration of treatment. Sadly, this was not possible due to the nature of our process of data retrieval. Still, due to the size of our sample it would hardly be feasible to make inferences.

Although unspecific of the condition, delayed milestones are frequently the first manifestations of DCD, even though many may achieve them in a fairly unremarkable fashion, as reproduced by our data. Walking without support and sitting without support

were the milestones on which most children had difficulties with. The fact that no children exhibited delayed first words was an interesting finding, especially given the frequent type of comorbidities that most children bore (such as language impairment and dyslexia). These delays should always raise suspicion over the presence of a neurodevelopmental disorder. Whenever a child has delayed milestones and is slightly "clumsy", even if he or she does not meet criteria for DCD, the physician should always reinforce the practice of physical activity and in selected cases specific motor training approaches.

It is reported in literature that approximately half of all patients diagnosed with DCD will have concomitant ADHD (Gillberg, 2003). Our case series results endorse this strong link between both clinical entities as 5 of 6 children also had this diagnosis. Besides ADHD, developmental dyslexia is another condition that frequently goes along with DCD, as expected half of our cohort had this comorbidity.

With regard to emotional problems, interestingly none of the children (6) included in this case series had a previous history of depression or anxiety, see *Table* 1. It should be taken into consideration that our cohort is relatively young with an average age of only 8,5 years old and this findings does not exclude subsequent psychological issues, which are in fact very frequent. Also, it is important to remember that mental health at young ages does not bear a high awareness, as seen in adolescents and adults, this circumstance increases the chance of a possibly missed diagnosis. We also reinforce the disclaimer that there was not conducted a questionnaire in order to ascertain if these clinical entities were present, instead, we based our data on the patient's past history. This fact, in addition to the above, possibly could explain our diverging results from literature reports regarding the high prevalence of emotional issues among patients with DCD.

In *Figure* 6, the lack of representativeness of DCD-only children among this cluster of patients corroborates that "pure DCD" patients can, in fact, be seen as the exception rather than the rule. Given the miscellaneous presence of developmental disorders in children with DCD, it becomes easy to understand why some authors theorized unified diagnosis such as DAMP. While it is still a cause of debate whether a common etiological

basis exists, this heterogeneous occurrence of developmental disorders makes finding a neural signature specific to DCD much harder.

The vast majority of our cohort stated difficulties with their academic performance with many experiencing handwriting difficulties, as all children had dysgraphia. This fact reinforces the need for addressing and reinforcing the child's penmanship and not only caring for their blatant gross motor impairments.

Remarkably, no parent had awareness that there might be something "off" with their child in such a manner that it would lead them in finding a healthcare professional to conduct an assessment. One should note that all the people noticing symptoms in the patients of our case series (both teachers and healthcare professionals) had means of comparison with their peers and/or knowledge on the matter. It would be important if awareness lectures were carried out among parents, especially at young ages in order to prevent social isolation and low self-esteem in the future (particularly in adolescence, a time when self-depiction and self-image play an immense role in the child's daily life). The first person to detect early manifestations of DCD varied greatly as well as the motive for referral to neuropediatrics appointment.

All patients in this case series were able to improve their motor performance (according to the DCDQ with an average increase of 15,5 points) and all stated that they felt the improvement. One very important observation to be made is that DCDQ serves its use as a screening tool, however, due to its impossible way of being employed in a retrospective study as ours and to some extent due to lack of funding, we did not possess means to use more objective and validated tools for evaluating motor deficits in a detailed and accurate fashion in DCD patients, such as the MABC-2 and BOT-2. Because the DCDQ is free to use and it can (at the cost of increasing the risk of bias) be used retrospectively , it provides an easy and accessible mean of having an understanding on the impact that symptoms exert on the child's daily life activities, reason why we employed this tool in our case series. The DCDQ is, as the name states, a questionnaire. This questionnaire may also be subject to interpretation by the person responding (parents).

There also remains the doubt, given that every child underwent the same intervention program (occupational therapy), on the awareness and employment of other treatment

regimens such as neuromotor task training, group and cognitive based interventions in Portugal. Nevertheless, occupational therapy is a somewhat vast term, traditionally including a wide range of tasks of different nature. Still, it would be of interest to explore the spread of newer and focused approaches in the future with a broader cohort.

Because it was not possible to get access to the duration of intervention for most of the patients and knowing that we have a small sample, we chose not to exhibit those results.

Also, keeping in mind that 5 children were on a central stimulant and improved their symptoms, the question remains if this pharmacological approach is to some extent helpful in ameliorating DCD's manifestations in children with ADHD. Besides the lack of literature support we could not dare to try to answer this question due to the nature and size of our study.

Conclusion

Despite not being a recent clinical entity, DCD remains a poorly understood developmental disorder. Despite the increasing tendency for conducting more studies on this matter in recent years, due to its high prevalence, lack of awareness and little understanding on how to improve its manifestations, it becomes of major relevance to carry out more research and efforts in order to better understand this intriguing condition. When contrasted with the literature review, our case series confirms the overall current understanding on this subject.

We confirmed the male predisposition for developing DCD, as well as that comorbidities were extremely frequent, as our cohort possessed very heterogeneous and overlapping developmental profiles.

Our findings revealed that there were no psychological comorbidities on our sample. We must take into consideration that our cohort was of reduced size and young age of the patients in our cohort. Besides our study's limitations, we must be critical and raise the possibility that the children included might have had at some point depression, anxiety or another psychiatric comorbidity only that it was not diagnosed by any physician at the time. Another explanation for these results is that perchance, because our cohort was diagnosed relatively early, they did not ever get to develop these comorbidities because of the carried out intervention.

Perinatal risk factors demand further investigations as we were not able to get access to birth weight data and did not possess sufficient data to analyze the effects of perinatal corticosteroid usage on neurodevelopmental profiles of our cohort.

Concerning treatment, all patients were on an occupational therapy based intervention. Because it encompasses such a wide range of intervention techniques we could not know for sure the specifics of each patient's treatment regimen. We also do not know about the employment of focused approaches in Portugal. Given the presence of this gray area, it would be helpful if newer approaches could be promoted between occupational therapists in articulation with developmental and neuropediatrics

departments, in order to be able to provide the DCD population with better and innovative approaches.

Despite not possessing validated tools to assess the motor deficits of our DCD patients, according to the DCDQ, after treatment all of the patients improved their motor performance pointing to the effectiveness of occupational therapy in the Portuguese setting.

As a concluding remark, this work serves as a contribution to update the current state of the art regarding DCD and the results of our case series reveal the need for further research with bigger cohorts on this matter, namely with regard to the currently employed intervention regimens for DCD, in Portugal.

The authors have no conflict of interest to declare.

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