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Introduction

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Developmental coordination disorder (DCD) is a neurodevelopmental condition involving problems in motor coordination that affect activities of daily living and academic achievement.[1] It is one of the most common disorders in childhood and affects 5 to 6% of school-age children.[2] Currently, DCD is a dynamic area of study, and much has been updated or discovered in the last few decades about the terminology, etiology, interventions, and consequences of this condition.

DCD was first described in The Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV); and DCD is the preferred term in countries that use the DSM classification, for example, the United States.[2] "Specific developmental disorder of motor function" is the preferred term in The International Classification of Diseases, Tenth Revision (ICD-10), which is used in many European countries.[3] Since DSM-5 was published in May 2013 and ICD-11 officially came into effect on 1 January 2022, much change was observed in the definition and diagnosis of DCD. In the first part of this issue of CASER, we will highlight some of these changes in the newer versions of diagnostic manuals and the clinical practice in Hong Kong.

The exact etiology of DCD is unknown. However, there has been a resurgence of interest in recent years regarding the underlying etiology. Functional magnetic resonance imaging (fMRI), genetic studies, and improved kinematic analysis will lead to a greater understanding in years to come. Some interesting findings will be discussed in the second part of this issue of CASER.[4,5]

Children with DCD could be assessed in a variety of ways, but currently there is no appropriate gold standard of assessment for doing so, nor is there any procedure which would map out the journey from child to adulthood. In many countries, the Movement ABC Battery[6] is the most widely used instrument, and it contains a standardised normative referenced test, plus a criterion referenced checklist. Is the test applicable and valid for our local children? How are children with DCD diagnosed in Hong Kong? Are there any assessment tools that have local norm? With the diagnosis of DCD, what are the current practices in helping these children? In the third part of this CASER, we will discuss and review popular management strategies and intervention approaches of DCD.

Previous research has shown that children with DCD are at an increased risk of suffering from mental health difficulties compared with their peers,[7] and findings from cross-sectional studies suggest that young adults with DCD have a higher risk of internalising problems, particularly mood impairments.[8] In the last part of this CASER, we will discuss DCD and its associated psychosocial impacts, from preschool to early adulthood.

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Update on the Definition and Diagnostic Criteria for DCD and Our Local Practice

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To enhance communication between experts, healthcare professionals, patients, and relatives, it was deemed important to develop a generally recognised definition of developmental coordination disorder (DCD). The definition of DCD was the subject of an expert consensus. Two systems are most popularly used worldwide: the first system is from the American Psychiatric Association, The Diagnostic and Statistical Manual of Mental Disorder, Fifth Edition (DSM-5)[1]; and the other is from the World Health Organization (WHO), The International Statistical Classification of Diseases and Related Health Problems, Eleventh Edition (ICD-11).[2] Since DSM-5 was published in May 2013 and ICD-11 officially came into effect on 1 January 2022, many changes were observed in the definition and diagnosis of DCD.

In addition, the European Academy of Childhood Disability (EACD), a well-known academic association that works with children with disabilities throughout Europe, updated the clinical practice guidelines in 2019.[3] They also gave recommendations on the definitions and criteria of DCD. We will look into all these in detail.

Definition of DCD in DSM-5

According to DSM-5,[1] DCD is defined by the following criteria:

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 (for example, dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (for example, 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 (for example, self-care and self-maintenance) and affects academic and school productivity, prevocational and vocational activities, leisure, and play.

C. The onset of symptoms happens 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 neurologic condition affecting movement (for example, cerebral palsy, muscular dystrophy, or degenerative disorder).

Changes from ICD-10 to ICD-11

The ICD describes the clinical status of a patient in a structured manner, a categorisation tool that can be used across countries and in different languages. The WHO updates ICD codes every few years to improve the clinical use, acknowledging the innovation in healthcare. The ICD-11 represents a more comprehensive list of diagnoses.

In the ICD-10,[4] DCD is referred to as "specific developmental disorder of motor function", coding as F82, under "learning disorder", whereas in ICD-11,[2] coding as 6A04, it falls under the broader title of "neurodevelopmental disorder" and the condition is named "developmental motor coordination disorder".

Similarities between ICD-11 and DSM-5

The description of DCD in ICD-11[2] shared a lot of similarities to those in DSM-5.[1] In both systems:

1. Coordinated motor skills are markedly below that expected of the chronological age.
2. Onset occurs during the developmental period and is typically apparent in childhood.
3. It causes significant and persistent limitations in functioning, for example, in activities of daily living, school work, and vocational and leisure activities.
4. It cannot be fully explained by a disease of the nervous system, musculoskeletal system or connective tissue, sensory impairment, or intellectual disability.

Recommendation about the Diagnosis of DCD in EACD

The EACD updated recommendations of clinical practice and guidelines in 2019 to address key questions on the definition, diagnosis, assessment, intervention, and psychological aspects of DCD relevant for clinical practice.[3] Recommendations regarding the definitions and criteria of DCD are as follows:

1. According to the clinical guidelines of EACD,[3] the term developmental coordination disorder (DCD) should be used to refer to children with developmental motor problems in countries which adhere to the DSM-IV-TR classification. In countries where ICD-10 has legal status, the term "specific developmental disorder of motor functions" (SDDMF) (F82, ICD-10) should be used.

However, after the release of ICD-11, the condition is now named "developmental motor coordination disorder".

2. The diagnosis of DCD is made by a medical professional or a team suitably qualified to assess the individual according to the specified criteria.

3. The criteria for the diagnosis of DCD follow closely those proposed in DSM-5 with some minor changes, including the order of Criteria III and IV:

I. The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and sufficient opportunities to acquire age-appropriate motor skills.

II. The motor skills deficit described in Criterion I significantly and persistently interferes with the activities of everyday living appropriate to chronological age (for example, self-care, self-maintenance, and mobility) and impacts upon academic and school productivity, prevocational and vocational activities, leisure, and play.

III. The motor skills deficits are not better accounted for by any other medical, neurodevelopmental, psychological, or social condition, nor are they accounted for by cultural background.

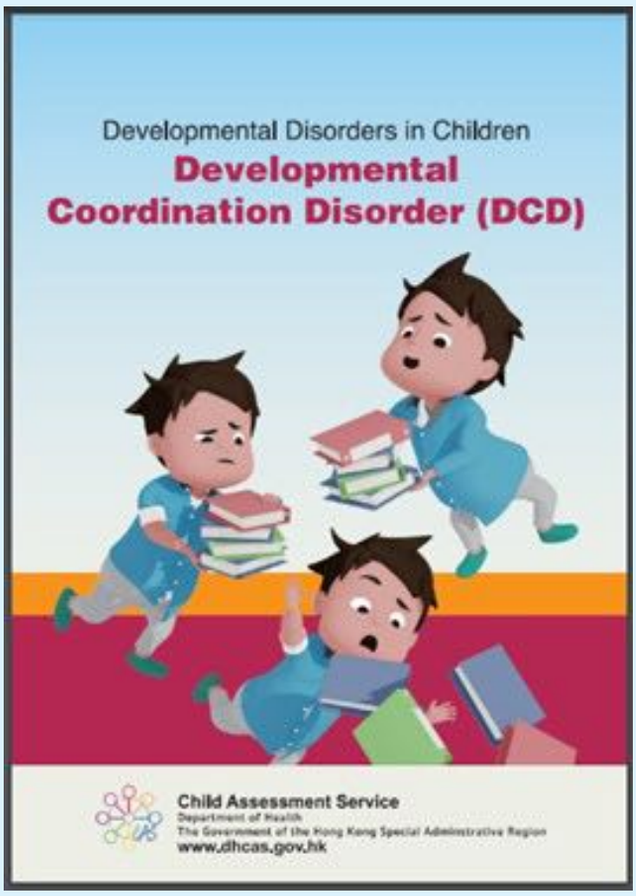
IV. The identification of the onset of symptoms in childhood (although it is not always possible to identify until adolescence or adulthood).

Comment: Criterion I: The symptoms of DCD may include slowness and inaccuracy of motor skills performed in isolation or in combination.

4. A formal diagnosis of DCD under the age of 5 years, made only in cases of severe impairment, is recommended. In such instances, the decision to make a diagnosis should be based on the findings from at least two motor assessments carried out at least 3 months apart.

Local Situation of Diagnosis of DCD

In Hong Kong, primary school children who are suspected to have motor problems are referred to the Child Assessment Services (CAS) for assessment. The diagnosis of DCD in CAS is based on the criteria outlined in DSM-5. One of the criteria is that the motor difficulties are not better explained by other diagnoses, such as intellectual disabilities, visual impairments, or neurological conditions. Therefore, careful review of clinical history and a physical examination are essential to rule out known medical and genetic conditions that may influence the diagnosis, such as severe intellectual disability, cerebral palsy, visual function impairment, or specific neurological conditions affecting movements. Reports from psychologists and psychiatrists are useful in providing further information on other known diagnoses. A neurological examination by a medical professional will be arranged, in order to exclude any neurological conditions.



Academic reports from school are also essential to review the influence on an individual's academic achievement. DCD questionnaires will be filled in by parents, carers, and school teachers, in order to give information on the individual's emotional and behavioural concerns, self-care, activity level, ball skills, academic achievements, handwriting, motor planning, and participation in community settings. Cultural differences are addressed in the questionnaire, especially in activities of daily living.

After the affected children have been diagnosed with DCD, they will be referred to the physiotherapy and occupational therapy department in the hospital authority for treatment-based therapies.

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Etiology Update on DCD

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Developmental coordination disorder (DCD) is a highly prevalent neurodevelopmental disorder (1.8 to 6% of school-age children), with an early age of onset and persistence into adulthood.[1] DCD is a heterogeneous disorder, and its manifestations are varied and often complex.[2] No single cause has been identified, and its etiology appears to be multifactorial.[3,4]

In recent years, there has been a resurgence of interest regarding the underlying etiology. Neuroimaging, genetic studies, and improved kinematic analysis have led to greater understanding in this field.

Neuroimaging Studies of DCD

Previous clinical and experimental studies have indicated that motor skill difficulties in DCD children may be related to dysfunction in various parts of the brain including the parietal lobe,[5] the cerebellum,[6] the basal ganglia,[7] the hippocampus[8] and the corpus callosum.[9] However, because the motor system is highly complex, there was no definite conclusion. Neuroimaging, including structural magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), and diffusion tensor imaging (DTI), creates a new standard in the understanding of the complex cognitive functions in a child's brain.

Since August 2011, there have been around 15 studies about neuroimaging work on DCD. Multiple brain regions (across the association cortex, primary, paralimbic, and subcortical regions) have been associated with DCD, while data on the broader neural network is only just emerging.[10,11] Structural MRI shows reduced cortical thickness of the orbitofrontal cortex in DCD. DTI showed white matter differences in the corticospinal tract, posterior thalamic radiation, and the cerebellar pathways; all three of these regions have known roles in motor coordination.[10,11] However, most of these results were inconclusive.

Interestingly, the patterns of connectivity and neural recruitment in DCD are similar to those seen in children with mild cerebral palsy and born preterm, including evidence of cortical thinning.[12] However, movement artefacts and the use of non-parametric techniques could cause inconclusive results when using functional neuroimaging. Not all the previous studies showed MRI abnormalities in DCD when stringent statistical thresholds were used, nor strong relationships between neural changes and behavioural deficits. Therefore, it would be premature to make firm conclusions about the source of brain alterations in DCD. Those alterations of structural and functional neural connectivity may reflect immature or delayed development of brain connectivity or a developmental disorder of neural connectivity within the brain network as a whole.[13] In future, longitudinal MRI studies are necessary to build a brain-behaviour model of DCD that captures the most likely trajectories.

From these previous neuroimaging studies, we could see that children with DCD have atypical brain development. When compared with typically-developing children, they have different patterns of brain activation and white matter connections, there is less activation of brain regions responsible for motor automaticity, but an increase in activation of pathways for purposeful movement. The frontal-parietal connections, which integrate visual-spatial information, are also different.[14,15] The increased prevalence of left-handedness or ambidexterity among children with DCD compared with the general population (50 versus 10% respectively) suggests that incomplete lateralisation may play a role.[16]

However, most of these studies had small and non-homogeneous samples. The effects of other comorbidities were not controlled. Further research is needed to address these shortcomings. Nevertheless, neuroimaging studies of DCD reported interesting results on the etiology of DCD.

Genetic Studies on DCD

Neuroimaging studies provide descriptions of endophenotypes but do not offer an explanation as to what the underlying cause of a given disorder is. For this, researchers need to investigate the genetic basis of DCD.

Genetic factors are supported by a Swedish study conducted in 2010, on over 10,000 twin pairs in which genetic effects were estimated to account for approximately 70% of the variation in children with DCD.[17] However, the comorbidity between DCD and other neurodevelopmental disorders, particularly attention deficit hyperactivity disorder (ADHD) and specific learning disorders, makes it difficult to determine which gene or genes are responsible for which conditions.

In 2016, copy-number variations have been identified that may indicate a susceptibility to DCD and related coexisting conditions.[18]

In 2021, Mountford et al and their team studied genetic information from over 4,000 individuals in the Avon Longitudinal Study of Parents and Children, who were evaluated for motor coordination at the age of seven.[14] Their results suggest a potential neuronal etiology to motor coordination difficulties. They found out that the gene IQSEC1 would be the most interesting candidate gene that suggests a potential link to axon guidance and dendritic projection processes as a potential underlying mechanism of motor coordination difficulties and is the first step in understanding the causes of DCD.[14] Nevertheless, further validation would be necessary to understand the underlying mechanism.

Environmental Factors in DCD

DCD is a multifactorial disorder in which genetic factors and environmental factors as well as gene versus environment interactions play a role. The importance of environmental factors was underscored in DSM-5 by introducing the new exclusion criterion for DCD, namely the lack of opportunity for skill learning and use.

So far, the following environmental factors have been identified as increasing the risk of developing DCD: lower birthweight (less than 2500 g), lower socioeconomic status,[19] being born pre-term, being small for gestational age, being 15 months of age or more at walking attainment,[20] prenatal exposure to alcohol,[1] Caesarean section, maternal pre-eclampsia and low income.[21] Interestingly, gender differences have been reported. Lower than optimal birthweight was associated with poorer motor outcomes in males, whereas smoking during early pregnancy and stress during later pregnancy were linked to poorer motor development in females.[21] Future studies need to keep testing and refining the knowledge of environmental risk factors in DCD.

To conclude, the etiology of DCD is multifactorial and preliminary results appear to be rather interesting. More well-designed studies need to be done in the future.

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Current Trend and Updates on Motor-based Interventions for Developmental Coordination Disorder

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Many children affected by developmental coordination disorder (DCD) not only have inadequate or delayed motor skills but also decreased coordination, difficulties with motor planning, less mature walking or running patterns, and usually take more time to complete tasks. Those problems would render them less involved in physical activity participation and, consequently, at an increased risk of developing obesity and cardiovascular diseases.[1] Intervention that enhances activity and supports participation is important.

This article presents the recent trend of interventions from a literature review of research studies and international standards of intervention for children with DCD, with a concluding remark for local application.

There have been a wide range of movement-based or motor-based approaches to intervention for DCD. With the rapid development of virtual reality technology (VR),[2] active computer games or video games (AVGs, also known as “exergames”) have been the focus of recent

research on the potential benefits in rehabilitation for this client group. Exergames are video games that are active in nature and are classified under an array of terms including “exergame”, “active video game”, “serious game”, or “interactive video game” and involve consoles such as the PlayStation Move, Xbox 360 Kinect, and the Nintendo Wii. Wii Fit is an active motion-steered computer system which comprises a console and a wireless controller that the user wears on their wrist while mimicking the actions of the sports movements reflected on the console.

Does Virtual Reality Technology Work in the Treatment of DCD?

Figure 1. A screenshot from one of the promotional videos of an exergame

A study by Bonney et al[3] using Nintendo Wii Fit demonstrated that playing active video games provided positive transfer effects on balance tasks (hopping), running and agility tasks, as well as functional activities, including long jumping, sit-to-stand, and stair climbing. The study also suggested that some improvements in ball skills could be achieved, as dynamic balance abilities are trained with the exergames.

The use of VR or video-game-based intervention has potential benefits over traditional methods in that increased engagement, motivation, practice and repetition of movement, more challenging and varied activities, and instantaneous visual and auditory feedback[4] are possible (Figure 1). The feedback and motivational experiences make it conducive for children with DCD to learn new skills. The frequent augmented reality feedback also helps children to refine movement patterns to produce coordinated movements.[3]

In the aforementioned study by Bonney, the subjects played games that required weight shifting, anticipatory control, reactive control, and trunk and lower extremity control, which were similar to the majority of real-life skills such as sprinting or avoiding bumping into others during a game of tag or climbing stairs. It was reported that the subjects were able to generalise the balance skills they acquired in game settings to their natural environment.

From the review of 19 studies by Page et al,[4] it was found that the Wii platform was the most utilised AVG tool. The majority of the evidence explored the gross motor outcome of balance and found balance as the most conclusive evidence. It was probably due to the fact that the Wii platform could almost replicate real world balance skills. Lee et al[5] also concluded that VR tools have the feasibility to provide more realistic visual feedback, and that visual feedback is the key to balance skill and control.

Studies for the effectiveness of video games or VR technology for improving motor outcomes in children with DCD reported that the majority of children enjoyed and adhered to the video game intervention.[1] However, there are concerns that children may increase the time spent playing computer games, leading to less active outdoor play, which would offset the effect of encouraging children to engage in more games in sport-related environments. Some studies also noted that skill execution was poorly performed when children played sports video games without guidance.[6] An adverse outcome was reported when using the PlayStation and Xbox console as a home program, which found that children spent significantly less time playing outside during the AVG intervention period.[6] Hence, the relationship between improved AVG performance and engagement in physical activity is still in need of further investigation.[1]

The Roles of Conventional Therapy in DCD

Figure 2. Example of core stability training

While the use of AVGs for children with DCD has been growing, conventional or traditional therapy is still the mainstream. Those approaches to intervention of DCD are also motor based, including body functions, structures intervention, and task-oriented intervention.[1]

The three commonly used body functions and structures intervention programs in DCD literature are core stability training (CST) which aims to improve the muscles strength of the abdominal and lumbopelvic region (Figure 2), cardiorespiratory training (CRT) which aims to improve cardiorespiratory fitness (in particular endurance), and the functional movement-power training program (FMPT) which aims to improve balance and coordination with power and resistance training. Impairments identified in the examination of children with DCD are addressed, with positive outcomes reported in DCD literature.[6]

On the other hand, task-oriented intervention aimed to improve the execution of a task or skill. They focus directly on the functional skills with which a child experiences problems. Examples of task-oriented strategies are available from the official website of CanChild on the pages dedicated to DCD.[7]

Promising results have been reported for task-oriented intervention programs over the past two decades.[8] The four main task-oriented interventions used in DCD literature are motor skills training (MST), neuromotor task training (NTT), cognitive orientation to daily occupational performance (CO-OP), and motor imagery (MI).[9]

Figure 3. Practice jumping over the rope placed in front of the feet as one of the steps to learn rope skipping

Some common principles are shared by those task-oriented interventions. Basically, a task is broken into easier steps to facilitate children's step by step learning of the whole task (Figure 3). Multiple repetitions are to be practised, with varied environments arranged for the task-specific practice. Based on progress, the training would be adapted with increased environmental and task demands. Self-discovery would be facilitated using creative methods, for example, encouraging children viewing task practice videos with the guidance of a physiotherapist to identify modifiable task components. More importantly, accurate feedback would be given so that children understand how to improve.

According to the evidence-based clinical practice guideline (CPG) published by the Academy of Pediatric Physical Therapy of the American Physical Therapy Association 2020,[6] which is an international standard reference, intervention for children with DCD should aim

to improve motor performance, increase body function, and structure impairments to enhance participation at home, school, and in the community.[6] Hence, task-oriented intervention combined with related body function and structures intervention was the recommended approach for children with DCD.

For example, the functional movement-power training program (FMPT) combines a task-oriented approach using functional movement training (FMT), with task-specific exercises modified from the balance section of the MABC[10] with electromyographic biofeedback, to improve balance and coordination with power and resistance training.

For task-oriented programs, CPG recommended motor skills training (MST) and neuromotor task training (NTT) as the first choice, with cognitive orientation to daily occupational performance (CO-OP) and motor imagery plus task practice (MI) as the next choices. This is because the latter two required specific training in addition to the basic knowledge of motor control and motor learning, and more controlled studies are still needed to confirm the effectiveness of CO-OP on clinical tests of motor skill and physical participation.[1]

Figure 4. Soccer training to augment the therapeutic intervention

CGP also recommended supplemental activities to augment the therapeutic intervention. For example, soccer training (Figure 4) which addresses skills that require coordination, speed, agility, endurance, and power. Taekwondo also appears to improve components of physical fitness (balance and strength) that may benefit children with DCD, though it is still unknown if the improvement in balance and strength would be translated to functional skill or motor performance improvement.[11]

However, children with DCD may experience frustration or decreased participation if the demands of recreational sports are greater than their motor, attention, or cognitive skill levels. There is evidence that children with DCD participate less in team sports and experience anxiety in larger groups.[10] Adapted community teams with skilled coaches who can work to assure positive experiences for children with DCD should be sought, wherever possible. Families may also be advised to consider individual or small group sports, such as swimming, hiking, climbing, or running, where performance may be less likely to impact self-esteem.

Local Situation of DCD

In our local situation for school-age children, intensive treatment sessions would not be feasible due to the pressure associated with schoolwork and tight resources. Instead, home program and practice during physical education lessons in school, as well as supplemental activities such as taekwondo or the other extracurricular sports training aforementioned, are recommended to complement the intervention by physiotherapists.

Overall, from the review of literature, when concerning our local situation and the international standard (the

Clinical Practice Guidelines[6]), it is reinforced that intervention for children with DCD should stay close to the tasks and circumstances needed in their everyday life. Training everyday activities with a program that supports learning of complex but self-selected motor skills is important to enhance a child's readiness and willingness to participate in life activities, improve fitness, and prevent obesity.

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Occupational Therapy for Children with Developmental Coordination Disorder in Hong Kong

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Introduction

In Hong Kong, there is an increasing trend of children with developmental coordination disorder (DCD) being referred to the Child Assessment Service (CAS) for occupational therapy (OT) assessment regarding their functional motor problems and difficulties in handwriting and self-care activities. Most cases are identified by parents or school professionals such as teachers and educational psychologists when more obvious problems rise to the surface as the demands of school increases in primary schools. This article aims to share clinical views with updated international and local practice in assessment and management of children with DCD.

Assessment Tools Used for DCD Internationally and Locally

Internationally, the Movement Assessment Battery for Children-2 (MABC-2), the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2), and the Developmental Coordination Disorder Questionnaire (DCDQ) and its revised version (DCDQ-R) are commonly used for identifying children with DCD.[1-5] In order to address the cross-cultural differences, applying internationally developed standardised tests, conducting a validation study, and developing a local reference are crucial. The cultural variability of performance and the interpretation of test scores might hinder or mislead practitioners in their decisions about the diagnosis and the need for

intervention. Therefore, a decade ago, the CAS OT team conducted a study on the BOT in Hong Kong school-age children and found that there was a significant difference in the fine motor performance between Hong Kong and American children, in which the former scored better.[6] In that study, a local reference had been established, which largely facilitated the assessment process and diagnosis for children with DCD, particular that concerning fine motor aspects.

Recently, a new local fine motor test, the Fine Motor Test for the School-age (FMTS) (Figure 1), was developed by the Hong Kong Occupational Therapy Association (HKOTA, 2021).[7] FMTS is a standardised test which provides local age references for individuals' fine motor function aged 6 to 17 years 11 months. The test was reported to have good reliability and validity. The inter-rater reliability is 0.998 and the test-retest reliability is 0.928. The concurrent validity was established by correlating with fine motor subtests of BOT-2 while a group of children with DCD was recruited as a contrast group for comparison. A significant difference was noted for the performance of the DCD group as compared with their age and gender-matched normative sample of FMTS. In addition, satisfactory sensitivity (91.3% for children 6 to 12 years old, 86.11% for children 6 to 17 years old) and specificity (88.57%) measures of FMTS in identifying children with DCD were also reported.

In order to identify the fundamental deficits of children with DCD, sensory and visual perception tests may be needed on top of motor assessment. On the other hand, the DCDQ Chinese Version (DCDQ-C 動作協調問卷中文版)[8] (Figure 2) was used as supplementary information for collecting parents' perspective in viewing their children's motor coordination in daily activities. Additionally, thorough history taking, including developmental history at a younger age and other medical history, was also essential for ruling out any neurological and genetic conditions.

As for clinicians, besides performing standardised tests, clinical observations on the quality of movement in motor actions such as postural control and proximal stability, compensatory and associated movement pattern, motor planning, modulation of force, and fluidity in motor control should also be stressed when assessing children with DCD.[9,10]

Figure 1. Fine Motor Test for the School-aged (FMTS)

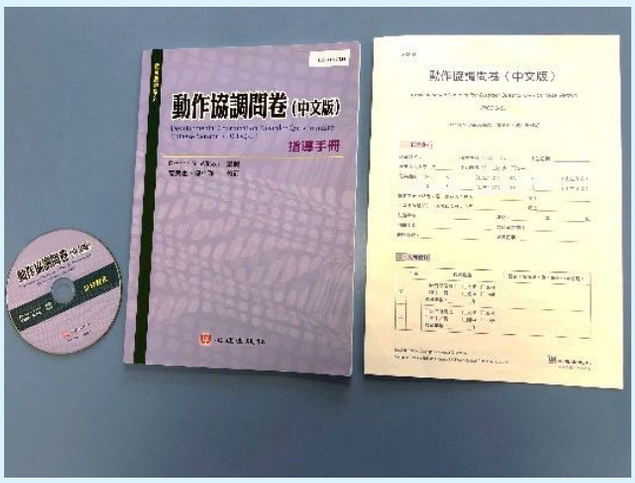

Figure 2. DCDQ Chinese Version (DCDQ-C 動作協調問卷中文版)

Evaluation on Functional Skills of DCD

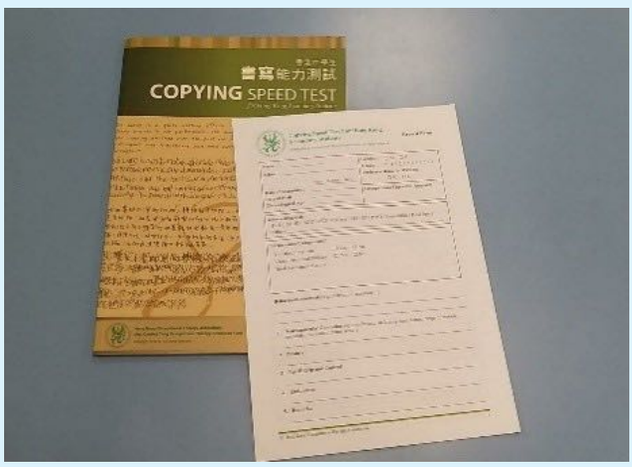

Figure 3. Copying Speed Test for Hong Kong Secondary Students (CST-HK)

As the diagnostic criteria for DCD requires a deficiency level in one's functional performance in relation to significant motor problems, the perspectives and reported dysfunction of the child's daily function at home and at school are important for clinicians in making a diagnosis. In most of the referrals to occupational therapists, the prioritized concern from the school teachers is handwriting problems which was highly rated activity and the most influential in school routine. Previously, there was a lack of Chinese handwriting assessment for secondary school students. Thus, the HKOTA has invited the CAS OT team to be the expert panel and develop the copying speed test for Hong Kong secondary students (CST-HK)[11] in 2012 (Figure 3). The CST-HK covers the age range from 12 to 18 years and includes both Chinese and English handwriting evaluation. Nowadays, one of the applications of CST-HK is to assess the clients with DCD and justify their need for special examination arrangements in public examination regarding their handwriting difficulties.

When evaluating the self-care and self-maintenance skills of children with DCD, it is important to consider the psychosocial factors such as the context in which the child is living and whether the child has had appropriate opportunities to learn and practise different skills that were typical within their respective home and community settings.[2] Since there is a large number of working parents in Hong Kong, it is a common phenomenon that children are taken care of by domestic helpers or grandparents. It is necessary to figure out whether the child's incapability of performing a particular self-care task is due to inadequate opportunity to practise or insufficient skills acquisition. In addition to clinical observation on the child's self-care skills such as dressing activities, using utensils for meals and handling materials for grooming, collecting information from parents and teachers about a child's daily functional problems (by interview, checklist, or questionnaire) is also important.

Intervention for DCD

In literature reviews, various intervention approaches and categories have been evaluated and discussed. In the past decades, the bottom-up and top-down categories were widely discussed in intervention.[12-16] In more recent empirical studies, intervention was commonly classified into process-oriented and task-oriented approaches.[5,17-19] Process-oriented intervention aimed to remediate the underlying process deficit so as to improve motor performance, whereas task-oriented/ task-specific intervention aimed to teach clients the functional skills so as to tackle their daily activities and generalise their skills in participation.[3]

Regarding the intervention effectiveness, Smits-Engelsman et al[20] observed that task-oriented approaches were more efficient than process-oriented approaches, yielding better functional performance outcomes in less time for children with DCD. However, Yu and colleagues[18] showed that both the task-oriented approach and a combined task- and process-oriented approach could help children with DCD. Thus, a multilevel approach could be adopted in DCD intervention. Recently, the European Academy of Childhood Disability[2] classified the interventions into three categories based on the International Classification of Functioning, Disabilities and Health (ICF): body-function-oriented, activity-oriented, and participation-oriented. They recommended both the activity-oriented approach and participation-oriented approach, such as task-specific training, neuromotor task training (NTT), cognitive orientation to daily occupational performance approach (CO-OP), to promote the long-term support for DCD.

Making up a realistic goal with clients would be of great benefit in providing the timely intervention as in the occupational therapy process. Current research put participatory measures and client-centred intervention into evidence-based practices.[21-22] The Canadian Occupational Performance Measure (COPM) has been one of the measures used by clinicians for reviewing

the treatment progress while research supported its usefulness and sensitivity in charting the small changes during goal evaluation for DCD.[23] Similarly, the Perceived Efficacy and Goal setting System (PEGS) is a pictorial-based tool for aiding children in self-evaluating and choosing relevant treatment goals.[24] The PEGS system has been validated locally and was recommended to be used as an outcome measure for intervention of DCD.[25] However, tactful use of this self-evaluating tool is needed, especially when considering the child's volition and family support. Besides having the active involvement of the client in treatment planning and the evaluation of treatment goals, it is also vital to incorporate explicitly the perspectives of other stakeholders such as parents and school teachers.

OT Management of DCD in CAS

In CAS, our intervention put parents' education and understanding as a core component in supporting their children's home training since we understood that transferring interventions to real-life situations requires active involvement of the children and their parents. After the assessment session, besides referral to the outpatient clinic of the Hospital Authority for receiving regular OT, CAS occupational therapists will provide home training advice. In addition, fine motor training groups, with the emphasis on the active participation of both the parents and the children, are conducted in summer holidays. The design of the training group is evidence-based and grounded in theory; in which various treatment approaches, such as the CO-OP strategies, the task-specific approach, and the perceptual motor approach, were adopted. Previously, a pilot study was also conducted on the application of CO-OP in group training for children with DCD, and the results showed that their problem-solving skills and organisation of daily chores in everyday life improved.[14]

Furthermore, in collaborating with other disciplines, parent and teacher training workshops are held regularly for public education. Emphasis has been put on enhancing parent and teachers' acceptance and understanding of the nature of DCD, as well as introducing fun and practical home training activities for improving fine motor, handwriting, and self-care skills. Pamphlets which introduce different training activities and factsheets about relevant information of DCD such as etiology, prevalence, and prognosis have also been available for parents in order to facilitate them to support their children.

In Hong Kong, there is a high demand for academic work, even in early years of primary education. Therefore, school accommodation is indispensable for children with DCD. For those children whose motor deficits significantly affect their participation in school and classroom activities, school recommendations will be suggested according to their motor and functional deficits. This may include enlarging grid size or providing wider space for promoting handwriting legibility, reducing repetitive copying tasks or handwriting demand in daily homework, alternating the answering modes, and providing extra time allowance in tests and examinations.

Looking Ahead

Although an abundant amount of DCD studies have been found in previous literature, there are still many gaps between research and clinical practice to be filled. At present, there is much variability in scheduling and the intensity of training protocols among different research studies. According to Blank et al,[2] new treatment approaches such as motor imagery training and active video-games-based training appeared promising, but additional data was required. Local research on the new treatment approaches is highly encouraged, especially those which emphasise the generalisation of the treatment approaches and the outcome measure of functional skills for children with DCD.

According to DSM-5,[26] persistence of motor difficulties was present in 50 to 70% of children with DCD. As children with DCD grew up and stepped into

adolescence or the early adulthood stages, there was increasing complexity and diversity of their daily functional problems. Tal-Saban et al[27] conducted a longitudinal study on young adults with DCD and revealed that participants in the DCD and borderline DCD groups scored lower in participation, quality of life, and life satisfaction. In O'Dea and Connell's study,[28] adolescents with DCD showed a heterogeneous profile of activity limitations and a range of participation restriction in academic, vocational, recreational, and family life areas. Hence, access to specific health services and therapeutic intervention was recommended. At present, local studies of DCD in adolescence and adulthood are very limited, and future research on this area is worthy of consideration.

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Developmental Coordination Disorder (DCD) and its Associated Psychosocial Consequences: From Preschool to Early Adulthood

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Developmental coordination disorder (DCD) is characterised by deficits in the acquisition and execution of motor skills that interfere with a child's ability to successfully perform activities as expected for his age. In children, these activities include those related to daily living, such as buttoning and tying shoelaces as well as school performance, such as handwriting and learning a particular kind of sport. DCD is one of the most common neurodevelopmental disorders, affecting about 5 to 6% of all school-age children.[1] Although the most distinctive feature of DCD is its motor impairments, studies have consistently found that individuals with DCD show more difficulties in the psychological and social domains when compared with their typically-developing counterparts.[2-4] In addition, there is growing evidence that these psychosocial difficulties are likely to persist into early adulthood.[4-7] The first part of this article attempts to look into some of those negative psychosocial consequences associated with DCD from as early as during the preschool period to a later developmental stage, that is, adulthood, followed by a section on exploring the underlying mechanisms between poor motor skills and increased internalizing problems.

A formal diagnosis of DCD is typically warranted after a child reaches school age. However, as one of the diagnostic criteria, the motor coordination difficulties of children with DCD are usually already manifest in the early developmental period.[1] There is a growing recognition that motor skills play an important role in psychosocial development as early as during infancy and preschool period. For example, having age-appropriate motor skills such as running and jumping enables one to participate in both structured and unstructured play activities with peers, which in turn helps one to develop appropriate social skills and peer relationships. Some studies have found that peer difficulties and social skills are one of those mediators between poor motor ability and internalising problems.[8,9] In a recent study conducted by Li and his colleagues, preschoolers between the ages of 4 and 5 were recruited as subjects and divided into two groups based on their scores on a standardised gross motor test: at risk for DCD (rDCD) group, and typically developing (TD) group.[10] Findings from the study suggested that young children in the rDCD group were reported by their parents to exhibit more internalizing problems than their counterparts in the TD group.

Numerous studies have shown that school-age children with DCD were more vulnerable to mental

health problems, in particular anxiety and depression, than children without DCD.[11-13] Apart from emotional and behavioural difficulties, as compared with their typically-developing counterparts, children with DCD were also found to experience more interpersonal setbacks such as having fewer friends, experiencing more social isolation and peer rejection, enjoying less positive peer relationships, perceiving a lower level of social support, and having a higher risk of being bullied by peers.[7] Likely due to their motor coordination problems, research has generally found that children with DCD were more socially isolated or introverted and involved less in peer-related physical activities in school, compared to their non-DCD peers.[14-16] Not surprisingly, research has also found that children with DCD developed more negative self-perceptions than their typically-developing peers. For instance, they reported lower self-esteem and self-competence than their normal counterparts.[17,18]

Motor skills are necessary for engagement in the physical activities throughout the entirety of our lives. Poor motor skills in childhood are likely to persist over time and affect the mastery of tasks specific to older individuals, such as learning to drive.[19] Thus, there is growing research and interest in exploring the association between motor skill deficits and negative psychosocial outcomes at a later developmental stage, that is, late adolescence to early adulthood. Recent studies which included both cross-sectional and longitudinal designs involving adolescent or adult samples have generally found that individuals with DCD showed more symptoms of anxiety and depression, and reported higher psychological distress than individuals without DCD.[4,5,20] Indeed, findings from the study of Skinner and Piek[18] suggested that the negative psychosocial impacts associated with poor motor skills may even become more prominent with age.

Towards a Model between DCD and Mental Health Outcome: The Environmental Stress Hypothesis

In a literature review by Mancini et al in 2016[21] and a subsequent literature review by Mancini et al in 2019,[7] the authors pointed out that existing research had generally shown the impacts of social, interpersonal, and psychological factors on the relationship between DCD and internalising problems (or mental health outcome). However, the underlying mechanism, as well as pathways among these factors, were not well researched and therefore less understood. In order to integrate the knowledge generated from existing research on the relationship between DCD and internalising problems, Cairney and his colleagues[22] proposed a model, known as the Environmental Stress Hypothesis (ESH). This model was then modified by Cairney et al[22] to include physical factors specific to DCD, because children with DCD were more likely to be reported to have higher body weight, higher BMI, and higher rates of obesity than those without.[23-25]

In this modified and elaborated version of the Environmental Stress Hypothesis,[22] DCD is posited to be a primary stressor, with direct impact on the psychological well-being of the individual, for example, the occurrence of internalising problems or mental illness. Moreover, DCD is also conceived to have an indirect impact on the psychological well-being of the individual, through chronic secondary stressors such as interpersonal conflicts with peers, parents, and school teachers. These secondary stressors may have a direct impact on a person's ***social resources*** (for example, social support from interpersonal networks) and a person's ***personal resources*** (for example, self-esteem, sense of mastery, and social competence) of the individual, which subsequently lead to the development of internalising problems. However, Cairney et al[22] posited that the social resources and personal resources also served as protective factors to the individual with stress buffering effects that affect the

outcome of the psychological well-being of the individual. A particular novel part of the modified version of this model is the inclusion of ***physical inactivity*** and ***obesity*** as specific factors related to DCD. Interested readers may refer to the literature review by various authors for more details.[10,22,26,27]

Current Research on Environmental Stress Hypothesis

Since the publication of the Environmental Stress Hypothesis, there has been a growing number of studies with different research paradigms (that is, cross-sectional studies, longitudinal and intervention-focused) and samples (for example, from comparison between clinical samples of DCD and community samples including DCD, cases at risk for DCD, and normal subjects with various degrees of motor functioning); all of which test different parts of the model.[7,21]

Literature reviews from different authors[7,21] reported consistent evidence supporting core relationships covered by the ESH in children and adolescents with DCD and at risk for DCD (also known as probably DCD, that is, the pDCD). Studies with clinical samples of DCD or community samples of subjects with pDCD showed that these subjects tended to have lower self-worth and self-esteem, negative self-concepts, less developed social support, poor social skills, and higher levels of anxiety. Such findings provided some support to the core ideas of the ESH: that DCD induces stress erosion effects to the personal resources and social resources of the individuals suffering from DCD or pDCD. Interestingly, results from a monozygotic twin study with pDCD[28] demonstrated the role of environmental factors (that is, the direct stressor of DCD but not the genetic predisposition) accounted for the higher risk of internalising problems. Moreover, findings from longitudinal studies,[29,30] using community samples with pDCD children and adolescents, also demonstrated the direct influence of DCD on the development of internalising problems.

Recently, a series of studies was conducted to explore the relationships described by the ESH, specifically targeting the variables related to physical and health aspects, using more sophisticated statistical analysis methods such as path analysis and structural equation modelling. Li et al[26] studied a large community sample consisting of children aged 12 to 14 years old with pDCD, looking at various aspects such as the relationship of motor coordination, physical activity, body mass index (BMI), global self-worth, and internalising problems. Path analysis was conducted to explore the pathways among these variables and the role of sex difference in these pathways. They found a significant relationship between BMI and global self-worth as well as physical activity and global self-worth for both males and females. In addition, the mediating effects of these two relationships were also significant in the relationship between pDCD and internalising problems. Their results were interesting and provided some support of the pathways proposed in the ESH.

In a subsequent study by Li et al[27] reported in 2018, using the data from the same sample from the aforementioned study by Li et al,[26] the moderating or mediating effects of physical activity and global self-worth on the outcome of internalising problems were explored. Results of this study provided support on the additive moderation model (that is, the higher level of physical activity acted as a primary moderator and interacted with global self-worth which was a second moderator), suggesting different levels of physical activity and global self-worth would end up with different outcomes on internalising problems.

In 2019, Li et al[31] reported a study using a community sample of 225 young adults aged 17 to 23. The technique of structural equation modelling was applied to study the relationships of motor coordination, physical activity, secondary stressors, variables on personal resources (for example, self-concept), social resources (for example, perceived social support and social relationships), as well as psychological distress. Results showed support to the

core parts of the ESH in the sample of normal adults and indicated a relationship between poor motor coordination and psychological distress mediated by personal and social variables such as secondary stressors, perceived social support, and self-concept. However, further study is required to explore the applicability of this model in adults with DCD.

More recently, Li et al[10] published a study in 2021 targeting preschool children aged 4 to 5 using a community sample consisting of typically developed preschoolers and preschoolers at risk for DCD (rDCD). They found direct effects of rDCD on internalising problems, though there were no significant mediating effects of physical activity level and BMI found. In other words, the prediction from the ESH was not supported by this study. However, ongoing research is needed to clarify possible factors that might be involved, for example, the nature and degree of motor impairment, as well as the role of developmental context faced by preschoolers.

Conclusion and Future Directions

The Environmental Stress Hypothesis represented a promising start to our understanding of the nature of DCD and mental health outcomes, especially for school-age children to adults. It stimulates ongoing research that contributes to our understanding of the impacts of DCD (also the full range of motor difficulties). As pointed out by Mancini et al in their literature review studies,[7,21] the model is too complex to be tested in a single study with all possible pathways explored. They suggested ongoing studies to verify different links and the mechanism mentioned in the model. Furthermore, longitudinal studies using subjects with different age groups, especially preschoolers, are highly recommended to confirm the pathways included in the ESH. Finally, the applicability of the ESH to Chinese culture is largely unknown. Research using subjects from Hong Kong or Chinese culture are highly recommended.

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