

Developmental Coordination Disorder in Uzbekistan preschool children.

Effects of a motor skill training program

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Porto, 2023



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“EL-YURT UMIDI”
FOUNDATION

UNDER THE CABINET OF
MINISTERS OF THE
REPUBLIC OF UZBEKISTAN

Education is the passport to the future, for tomorrow belongs to those who prepare for it today.

(Malcolm X)

DEDICATION

To my Family.

To my Professors.

By your Love.

By your Light.

By your Lessons.

By your Care.

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Although this dissertation has an individual nature, its preparation necessarily implies the participation and collaboration of several people and institutions. For this reason, I would like to express my thanks to those who have contributed not only to the preparation of it but also to my professional and personal growth.

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Abstract

Coordination difficulties have a widespread negative effect on children's lives in the various contexts of their daily activity. These difficulties, especially in the developmental coordination disorder (DCD) condition, continue into adulthood if there is no intervention, through appropriate programs, to help children overcome them. As a section of composing an update of the motor skill training programs in children with DCD according to gender, a systematic review of intervention studies in this domain, emphasizing gender differences, was made. This study aimed to (i) systematically review the available literature on the effect of motor intervention programs in children with DCD with a focus on gender differences (study 1). The effect of a motor skill training program in children with DCD considering their gender was investigated (study 2). Midline crossing behavior after an intervention program for children with DCD was explored (study 3). A follow-up research was applied to determine the sustainability of a given ten-week motor skill training program for children with DCD, to analyze skill changes from pre-test to post-intervention and to a retention-test, after 18 months without intervention (study 4). Outcomes of study 1 indicated that although activity- oriented and body function-oriented interventions can effectively affect motor function and skills in children with DCD, only a few studies indicated equal outcomes of the effectiveness of programs on both girls and boys. The effectiveness of the intervention program investigated in study 2 revealed to be similar across both genders. Study 3 showed that after intervention, DCD children in the experimental group (EG) showed fewer right-hand reaches in the contralateral space, but they improved their right-hand reaches in the midline, displaying a similar behavior to typical development children. Motor competence measurement from post-intervention to the retention test (after 18 months) indicated a decline in all the three motor domains of MABC-2. However, for the EG, results were better compared to those from the pre-test. It can be concluded that a 10-week motor skill training program can favorably change motor competence of children with DCD and this change lasts even after 18 months without the intervention.

KEY WORDS: DEVELOPMENTAL COORDINATION DISORDER (DCD); CHILDREN; GENDER**;** MIDLINE CROSSING**;** LATERALITY; MOTOR SKILL TRAINING PROGRAM; RETENTION TEST

LIST OF ABBREVIATIONS

MI - Motor Imagery

MP – Manual Preference

PH –Preferred Hand

NPH - Non-Preferred Hand

DCD - Developmental coordination disorder

MD - Manual Dexterity

SBS - Standard Balance Score

pDCD - probable Developmental Coordination Disorder

r-DCD – risk of Developmental Coordination Disorder

6MWT - Six Minute Walk Test

CONV - Conventional intervention

VR - Virtual Reality

BOTMP - Bruininks-Oseretsky Test of Motor Proficiency

CHAPTER I

GENERAL INTRODUCTION AND ORGANIZATION OF DISSERTATION

GENEREAL INTRODUCTION AND ORGANIZATION OF DISSERTATION

1.1 Introduction to Motor Coordination Disorder

Historical perspective

Discussions about developmental coordination disorders (historically, this disorder has had different designations) in the research space have lasted for more than 100 years and continue even today (Barnhart et al., 2003). In the beginning, like all specific learning disorders - dyslexia, dysgraphia, dyscalculia, and attention deficit hyperactivity syndrome - the development coordination disorder was also considered a disorder of mental development. But there was another group of children who were considered clumsy and were not given any attention. Children who had problems with motor skills (tying shoelaces, physical activities, holding small objects, planning, and organizing themselves) were considered lazy, clumsy, and sloppy. At that time, there was a belief that if there was more discipline and punishment, then they would "grow out of it." It should be noted that such a view still prevails in part of society, even though many studies have been conducted and it has been proven that this "doesn't grow up" and needs support in alleviating these disorders, thus promoting successful integration into society.

Developmental coordination disorders were studied for a long time as secondary disorders in cases of cerebral palsy, muscular atrophy, aphasia, and also other specific learning disorders, but in the 1990s, when the term "developmental coordination disorder" (DCD) first appeared, researchers began to look at it also as primary disorder. Differentiating a primary or secondary disorder has always been a big challenge for researchers, because when analyzing specific learning disorders, it can be concluded that their symptoms are very similar. Scientists note that

developmental disorders of coordination will primarily have motor problems and secondary - writing, reading and behavior problems (Blank et al., 2019).

The first documented study is from L. Lippitt's "Poor Muscle Coordination in Children" in 1926 (Cermak et al., 2002). Lippitt was one of the first to suggest that poor motor coordination is caused by damage to the central nervous system (CNS) and noted the link between brain damage and dysfunctional movement. In his study, Lippitt stressed that poor motor coordination needs to be fixed with specific therapies.

At the beginning of the 20th century, circa 1930, the American Doctor Orton S., who is considered the pioneer of studying learning difficulties, examined and analyzed reading disorders and dyslexia and also touched on motor problems. Orton described a group of children with motor disabilities who also have reading and writing difficulties. His focus on motor disorders can be explained by the fact that reading disorders and dyslexia are also closely related to coordination disorders. In the study, Orton discusses developmental dyspraxia as congenital maladroitness or abnormal clumsiness and believes that not all children have a medical cause of clumsiness. In his research, he also mentions that a child's congenital clumsiness does not always affect intelligence but always affects learning. Orton is thought to have been one of the first researchers to notice a link between problems with motor skills and trouble learning (Orton, 1937).

Terminology

DCD was initially described in the Diagnostic and Statistical Manual of Mental Disorders (Blank et al., 2019). Diagnostic criteria for DCD can be found in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR) (APA, 2022). These criteria are similar to those suggested by the European Academy of Childhood Disability (Blank et al., 2019) and the International Classification of Diseases, 11th Revision (ICD-11), for specific

developmental disorders of motor function (Blank et al., 2019). DSM-5-TR criteria for DCD include (APA, 2022):

● Coordinated motor skill achievement and performance are significantly below that expected given the child's chronological age and opportunity for skill learning and use.

● Poor functioning significantly and persistently interferes with chronological age-appropriate activities of daily living and affects school / academic performance, occupational and vocational activities, play, and leisure.

● Symptoms started early in the development period.

● Motor skill impairments are not explained better by mental visual impairment or intellectual disability, and they cannot be attributed to another neurological or neuromuscular condition affecting movement (e.g., muscular dystrophy, cerebral palsy, degenerative disorder).

Diagnostic criteria for adults and adolescents are the same as for children. However, motor function tests commonly used in children have not been validated in adults.

Etiology

The etiology of DCD is not known. Normal motor function depends on the coordination of neurologic, biological, and physiological factors, such as proprioception, strength, vestibular integration, coordination, balance, praxis, dexterity, visual motor coordination, and visual ability. Problems in any of these areas may lead to motor skill impairment (Hamilton et al., 2022).

The group of children with impaired motor abilities is diverse, and various mechanisms may underlie the difficulties in various children (Blank et al., 2019). These difficulties may stem from the task (e.g., complexity, speed), the surroundings (e.g., visual clues, chance for practice, encouragement), the level of motivation; the capacity of perseverance, the difficulties performing physical activities, the

problems with proprioception (Smyth et al., 1997; Smyth et al., 1998), and with visual processing (Sigmundsson et al., 2003), abnormal brain development (Wilson et al., 2017), and hereditary factors (Lichtenstein et al., 2010).

Prevalence

According to the DSM-5-TR™ (APA, 2022), the prevalence of DCD is estimated at between 5% and 8% in the age group between 5 and 11 years old. However, as mentioned by Rodrigues et al. (2015), in some areas, the prevalence of probable DCD is low, such as 1.8% in Southwest England (Lingam et al., 2009), 4.9% in Sweden (Kadesjö et al., 1999), and 8% in Canada (Tsiotra et al., 2006). Higher percentages of incidence of probable DCD have been reported in some countries that have conducted studies on a large scale, such as 15–19% in Greece (Tsiotra et al., 2006), 19.9% (Valentini et al., 2012), 21.1 and 25.3% (Cardoso et al., 2012) in Brazil, and above 25% in Spain (Ávila et al., 2008).

Lingam et al. (2009) suggest that one of the main reasons for these very different percentages of prevalence relates to the way in which DCD cases are identified. In certain studies, higher prevalence rates may result from not having applied all of the diagnostic criteria for DCD. On the other hand, while some studies report only the percentages of children with probable DCD, other studies add children at risk of DCD to this percentage. Freitas et al. (2014) also suggest that the different prevalence of DCD may result, in part, from cultural differences expressed by children in the performance of motor tasks.

Prevalence between genders

As with many other types of developmental disorders, the overall prevalence of DCD is higher in boys than in girls. According to Faebo et al. (2013) and Zwicker et al. (2013), boys are 1.7–2.8 times more likely than girls to have DCD. However, Lingam et al. (2009) found small differences in prevalence (1.9 boys and 1.0 girls).

Rodrigues et al (2019), systematically reviewed the distinctions in the motor performance between boys and girls in studies using only the Movement Assessment Battery for Children-2. The results indicated that gender differences in performance were constant across studies since girls did better activities involving fine motor skills, and boys had more success and ease in activities involving gross motor skills. Regarding balance, the results of the various studies also did not reveal consistency on the effect of sex on motor performance.

1.2 Standardized assessment of motor skills

When we think a child has DCD, we usually send he/she to a pediatric physical or occupational therapist for a standard evaluation of their motor skills. These tests look at the child's motor skills in many different ways, such as how well they can hop, jump, and thread beads.

DCD is a difficult condition to study, especially with regard to its identification, especially in research environments. There are no unique symptoms or unique laboratory findings. In 2007, Kirby et al. (2007) had already drawn attention to the importance of aligning the terminological, evaluation, and diagnostic frameworks for the progress of knowledge in this area. According to these authors, children with DCD are evaluated in several ways, and, currently, there is no assessment or "gold standard" instrument that estimates, in an adequate and adapted way, the entire development path of the subject, from childhood to adulthood.

The most regularly utilized and well-studied measures of gross motor impairment in children with suspected DCD is the Movement Assessment Battery for Children, Second Edition (MABC-2) (Blank et al., 2019; Timmons et al., 2012). MABC-2 is an appropriate instrument with which to assess the development of the motor competencies of preschool children, and acceptable overall evidence of its validity and reliability for age band one has been found (Griffiths et al., 2018). Smits-Engelsman et al. (2011) studied the psychometric properties and the confidence of

the MABC-2 in 50 typical children (3 years of age) and concluded, based on the test-retest, that the test offers a good degree of confidence, even for three-year-old children, making it sensitive at detecting individual changes. Moreover, Ellinoudis et al. (2011), using band 1 on 183 Greek children, suggested that the MABC-2 could be a valid and reliable tool to assess children aged 3 to 5 years of age with movement difficulties.

The MABC-2 (Henderson et al., 2007) is divided into two sections: the checklist and the performance test. The checklist has to be completed by someone who has regular contact with the child, such as a teacher, parent, or therapist. There are three sections to complete, concerning different matters: Section A has 15 items about movement in a static and/or predictable environment; Section B also has 15 items about movement in a dynamic and/or unpredictable environment; and Section C has 13 items about non-motor factors that might affect movement. After the application of the checklist, the results of every question are summed, and the total is rated according to the "Traffic Light" system for the checklist total motor score. On the other hand, the Performance Test is divided by band ages: age band 1 (3 to 6 years old), age band 2 (7 to 10 years old), and age band 3 (11 to 16 years old). It evaluates three factors: manual dexterity, aiming and catching, and balance, each one with 8 tests.

Another three instruments also developed with the purpose of diagnosing movement skills and motor coordination difficulties in children are the Test of Gross Motor Development 2 (TGMD-2) (Ulrich, 2000), the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) (Bruininks et al., 2005) and the Körperkoordinationstest für Kinder (KTK) battery (Kiphard et al., 1974).

Concerning TGMD-2 (Ulrich, 2000), is referenced to the American population (normative tables considering age, sex, geographic region and ethnicity), assesses fundamental motor patterns in children aged 3 to 11 years old. It also identifies children who are delayed in their global motor development in relation to their peers and provides standardized results, percentage scores, and a Global Motor Quotient.

The battery assesses 12 fundamental motor skills, encompassing locomotor (running, galloping, hopping, hopping, horizontal jumping, and sliding) and manipulative (bouncing a stationary ball, dribbling without displacement, kicking, grasping, throwing over the shoulder, and rolling a ball) skills.

With respect to the KTK battery (Kiphard et al., 1974), it assesses motor difficulties in children between 5 and 12 years of age, but which may also be applied to typical children. The structure of this battery is composed of a single factor (gross motor coordination), marked by four tests (walking backwards along a balance beam, hopping on one foot, jumping sideways, and moving sideways on boxes).

Finally, the BOT-2 (Bruininks et al., 2005) aims to provide information on a wide range of motor skills and allows to identify motor coordination problems. This battery involves eight areas: fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper-limb coordination and strength.

1.3 Motor Skill Interventions and the role of follow-up after the intervention process

Longitudinal studies indicate that motor impairments caused by DCD may persist into adolescence and adulthood if appropriate interventions are not implemented (Losse et al., 1991; Blank et al., 2012). That is why, during the past few decades, significant effort has been placed into strengthening interventions that alleviate the related problems and remediate motor impairments. In a systematic review, Hillier (2007) and Yu et al. (2018) discovered that interventions focused on enhancing motor skills were effective for children with DCD.

A frequently discussed issue in the literature when designing interventions for the development of motor skills is the type of training approach used. Such interventions are generally divided into two main approaches, namely, top-down (task-specific) and bottom-up (process-oriented) (Blank et al., 2012). Task-oriented approaches

(cognitive orientation to occupational performance, neuromotor task training) emphasize improving skill acquisition and performance in functional tasks. In contrast, process-oriented approaches (kinesthetic training, sensory integration training) are designed to improve body functions (sensory integration, perception, muscle strength) in an attempt to improve motor performance. Existing reviews (Smits-Engelsman et al., 2013; Armstrong et al., 2012; Missiuna et al., 2006; Pless et al., 2000) indicate that task-oriented approaches tend to be more effective than process-oriented approaches at enhancing motor performance. In addition, a multilevel approach, which takes both task- and process-oriented approaches into account, has been previously recommended (Wilson et al., 2005; Zwicker et al., 2012), and this is because impairments of DCD are multifaceted in nature.

The investigation of the characteristics of different interventions is also important to optimize the treatment approach and improve cost-effectiveness. In a meta-analysis by Pless et al. (2000) motor skill interventions were divided into different subgroups based on study design, participant age, and intervention components (setting, length, and frequency) and then compared based on their training effects. According to the authors, the interventions are most effective when they are given to 5-year-old children, in groups or at home, and when they are implemented at least 3-5 times per week.

Kirby et al. (2007) suggest that the intervention programs should: (i) combine the practice of fundamental motor skills with sports and health promotion activities; (ii) organize small groups with a wide variety of tasks and conditions; (iii) present exercises with problem-solving strategies and promotion of creativity; (iv) proportionate video games experiences, but never forgetting that the protagonist is the body in movement; (v) apply different interventions and groups (age, gender, severity of PDC, different comorbidities and risk factors); (vi) always include a retention evaluation and a follow-up period. According these authors, 70% of children without intervention continue to have difficulties in adolescence and adulthood.

Concerning the follow-up after the intervention process, Bulbulia et al. (2011) say that long-term follow-up of trial participants is important because effects can still be seen years after treatment has stopped. In addition, delayed risks may only appear years after exposure to certain treatments. Therefore, follow-up can add significant scientific value to the evaluation of many health interventions.

There is a lot of information about how important it is for randomized controlled trials to have complete follow-up during the trial period because, without it, the results may not be completely unbiased and the statistical power will be much lower (Moher et al., 2001). Many different ways to improve follow-up in randomized controlled trials have been looked into, and more research is still being done in this area (Brueton et al., 2014). Without high-quality in-trial follow-up, the value of post-trial follow-up will be highly limited.

Follow-up helps to determine the ultimate effectiveness of interventions given through a research method, because the benefits achieved by intervention may lose their effectiveness over time. For example, if we focus on Yu's et al. (2018) systematic review article, when the effectiveness of interventions that positively affected DCD children was examined after a certain time, some children's motor abilities, which had improved as a result of the intervention, had regressed to their earlier levels. For example, looking at research conducted by Hammond et al. (2014), a 1-month intervention program was able to improve the motor skills of DCD children, but after 2.5 months without intervention, the children's motor skills, tested again with the BOT-2 test, returned to their previous state. Similar results were also observed in the studies of Sugden et al. (2003) and Wood et al. (2017). However, in other studies, a slightly different result was observed, namely, the post-test results were preserved in the follow-up period (Fong et al., 2016; Miles et al., 2015). In a small number of research studies, the motor skills of children with DCD improved from the post-test to the retention test (Coetzee et al., 2013). In order to verify the effectiveness of the given interventions, most of the follow-up tests were re-examined around 1 to 5 months after the end of the intervention program (Fong et

al., 2016; Miles et al., 2015). In the study of Coetzee et al. (2013), for example, the effectiveness of the intervention was re-examined two years after the post-test, and it was observed that the overall results of the MABC decreased over time.

1.4 Midline crossing and motor coordination difficulties

The midline is an imaginary line through the center of the human body. Crossing the midline of the body is the ability to move spontaneously with a part of the body, such as the legs or arms, to reach the center of the body. When a child can cross the midline, it means that both sides of his or her brain are talking to each other and that he or she can use both sides of his or her body at the same time, which is important for learning skills and moving well (Ayers, 1971). Subsequently, midline crossing is an essential developmental milestone. This is because if the child learns to cross the midline, he/she will become more likely to use the preferred hand, and he or she will keep practicing every day or acquire sports skills more easily (Schilder, 1950). In addition, the midline of the body has been shown to contribute to the formation of spatial orientation, bilateral integration, body schema, orientation, and laterality (Schilder, 1950; Stilwell, 1987), indicating the integration of the body's midline, which makes bilateral coordination possible (Smith, 1983). Body movement positions such as walking, standing, turning, lying, or sitting involve both halves of the body and move parallel to the central axis of laterality, in the opposite direction, or in a circle (Stilwell, 1987).

Sherick, (1976) found that if a baby doesn't do enough midline behaviors when he or she is young, it can lead to problems later in life that show up as laterality disorders, which can lead to cognitive learning and motor learning disabilities. Midline crossing problems are associated with children with atypical development, such as learning disabilities (Murata et al., 2009), attention deficit hyperactivity disorder or autism spectrum disorder (Begum et al., 2020), down syndrome (Groen et al., 2008), and developmental coordination disorder (DCD) (Hill et al., 1998). The results of these studies show that these children tended to cross the midline less

often, and were less likely to cross the midline with their preferred hand into the contralateral space, and tended to be less consistent in their hand preference within and across activities.

Moreover, children who doesn't develop midline behaviors, will possible present difficulties in contralateral workspace tasks. A kinematic study conducted by Smits-Engelsman et al. (2006) gives precise measurements of children with and without DCD in terms of accuracy and speed when making aim-directed movements across the midline. Contrary to expectations, this study found that DCD children generally did not have preferentially impaired when making movements in a contralateral workspace, even though they were not as good as their peers overall. This supported the findings of Zoia et al. (2007) in a reaching task performed by children with and without DCD under normal and perturbed vision.

Up to now, in Uzbekistan, there is no scientific available information regarding motor coordination problems in children of this country and, specifically, on children with possible DCD. We know, in agreement with Gallahue et al. (2006), that motor coordination is fundamental for a good development of basic motor skills and for learning motor skills specific to a particular sport. Thus, to overcome possible motor coordination difficulties in early childhood, it is essential to know the state of children's coordinative development. In other words, "to know well in order to intervene better". The fact of knowing well the coordinative difficulties of children, allows the government of the country, through its educational system, to develop and implement in schools more appropriate intervention programs helping children to overcome these difficulties. As a consequence, the country will have more coordinated children with fewer motor difficulties, which may be reflected in a greater number of healthier children, since physical exercise is a source of pleasure rather than frustration, and in a greater number of children practicing high performance sport, raising the country's sporting visibility levels.

Hence, the research included in this thesis has as its main objective to answer the questions about which is the percentage of children with probable DCD and with at

risk of DCD and if a motor skill training program for children with DCD improve their motor competence.

As specific objectives, outlined in the purposes of the empirical studies published in the articles that compose this thesis, we intend to: (i) systematically review the available literature on the effect of a motor intervention program in children with DCD with a focus on gender differences and to find clues that possibly explain these differences if they are highlighted (Review Study); (ii) investigate the effect of a motor skill training program in children with DCD considering their gender (Empirical Study 1); (iii) analyze midline crossing behavior after an intervention program for children with DCD (Empirical Study 2); (iv) determine the sustainability of a given ten-week motor skill training program for children with developmental coordination disorders after 18 months without participating on that program (Empirical Study 3).

All of these studies have been published in a top database:

- A review study was published in the journal Neuropsychiatrie de l'Enfance et de l'Adolescence, which was included in the Scopus list. It should be noted that the article published in this scientific journal is included in the list of goals set by UNESCO Sustainable Development Goals.
- The empirical Study 1 was published in the journal Children, which lists Scopus, PubMed and Web of Science (Impact factor 2,835).
- The empirical Study 2 was published in the journal Symmetry, which lists Scopus, PubMed and the Web of Science databases (Cite score 4.3 and Impact factor 2,713).
- The empirical Study 3 was published in the journal Sports, which lists Scopus, PubMed and the Web of Science databases (Cite score Q1).

General Organization of the dissertation

The structure of the dissertation approaches the Scandinavian model. The planning of studies and the subsequent submission for publication as well as the raising of the scientific level in the field allow for wider dissemination and faster results.

Table 1: Synopsis of the structure and content of this dissertation.

Chapter I	**General Introduction, purposes and formal structure of the thesis**
Chapter II	Systematic review study **Paper I** **Motor skill training programs for children with developmental coordination disorder: Does gender matter?** **Aims: This study aimed to (i) systematically review the available literature on the effect of a motor intervention program in children with DCD with a focus on gender differences; (ii) to find clues that possibly explain the observed outcomes according to gender.** **Authors: O.A. Saidmamatov, M.M. Nascimento, J.C. Cerqueira, P. Rodrigues, O. Vasconcelos (2022).** ***Published in the Neuropsychiatrie de l'Enfance et de l'Adolescence, 70(4), 183-194. ISSN 0222-9617, https://doi.org/10.1016/j.neurenf.2022.03.001***
Chapter III	**Paper II** **Ten-Week Motor skill training Program Increases Motor Competence in Children with Developmental Coordination Disorder.** **Aims: To investigate the effect of a motor skill training program in children with DCD considering their gender. The Movement Assessment Battery for Children (MABC-2) classified the children and assessed their skill changes over time.** **Authors: Saidmamatov O, Raximov Q, Rodrigues P, Vasconcelos O. A** ***Published in the Children (Basel) journal. 2021 Dec 6;8(12):1147. https://doi.org/10.3390/children8121147***
	Paper III

	Motor skill training Program Reinforces Crossing the Body's Midline in Children with Developmental Coordination Disorder. **Aim: to find out midline crossing behavior after an intervention program for children with DCD.** **Authors: Saidmamatov, O.; Rodrigues, P.; Vasconcelos, O.** ***Published in Symmetry journal 2022, 14, 1259.*** *https://doi.org/10.3390/sym14061259*
	Paper IV **Sustainability of a Given Ten-Week Motor skill training Program for Children with Developmental Coordination Disorder.** **Aim: to determine the sustainability of a given ten-week motor skill training program for children with developmental coordination disorder (DCD).** **Authors: Saidmamatov, O.; Rodrigues, P.; Vasconcelos, O.** ***Published in Sports 2022, 10(11), 164.*** *https://doi.org/10.3390/sports10110164*
Chapter IV	**Conclusions and Final Considerations**

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CHAPTER II

REVIEW STUDY

Review study

Motor skill training programs for children with developmental Coordination disorder: Does gender matter?

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ABSTRACT

As a section of composing an update of the motor skill training programs in children with developmental coordination disorder (DCD) according to gender, a systematic review of intervention studies in this domain, emphasizing gender differences, was made. This study aimed to (i) systematically review the available literature on the effect of a motor intervention program in children with DCD with a focus on gender differences; (ii) to find clues that possibly explain the observed outcomes according to gender. An electronic search in 4-four databases (Web of Science, Scopus, Google Scholar, and PubMed) was conducted for studies that evaluated motor-based interventions in participants of both genders with DCD assessed using the Movement Assessment Battery for Children. The systematic review followed the guidelines defined in the Preferred Reporting Items for Meta-analysis (PRISMA) and Systematic Reviews and comprised articles published from January 2000 to January 2021. Each study extracted information about methodology, participant characteristics, intervention program (characteristics, duration, and frequency), outcomes, and differences according to gender. Outcomes indicated that although activity- oriented and body function-oriented interventions can effectively affect motor function and skills in children with DCD, only a few studies indicated equal outcomes of the effectiveness of programs on both girls and boys. However, those studies did not describe the gender effect in sufficient detail to help researchers and clinicians understand what it was about the treatment that made it equivalent. Future studies need to address this.

R É S U M É

Dans le cadre de la rédaction d'une mise à jour des programmes d'entraînement des habiletés motrices chez les enfants atteints de troubles de la coordination du développement (TDC) en fonction du sexe, une revue systématique des études d'intervention dans ce domaine, mettant l'accent sur les différences entre les sexes, a été réalisée. Cette étude visait à (i) passer en revue systématiquement la littérature disponible sur l'effet d'un programme d'intervention motrice chez les enfants

atteints de TAC en mettant l'accent sur les différences entre les sexes; (ii) pour trouver des indices qui pourraient expliquer les résultats observés selon le sexe. Une recherche électronique dans 4 bases de données (Web of Science, Scopus, Google Scholar et PubMed) a été menée pour des études évaluant des interventions motrices chez des participants des deux sexes atteints de DCD évalués à l'aide de la Movement Assessment Battery for Children. La revue systématique a suivi les lignes directrices définies dans les éléments de rapport préférés pour la méta-analyse (PRISMA) et les revues systématiques et comprenait des articles publiés de janvier 2000 à janvier 2021. Chaque étude a extrait des informations sur la méthodologie, les caractéristiques des participants, le programme d'intervention (caractéristiques, durée, et fréquence), les résultats et les différences selon le sexe. Les résultats ont indiqué que bien que les interventions axées sur l'activité et les fonctions corporelles puissent affecter efficacement la fonction et les habiletés motrices, chez les enfants atteints de TAC, seules quelques études ont indiqué des résultats égaux de l'efficacité des programmes sur les filles et les garc¸ ons. Cependant, ces études n'ont pas décrit l'effet du genre de manière suffisam- ment détaillée pour aider les chercheurs et les cliniciens à comprendre en quoi le traitement le rendait équivalent. Les études futures doivent aborder ce problème.

Keywords: Developmental coordination disorder (DCD); Children; Gender
Mots clés: Trouble de la coordination du; développement (DCD); Enfants; Genre

Introduction

Developmental coordination disorder (DCD) is classified in the DSM-5 and not always detected and intervened in school settings. DCD is categorized under the motor disorders subcategory of neurodevelopmental disorders, reporting that the spread rate of children with DCD is around 5–6% of all school-aged children (APA, 2013). About half of these children detected with movement problems in early childhood proceed with these troubles in youth and early adulthood (Kirby et al., 2013). Moreover, children with DCD regularly encounter a range of comorbid problems, including attentional issues, language, behavioral issues, and psychosocial problems, including anxiety, low self-esteem and depression. Generally, the more comorbid issues and the higher the severity of DCD, the worse the motor skills result (Peters et al., 2001). Poor motor coordination also impacted decrease physical activity participation and lower fitness results in populations with DCD (Rivilis et al., 2011; Schott et al., 2007). As a result, the risk of increasing obesity and cardiovascular illnesses is enhanced (Faught et al., 2005; Cantell et al., 1994). This cluster of formative issues and the persistent nature of DCD indicate the importance of intervention that enhances the activity and supports participation (Smits-Engelsman et al., 2013; Smits-Engelsman et al., 2015; Wilson et al., 2013).

There have been various movement-based approaches to intervention for DCD (Smits-Engelsman et al., 2013; Wilson et al., 2013; Miyahara et al., 2017), customarily grouped into two wide ranges: those that utilize movement to target main performance problems, frequently focused to as process-oriented approaches, and, those that use activity to address the performance itself, frequently focused to as task-oriented approaches. Task-oriented approaches were shown to be more successful than process- oriented approaches in a review published in 2013, yielding better functional performance results in less time for children with DCD (Smits-Engelsman et al., 2013). The main effectiveness of task-oriented approaches rather than process-oriented approaches may be that they work on teaching essential activities of daily living and, thereby, stimulate participation at home, school, in leisure, and sports. Cochrane study by Miyahara et al. (2017) was known for

purposing all extant randomized controlled trials that estimated task-oriented interventions especially, regardless of publication date. In the study of Miyahara, it was scientifically substantiated that the incidence of DCD was ratio in both sexes. However, it was not studied how the interventions affected members of both sexes. Adhering to very tight inclusion criteria and fairly rigorous methodology, only 15 acceptable studies were involved (eight randomized controlled trials and seven quasi-randomized controlled trials). Results revealed that gender is an essential issue in motor skills acquisition.

Furthermore, these differences between boys and girls have been pointed out (Gaul et al., 2016; Kita et al., 2016; Kokstejn et al., 2015; Rodrigues et al., 2019. For example, Rodrigues et al. (2019) systematically reviewed the distinctions in the motor performance between boys and girls in studies using only the Movement Assessment Battery for Children-2 (Henderson et al., 2007). The results indicated that gender differences in performance were constant across studies since girls did better activities involving fine motor skills, and boys had more success and ease in activities involving gross motor skills. Regarding balance, the results of the various studies also did not reveal consistency on the effect of sex on motor performance. In addition, the gender distinction in interceptive visuomotor coordination combined with the performance of catching or hitting a ball may be different between boys and girls (Moreno-Brisen˜o et al., 2010). It is also estimated that girls may override boys in developing postural control. Besides, gene- rally different body heights between the genders might also be partly responsible for gender differences in balance (Nolan et al., 2005).

Thought some systematic reviews have been concerned about the effectiveness of intervention programs, it remains indeterminate whether such interventions are efficient in a similar way regarding the gender of the child with DCD. That is why another systematic review is needed to explore the effect of motor skill interventions on motor performance regarding the gender of the child with DCD.

Methods

The guidelines determined in the Preferred Reporting Items for Meta-analysis (PRISMA) Statement and Systematic Reviews (Moher et al., 2009) were used to guide our methodology and to report.

Eligibility criteria

Four authors (OS, PR, MN, and JC) independently assessed the studies' eligibility based on the following inclusion criteria:

- articles in which intervention programs on children with DCD were a central goal and gender was considered;
- the participants in the research had no health problems or disorders other than DCD (e.g., traumatic brain injury, cerebral palsy, intellectual disability, stroke, attention deficit hyperactivity disorder);
- studies had to have motor outcome measures with the Movement Assessment Battery for Children;
- any study design was considered (e.g., longitudinal, cross- sectional, or experimental/quasi-experimental);
- only studies written in English were included.

Unpublished work, conference proceedings, abstracts, review papers were excluded.

Information sources and search

We conducted an electronic search from the inception of each of the following databases: Web of Science, Scopus, Google Scholar, PubMed. The combinations of the following keywords: "develop- mental coordination disorder," "MABC," "intervention program," and "gender" were used. A study's title and abstract were required to contain at least the developmental coordination disorder term and intervention program to be considered for inclusion in the review.

The literature search was limited to studies published from January 1st, 2000 to January 30th, 2021, since this time frame allows capturing all articles that had to use the MABC instrument (since the MABC was introduced).

Study selection

Articles were excluded or included in the first part of the research by screening their titles for relevance. The abstract was also screened when the article's appropriateness could not be determined only by the title. When the article's relevance could not be identified by the abstract, the full text was examined. Additionally, all selected articles' references were checked for other papers suitable for inclusion (snowballing search) (Fig. 1).

After the initial search, various steps were taken to select the studies for analysis:

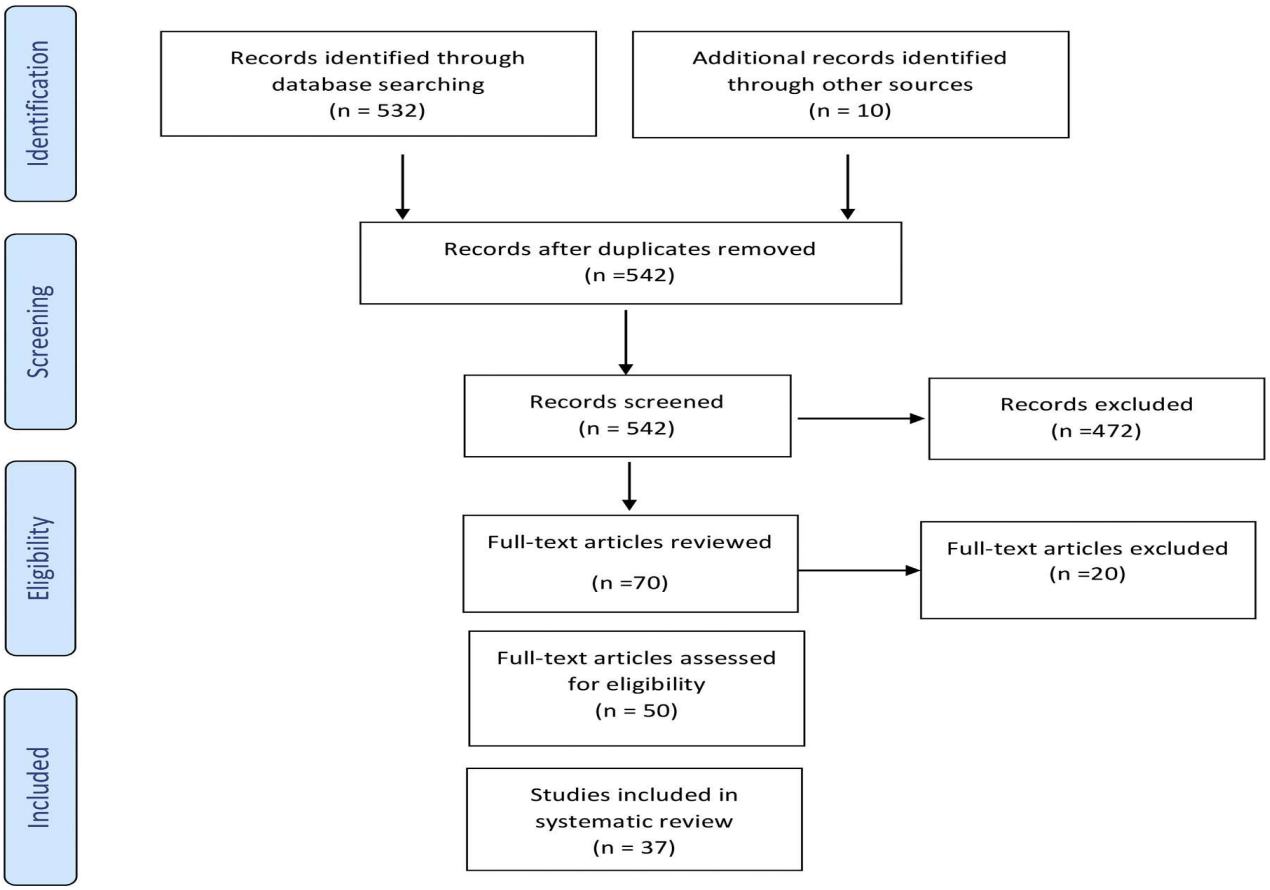


Fig. 1. The flow of article selection.

- removal of all copies;
- screening and removing articles based on the title and abstract. When there were any doubts or insufficient information, the full text was retrieved for further analysis in order to make a proper decision;
- sorting and removing articles based on the full-text articles selected in the previous step;
- sorting and removing articles based on full-text articles incorporated from the snowballing search.

All decisions, in all stages, were made separately by two of the authors (PR and OS). The results were accepted after each stage, and the next stage would only launch when the complete consensus was reached. Accordingly, there was general agreement in all final articles.

Data collection process

In this stage, all the information concerning references, study design, sample type, DCD sample characteristics, DSM diagnostic criteria, and results was organized by three authors (OS, MN, and JC). No instrument was used to determine the studies' quality assessment.

Results

There were 565 possibly relevant papers found during the search (Fig. 1). After reviewing the titles and abstracts and eliminating duplicates, 542 articles that covered our relevancy requirement were identified. To avoid repetition, we grouped those studies that the same authors published in multiple papers, particularly the studies of (Ferguson et al., 2013; Mombarg et al., 2013; Bonney et al., 2017) that used the same interventions. This systematic review narrowed the results down to a total of 37 studies that proceeded to the evidence synthesis stage.

Given the time interval used to select the studies, it was noted that 77% of publications focused on the last seven years.

Study samples were drawn from various locations all over the world (i.e., South Africa 6 studies, Netherlands 3 studies, Israel 2 studies, Australia 4 studies, Chine 1 study, Finland 1 study, UK 6 studies, Taiwan 1 study, Hong Kong 4 studies, USA 2 studies, Tunisia 2 studies, Brazil 2 studies, Canada 1 study, India 1 study, Sweden 1 study). Of the 37 studies included in this systematic review, five articles were analytical studies, nine pilot studies, 12 randomized controlled trials, and other study designs. Twenty-seven studies used a school sample, 6 used a clinical sample, and one was from a mixed (school/clinical) sample.

A total of 1255 participants (children with DCD: n = 1086, children with typical development: n = 169) were involved in the included studies. Sample sizes varied greatly, from n = 8 (Adams et al., 2017) to n = 145 children with DCD (Ma et al., 2018) most studies had a sample size between 20 and 45. Some researchers (Mombarg et al., 2013; Niemeijer et al., 2007; Laufer et al., 2013; Hung et al., 2010; Sugden et al., 2003; Fong et al., 2012; Maharaj et al., 2016) did not consider gender issues; thus, only 1/3 of the engaged children were girls. The age of participants ranged from 4 years to 16 years, with the majority of participants between 6 and 12 years.

In the 37 articles studied, it was found that about 50% of the researchers used MABC, while the remaining 50% of the researchers used MABC 2 as a diagnostic criterion. Interestingly, although the MABC-2 already exists, it can be seen that the MABC battery is still used in some recent scientific studies (Table 1).

After analyzing the results of the present articles, it was identified that motor skill training (Hung et al., 2010), fascia Bowen therapy (Morgan-Jones et al., 2019), goal-oriented approach (Cacola et al., 2016), as an intervention, and sport stacking interventions improved significantly the dimensions assessed by MABC and MABC 2 batteries: manual dexterity, aiming and catching, and balance skills. The Wii Fit, task-oriented functional training, and virtual reality (Ferguson et al., 2013; Bonney et al., 2017) can be more effective for balance and manual dexterity instead of aiming and catching. However, virtual environments (Laufer et al., 2013) can improve aiming and catching and balance skills. Moreover, visual therapy (Coetzee et al.,

2013) is not recommended if children have problems with balance, aiming and catching, or manual dexterity. The maximum period of the intervention was 20 minutes, 3–4 sessions a week during 40 weeks (Sugden et al., 2003), and the minimum was 60 minutes, one session a week for ten weeks (Cacola et al., 2016). Based on the present results, the conclusion is that the six- week Wii Fit intervention effectively improves motor performance in children at risk for DCD (Mombarg et al., 2013). According to Adams et al. (2017), motor imagery and occupational performance training may partially improve DCD children's M-ABC 2 total score. However, the effectiveness of these interventions was not 100% on the M-ABC 2 total score; for example, the motor imagery was compelling for 50% of DCD children, and the occupational performance training was practical for 75% of DCD children. The major shortcoming of the Adams et al. (2017) research is that the number of children involved in the motor imagery study was minimal. Adams et al. (2017) and Wilson et al. (2013) also utilized motor imagery and the similarity of their study was that the motor imagery was effective in improving the M-ABC 2 total score of DCD children. However, the effectiveness of intervention would not impact samely all DCD children in both groups. Hung and Pang et al. (2010) mentioned that group-based and individual-based motor skill training programs are equally effective in improving the motor proficiency of children with DCD. Moreover, the research has a similarity to the training program of Farhat et al. (2016). The similarity was that after both motor skill training, the MABC percentage of 50–71% DCD children attained a score above the 15 percentile. Moreover, other scholars such as Niemeijer et al. (2007); Maharaj et al. (2016); Farhat et al. (2016); Morgan et al. (2019) indicated a score at or below 15 percentiles on MABC to meet the criteria of DCD, but other researchers as Ferguson et al. (2013); Jelsma et al. (2014); Bonney et al. (2017); Bonney et al. (2018); Adams et al. (2017); Straker et al. (2015) considered the condition of DCD if children showed score at or below 16 percentiles on MABC2.

Wood et al. (2017) stated that DCD children improved their gaze control and catching coordination following quiet eye training, compared to technical training.

According to Maharaj et al. (2016), gross motor training can be a positive intervention strategy for physiotherapists to improve MABC and MABC-2 function scores for DCD children. Moreover, Fong et al. (2012) stressed that taekwondo training could improve sensory organization and standing balance for children with DCD.

Cacola et al. (2016) stated that the motor skill training and the direct goal-oriented approach for training of skills chosen by the children could be effective to improve the total score of DCD-Q, MABC-2, and Predilection for Physical Activity Scale instead of Preferences for Activities of Children and Strengths and Difficulties Questionnaire. Ferguson et al. (2013) clarified that the impact of weekly two interventions (Neuromotor Task Training intervention program and Wii training program) could effectively improve the total score of MABC-2. However, examining the individual MABC-2 components, more significant improvements for the Neuromotor Task Training group compared to the Nintendo Wii Fit Training group were seen in manual dexterity and balance domains. Boney et al. (2017) applied the Task-Oriented Functional Training and Wii training and observed that 81% of children (17) in the Wii group and 72.7% children (16) in the Task-Oriented Functional Training group improved motor performance to achieve average range scores on the MABC-2 after the intervention. While no participant was still determined as impaired on the MABC-2 in the Wii group, only 3 (13.6%) had scores denoting definite motor impairments in the Task-Oriented Functional Training group. Moreover, Boney et al. (2018) mentioned that Wii training could significantly improve aerobic and anaerobic fitness.

Out of the 37 papers mentioned below, most researchers did not consider gender in the result analysis part. In a few studies, the numerical equality of children of both genders was considered (Niemeijer et al., 2007; Laufer et al., 2013; Hung et al., 2010; Sugden et al., 2003).

The remaining 29 scholars explored both genders. In the research of Thornton et al. (2016); Soares et al. (2019); Morgan et al. (2019); Farhat et al. (2016); Dunford et al. (2011), only boys were focused while Bonney et al. (2018) and Bonney et al.

(2017) concentrated only on girls. However, Nimeijer et al. (2007) and Sugden et al. (2003) had a minor focus on comparing genders using intervention programs and summarized that the program had the same effect on both genders that is, MABC-2 indicators developed at the same rate.

Discussion

Children with DCD are often submitted to intervention programs oriented by several professionals, such as psychomotor therapist, physical education teachers, doctors, and psychologists, who use various therapeutic approaches to address the functional problems. Since the earlier recommendation for interventions for children with DCD (Blank et al., 2012), numerous new papers have been published in this field. Uncommon other reviews, we have involved motor- based intervention studies published between 2000 and 2021, independent of design (i.e., case-study to randomized controlled trial); research of different rigor and complexity has been involved. The final review reported on 37 intervention studies. Overall, the design of the studies was moderate, and data on several approaches enhanced motor skills of MABC-2 (e.g., Virtual Reality, Training Sport/Play related Skill Training).

Another important new finding was that although the MABC-2 was already in the market in 2007, researchers still use the first edition. However, a difference was found in the DCD detection of children through the MABC and MABC 2 programs. Based on the following data, we believe that assessing children's DCD performance through the MABC and MABC 2 programs is the samely reliable, but we suggest using MABC-2 because most of the scientific work has been done through this version. Additional information is that the concern about the effect of intervention programs in children with DCD has increased in the last few years. In fact, after applying the inclusion and exclusion criteria in our systematic review, we observed that most of the studies had been published in the last six years (2013–2018). We also noticed a more excellent geographical distribution of publications, mainly in the African and Asian continents. However, the Netherlands continues to lead, confirming the suggestion of McGlashan et al. (2017) that outlined the need for

studies from countries other than Europe and North America. Our study shows an evolution in this scenario as both findings indicate a growing concern about DCD conditions. It is also important to note that 99% of the scientific studies we reviewed did not address how the interventions used affected gender. The studies of Nimeijer et al. (2007) and Sugden et al. (2003) were the only ones that reported a comparison between genders through the intervention program that had the same effects on both genders. Indeed, girls and boys have different motor skills, and that intervention programs should consider that.

Considering that in the studies with only girls or only with boys there was an identical and positive evolution of motor coordination as a result of the intervention programs and that the only two studies comparing the effect of gender did not observe significant differences after intervention programs, we can conclude that gender does not matter. As Miyahara et al. (2017) suggested, future intervention studies need to report their results fully, in terms of group means and standard deviations, the number of participants in clinical terms (probable and definite DCD), socio-demographic data, specially gender.

Table 1 Summary of the Studies Reviewed

Reference	Study design	Sample Type Total N, Age Instrument	Program Groups DCD sample (N/%) N	DSM DIAGNOSTIC CRITERIA diagnostic CRITERIA (assessment tool+cut-offs, exclusion criteria)	Information about interventions *Type and Characterization of program*	 *Duration/ frequency/ Time of sessions*	Results	Gender efficiency
Adams et al., 2017 AUS	Pilot study	Clinic sample 8 children (n =5 ♂) (n=3 ♀) 7–12 years **MABC 2** **DCDQ**	MI (n=4, one left-handed) CO-OP (n=4, all right-handed) All children=DCD	DSM-5 MABC total score ≤ 16th % or component score ≤ 5th %	MI (Motor Imagery) CO-OP (Occupational performance)	Both groups 9 weeks 9 treatment sessions 45 min per treatment	MI group: MABC 2 ↑TTS 50% of children CO-OP group: MABC 2 ↑TTS 75% of children	no
Ashkenazi et al., 2013 ISR	Analitical study	Clinic sample 30 children (n=25 ♂) (n=5 ♀) 4-6 years **MABC 2** **DCD-Q**	Virtual reality games VR (n=15) Conventional intervention groups (n=15) All children=DCD	MABC 2 score ≤ 15th %=DCD	VR group CONV group	Both groups 10 weeks 10 treatment 60-min	VR group: MABC 2 ↗↑TSS ─↑MD ↑AC ↗↑Balance CONV group: MABC 2 ↗↑TSS ─↑MD ↑AC ↑Balance TSS, Balance: VR< CONV MD, AC: VR> CONV	no
Ashkenazi et al., 2013 ISR	Pilot study	Clinic sample 9 children (n=2 ♂) (n=7 ♀) 4-6 years **MABC 2** **DCD-Q**	Virtual Reality group All children=DCD	MABC 2 score ≤ 15th %=DCD	Virtual Reality 2 parts: -VR-based intervention -Goal-directed task	12 weeks 10 treatment 60-minute	VR group: MABC 2 ↗↑TSS ↑MD ─↑AC ↗↑Balance ↗↑DCD-Q	no

Au et al., 2014 HKG	Randomized controlled trial	Clinic sample 22 children (n=15 ♂) (n=7 ♀) 6-9 years **MABC** **BOTMP 2**	Core stability program group Task-oriented training program group All children=DCD	DSM- 4 MABC 2 score ≤ 15th %=DCD	Core stability program Task-oriented training program	8 weeks 8 session 60 minutes	Both groups /↑ Motor proficiency Task-oriented group /↑ Composite equilibrium score	no
Bonney et al., 2017 ZAF	Analitical study	School sample 43 children (n=43 ♀) 13–16 years **MABC 2**	TFT (n=22) Wii training (n=21) All children=DCD	DSM-5 MABC 2 score <16th %=DCD	Wii training Taskoriented Functional Training TFT	Both group 14 weeks 14 training 45 min	TFT group: MABC 2 /↑TSS /↑MD —↓AC ↑Balance Wii group: MABC 2 /↑TSS /↑MD —↑AC /↑Balance	no
Bonney et al., 2018 ZAF	Pilot study	School sample 16 children (n=16 ♀) 13-16 years **MABC 2**	One group: at risk of DCD (n=11) Definite motor impairments (n=5)	DSM-5 MABC 2 score ≤ 16th %= DCD	Wii training *physical fitness*	14 weeks 14 sessions 45 min	↑ 6MWT 69% children ↑ MPST 75% children —↓Enjoyment rating scale	no
Cacola et al., 2016 USA	Analitical study	Schools sample 14 children (n=11 ♂) (n=3 ♀) 7-12 years **MABC 2** **DCD Q**	Program 1 (n=8) Program 2 (n=6) All children=DCD	DSM 5 MABC 2 score <5th %= DCD	Group Motor Skill Intervention Program	Program 1 12 weeks 24 sessions 60 min Program 2 10 weeks 10 sessions 60 min	Program 1 ↑TTS /↓MD /↑AC /↑Balance Program 2 /↑TTS —↓MD —↓AC ↓Balance	no

Caçola et al., 2016 USA	Pilot study	Schools sample 24 children (n=19 ♂) (n=5 ♀) 7- 12 years **MABC 2** **DCD-Q**	Program A (n=11) Program B (n=13) All children=DCD	DSM 5 Program A: MABC 2 score < 9th %= DCD Program B:by DCD-Q	A. Large group involving motor skill training and collaboration and cooperation among children, B. Smaller-group a direct goal-oriented approach for training of skills chosen by the children	Both group 2 weeks 10 sessions 1 h each	Program A: MABC 2 ⁄↑TTS ⁄↑MD ⁄↑AC ⁄↑Balance ⁄↑DCD-Q Program B: MABC 2 ⁄↑TTS ⁄↑MD ⁄↑AC ⁄↑Balance ↑DCD-Q	no
Coetzee et al., 2013,ZAF	Pilot study	School sample 32 children (n =20 ♂) (n=12 ♀) 7-8 years **MABC**	Group 1 (no ocular muscle control deviations n = 16) Group 2 (one to three ocular muscle control deviations n = 16) All children=DCD	DSM 5 MABC score <15th %= DCD	Visual therapy	Both group 18-weeks 18 therapy 40 min	MABC total and the sub-sections: Group 1<Group 2	no
Capistran eta al., 2016 CAN	Multiple baseline	Clinic sample 4 children (n=3 ♂) (n=1 ♀) 7-12 years **MABC 2** **DCDQ**	Intervention group (n=4) All children=DCD	DSM 4 MABC 2 score ≤ 15th %= DCD	Motor activities practice using CO-OP strategy	10 weeks 10 sessions 60 min	No information about the result of MABC 2	no

De Milander et al., 2014 ZAF	Quasi-experimental	School sample 18 children (n=12 ♂) (n=6 ♀) 6 - 7 years **MABC 2**	The control group was 5the % MABC 2 (n=8) The intervention group was 9the % MABC 2 (n=10) All children=DCD	MABC 2 score 5th - 15th % (amber zone) = DCD	Sport stacking	8-weeks 3 sessions/ weeks 30 min/ session	Control group: MABC 2 /↓TTS -↓ MD /↑ AC /↓Balance Intervention group MABC 2 /↑TTS /↑ MD /↑ AC /↓Balance	no
Dunford et al., 2011 UK	Pilot study	School sample 8 children (n=7 ♂) (n=1 ♀) 7 - 11 years **MABC 2**	Intervention group (n=8) All children=DCD	DSM 4 MABC 2 score ≤ 5th %= DCD	Goal-Orientated Group Intervention	2 weeks 8 sessions 50-min	/↑ COPM and MABC scores	no
Ferguson et al., 2013 ZAF	Analitical study	School sample 46 children (n =24 ♂) (n=22 ♀) 6–10 years **MABC 2**	Neuromotor Task Training intervention program NTT (n = 27) Wii training program (n = 19) All children=DCD	MABC 2 score ≤ 16th %=DCD reported functional motor problem (teacher)	NTT intervention program Wii Fit training	**NTT** 9 weeks 18 sessions 45 and 60 min. **Wii Fit training** 6 weeks 18 sessions 30 min	NTT group: MABC 2 /↑TSS /↑MD —↑AC /↑Balance Wii group: MABC 2 —↑TSS —↑MD —↑AC ↑Balance	no
Fong et al., 2012 HKG	Randomized controlled trial.	no 62 children (n=49 ♂) (n=13 ♀) 6-9 years **MABC 2**	TKD training (n=21 DCD) No training (n=18 TD) (n=23 DCD)	DSM 4 MABC 2 score ≤15th %=DCD	Taekwondo training (TKD)	12 weeks Daily 60 min	Vestibular ratios, UST sway velocities: TKD group < DCD control Vestibular ratios, UST sway velocities: TKD group =TD control No information about MABC2	no

Farhat et al., 2015 TUN	Gross sectional study	School sample 41 children 6–10 years (n=41♂) **MABC**	Experimental training group (n=14 DCD) Control non-training group (n=13 DCD) Control non-training group (n=14 TD)	DSM 4 MABC score ≤5th %=DCD	Fundamental motor skill training	8-weeks 24 sessions 60 min	DCD training group: /↑maximal power output at anaerobic threshold ↑walking distance ↑ MABC total score Control non-training groups: ↔on any of the measures	no
Farhat et al., 2016 TUN	Gross sectional study	School sample 41 children 6–10 years (n=41♂) **MABC**	Experimental training group (n=14 DCD) Control non-training group (n=13 DCD) Control non-training group (n=14 TD)	DSM 5 MABC score ≤15th %=DCD	Fundamental motor skill training	8-weeks 24 sessions 60 min	DCD training-group: /↑MD /↑Balance /↑Ball skills ↑ n=10 above 15th % Other both groups ─ MABC components	no
Ganapathy et al., 2020 IND	Pilot study	no 10 children (n=5 ♂) (n=5 ♀) 5-10 years **MABC**	Group A (n=5) treatment Group B (n=5) no-treatment All children=DCD	MABC and TGMD	Neuromotor Task Training (NTT)	no 10 sessions 30 min	Group A ↑MABC and TGMD Group B ↓ MABC	no
Hung et al., 2010, CHN	Pilot study	Clinic sample 23 children (n =19 ♂) (n= 4 ♀) 6-10 years **MABC**	Group-based training (n=12) Individual-based training (n=11) All children=DCD	DSM 4 MABC score <15th %=DCD	Motor skill training	Both group 8 weeks 8 training 45-min	Both groups: MABC ↑TSS 50-54% of children /↑ MD Individual-based training: /↑ Static/dynamic balance	no

Jelsma et al., 2014 NLD	Prospective study	*Preschool sample* *48* children (n =29 ♂) (n=19 ♀) *6-12 years* **MABC 2** **BOT2** **Wii Fit ski slalom test**	Balance problems BP (n=28) divided into two groups: BP1:(n=14) BP2:(n=14) 6 weeks no intervention, 6 weeks' intervention TD typical developing (n=20)	MABC 2 score ≤ 16th %=DCD	Wii Fit plus balancing games	6 weeks 18 treatment sessions / 3 times a week/ 30 min at a time	BP groups: MABC 2 /↑TSS ─↑MD ─↑AC /↑Balance Wii z-score: BP g < TD g	no
Mombarg et al., 2013 NLD	Randomized controlled trail	School sample 29 children (n =23 ♂) (n=6 ♀) 7–12 years **MABC 2** **BOT-2**	Experimental group (n = 15) Control group (n = 14) All children=DCD	MABC 2 score <16th %=DCD	Wii-balance board	6 weeks 18 training-periods 30 min	Experimental group: MABC 2: /↑ Static balance /↑BOT-2 total balance-scores Control group: MABC 2: ─↑ Static balance ↔ BOT-2 total balance-scores	no
Maharaj et al., 2016 ZAF	Gross sectional study	School sample 60 children (n =43 ♂) (n=17 ♀) 6–12-year **MABC** **DCDQ**	Intervention group (n=30) Control group (n=30) All children=DCD	MABC score ≤ 15th %=DCD	Gross motor training General therapy and activities of daily living	Both group 8 weeks 8 training 30 min	Intervention group: /↑MABC score /↑Ball skills /↑Balance /↑DCDQ Control group: -↑MABC scores -↑Ball skills -↑Balance -↑DCDQ	no
Ma et al., 2018, HKG	Randomized controlled trial	Schools sample 145 children 5-9 years **MABC**	TKD group (n=51) Control group (n=94) All children=DCD	MABC score < 5th %=DCD MABC Questionnaire	TKD group: Taekwondo Training Control group: Jogged in their natural environment	TKD group: 12 weeks 12 training 60 min Control group: 12 weeks 12 training 60 min	↑ Skeletal development in both groups ↑ MABC both groups	no

McGlashan et al., 2017 UK	Randomized controlled trial	Schools sample 21 children (n =7 ♂) (n=14 ♀) 8-10 years **MABC 2** **Tapping tasks**	Intervention group (n=16) Control group no intervention (n=9) All children=TD	MABC 2 no	Online games	4 weeks 5 time a weeks 10 min	Intervention group: MABC 2 ⁄↑ MD Control group: MABC 2 ⁄↓ MD ↔ tapping task (Both groups)	no
Morgan et al., 2019 UK	Pilot study	School sample and in a non-NHS clinic 10 children (n= 10 ♂) 8-11 years **MABC 2;** **DCDQ-P**	Therapy group (n=10) All children=DCD	MABC score ≤ 15th %=DCD	Fascia Bowen therapy	8 weeks 6 therapy 45 min	MABC 2 ⁄↑MD ⁄↑AC ⁄↑Balance - DCDQ-P	no
Miles et al., 2015 UK	Randomized controlled trial	School sample 30 children (n=19 ♂) (n=11 ♀) 8–10 years **MABC 2**	QET group (n=15) TT group (n=15) All children=DCD	MABC score ≤ 5th %=DCD	Quiet eye training (QET) Traditional training (TT)	6-8 weeks 85 practice trials 1 session per weeks	QET group ⁄↑Catching performance MABC-2 percentile scores: QET=TT	no
Männistö et al., 2006 FIN	Gross sectional study	School sample 33 children (n =13 ♂) (n=20 ♀) 5-7 years **MABC** **MABC checklist**	1. motor learning difficulty group (n = 10) 2. borderline motor learning difficulty (n = 5) 3. trained controls (n = 9) 4. untrained controls (n = 9) All children=DCD	1.group: MABC score <15th %=DCD	Movement program	26 weeks 26 sessions 60 min	Balance skill: MLD group < TG, UTG MD: UTG > MLD, TG	no
Niemeijer et al., 2007 NLD	Randomized controlled trial	School sample 39 children (n=30 ♂) (n=9 ♀) 7 years **MABC** **TGMD-2**	Treatment group (n=26) Non-treatment Control group (n=13) All children=DCD	MABC score <15th %=DCD	NTT Neuromotor task training	**Treatment group:** 9 weeks 9 sessions 30-minute **Non-treatment group** 9 weeks	Treatment group: ⁄↑ MABC ↑ TGMD-2 Control group: ─ MABC ⁄↓ TGMD-2	♂=♀

Pless et al., 2000 CHE	Randomized controlled trial	Clinic sample 37 children (n=26 ♂) (n=11 ♀) 5-6 years **MABC**	DSM 4 Experimental group (n=17) Control group (n=20) All children=DCD	MABC score ≤ 15th %=DCD	Group motor skill intervention	10 weeks 10 times	Experimental group ↑ MABC score 52 % children Control group ↑ MABC score 50 % children	no
Straker et al., 2015 AUS	Randomized and controlled	School sample 21 children (n=10 ♂) (n=11 ♀) 9-12 year **MABC 2** **DCDQ**	Normal activities NAG (n=11) Active video game AVG (n=10) Children at risk of DCD	DSM 5 MABC score ≤ 16th %=DCD DCDQ≤ 15th percentile	Active video game (AVG) Normal activities (NAG)	32 weeks 4-5 weeks 20 min a day	NAG ⁄↑Motor skill AVG ↔Motor skill	no
Sugden et al., 2003 UK	Analytical study	School sample 31 children (n =22 ♂) (n= 9 ♀) 7 - 9 years **MABC**	Group 1 (worked with parents) Group 2 (worked with teachers) All children=DCD	DSM 4 MABC score 5th-15th %=DCD	Cognitive-motor approach	40-weeks 3 to 4 sessions a week 20 minutes	⁄↑motor skills 87% children Group1 > Group 2	♂=♀
Sit CH et al 2019, HKG	Randomized controlled trial	Primary children 131 children (n=82 ♂) (n=49 ♀) 6- 10 years **MABC 2**	Intervention group: DCD-FMS n = 35 TD-FMS n = 29 Control group: DCD- PA n = 34 TD- PA n = 33	MABC score ≤ 15th %=DCD	Fundamental movement skills (FMS) Physical activity (PA)	8 weeks 8 session 40 min	DCD-FMS group: ⁄↑Enjoyment FMS groups: ⁄↑Jumping ⁄↑Locomotor skills Control groups: ⁄↑Jumping ⁄↑Locomotor skills	no
Soares et al., 2019 BRA	Case study	1 child (n=1 ♂) **MABC 2** **DCDQ**	Phase A1: period without intervention II. After one month without intervention Phase B: Intervention period III. After without intervention Phase A2: Period without intervention	DSM 5 MABC 2 score ≤ 15th %=DCD	Microsoft Kinect games	4 weeks 12 sessions 50 min	Phase B2 intervention ↑ MABC 2 Phase A2 intervention ⁄↑ MABC 2	no

Tsai et al., 2009 TWN	Gross sectional study	School sample 43 children 9-10 years **MABC**	DCD groups (n = 27) 1.Training group 2 Non training group TD typically developing groups (n = 16)	DSM 4 MABC score ≤ 5th %=DCD MABC score >15th %=TD	Table-tennis training	Both groups 10 weeks 30 sessions 50-min	↑ TD group on MABC total impairment score ↓ DCD groups on MABC total impairment score	no
Thornton et al., 2015 AUS	Randomized controlled trial	School sample 20 children (n=20 ♂) 8–10 years **MABC 2**	Daily Occupational Performance CO-OP framework (n=10) Control group (n=10) All children=DCD	DSM 4 no	CO-OP strategy on fine motor skills	10 weeks 10 sessions 60 minutes +15 minutes at home	Handwriting Speed Test (HST): CO-OP< Control AC, Balance: CO-OP=Control	no
Wilson et al., 2016 AUS	Replication study	School sample 36 children 7–12 years **MABC**	Motor imagery training MI (n=12) Perceptual-motor therapy PMT (n=13) wait-list control (n=11) All children=DCD	DSM 5 MABC score <10th %=DCD	MI PMT	Both group 5 weeks 5 training 60-min	MI group: ↑ MABC 83% of children PMT group: ↑ MABC 77% of children	no
Wood et al., 2017, UK	Randomized controlled trial	School sample 21 children (n =15 ♂) (n=6 ♀) 7–11 years **MABC 2**	Quiet eye training (QET) group (n= 11) Technical based instruction (TT) group (n= 10) All children=DCD	MABC 2 score < 5th %=DCD throw (QE1) catch (QE2)	Quiet eye training Mechanics of the skill	Both group 4 weeks 4 sessions 60 min	↑ catching ability, general coordination by parents reported QET group ↑ social skills and predilection for physical activity by all parents reported Both groups	no

Zanella et al, 2018 BRA	Gross sectional study	School sample 48 children (n=24 ♂) (n=24 ♀) 5 -8 years **MABC 2**	Intervention (n=24) DCD n=7 r-DCD n=5 TD n=12 Control (n= 24) DCD n=7 r-DCD n=4 TD n=13	MABC 2 score ≤ 5th %=DCD MABC 2 score 6 to 15th %=DCD MABC 2 score >16 %=TD	Motor intervention program	26 weeks 32 sessions 70 minutes two days a week	↑ MABC 2 Both groups	no

♂:boy;♀: girl; =: equal; ↔: immutability; no: no information; / : significantly; ↑: improvement; ↓: decrease; >: better; –: slightly; DCD: developmental coordination disorder; pDCD: probable DCD; r-DCD: risk of DCD; 6MWT: Six Minute Walk Test; CONV: conventional intervention; VR: virtual reality; BOTMP: Bruininks-Oseretsky Test of Motor Proficiency; CO-OP: daily occupational performance; MI: motor imagery; NTT: neuromotor task training; TD: typical development; TFT: task-oriented functional training; PMT: perceptual-motor training; FMPT: functional movement–power training; FMT: functional movement training; MPST: Muscle Power Sprint Test; TTS: Total test score; TSS: Total standard score; MD: manual dexterity; AC: aiming and catching; SBS: standard balance score.

Future research and limitations

There are some limitations to this study. The first one regards the methodological quality of the studies included that were not evaluated. Also, a meta-analysis was not provided. Lastly, this study was not registered in any international registration system. Future research is required to fully understand the role of gender in promoting motor and psychological performance of children with DCD in both the short- and longer-term.

Conclusion

To the best of our knowledge, a closer look at the research reveals that various interventions have been used to improve the physical condition of children with DCD, but almost none of them have been reported to affect gender issues. However, it is known that besides motor skills are different for boys and girls, the incidence of DCD is higher among boys than among girls, so it is likely that there is a gender imbalance in the intervention.

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CHAPTER III

EMPIRICAL STUDIES

Empirical study – 1

A Ten-Week Motor skill training Program Increases Motor Competence in Children with Developmental Coordination Disorder

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Abstract

The present study aimed to investigate the effect of a motor skill training program in children with DCD considering their gender. The Movement Assessment Battery for Children -second edition (MABC-2) classified the children and assessed their skill changes over time. The study was implemented at four kindergartens in the Khorezm region of Uzbekistan. In the study, all the children suffered from DCD (5.17 ± 0.70 years; 10 girls), and all the indicators of MABC-2 were less than 16%. The participants were divided into an experimental group (n = 17), receiving ten weeks of motor skill training program for 45 min twice per week; and a control group (n = 7), which proceeded with exercises of everyday living. The ANCOVA showed differences between the groups in the post-test concerning each domain: manual dexterity ($F_{(1, 20)} = 18.703$, $p < 0.001$; $\eta^2 = 0.471$); aiming and catching ($F_{(1, 20)} = 9.734$, $p = 0.005$; $\eta^2 = 0.317$); balance ($F_{(1, 20)} = 35.140$, $p = 0.000$; $\eta^2 = 0.626$); and total MABC-2 test score ($F_{(1, 20)} = 66.093$, $p < 0.001$; $\eta^2 = 0.759$), with all the children in the EG exhibiting better results. The Wilcoxon test revealed statistically significant differences for the EG between moments for all the variables ($p < 0.001$) but not for the CG ($p > 0.050$). The effectiveness of the intervention program was similar across both genders. The study suggests that a 10-week motor skill training program can increase the quality of children's motor competence and represent a valuable procedure for physical education specialists to enhance motor competence for children with DCD.

Keywords: Developmental coordination disorder (DCD); motor skill training program; MABC-2

Introduction

Developmental coordination disorder (DCD) is characterized by a delay in the development of motor competence, especially the coordination of movements, which visibly impairs the child's movements and accomplishment of daily tasks (APA, 2013). Furthermore, the feelings of inadequacy accompanying poor motor coordination are invariably reinforced through relationships with peers (Gaines et al., 2008). DCD may decrease motivation to perform physical activities and decrease opportunities to develop motor competence and fitness (Rivilis et al., 2011). Rivilis et al. (2011) previously observed that children with DCD, in addition to their motor problems, present lower levels of health-related physical activity. If not treated in time, the symptoms of movement problems persist in a large percentage of individuals into adulthood. Children with movement difficulties tend to be less physically active and engage in less physical activity (Haga et al., 2009).

However, spare time or recreational physical activity is essential for children and adolescents' healthy social and physical development (Smits-Engelsman et al., 2018). Consequently, DCD has received significant attention from scientists across disciplines, including pediatrics, occupational therapy, physiotherapy, kinesiology, and psychology (Wilson et al., 2008). Researchers and health professionals have developed several types of interventions focused on motor skill training programs to overcome DCD. These programs are based on daily motor skills, exercises, and activities involving fundamental motor competence. The majority of investigators studying this domain agree that these programs enhance the quality of movement and diminish DCD difficulties in children (Smits-Engelsman et al., 2018; Adamchick et al., 2021; Navarro-Patón et al., 2021). Moreover, besides improving motor competence, short- term motor skill interventions have also been shown to improve other cognitive, emotional, and psychological aspects in children with DCD (Yu et al., 2018). Regarding the design of motor skill interventions, there have been different movement-based approaches to intervention for DCD, which are typically grouped into two wide ranges: those that utilize movement to target main performance problems, frequently defined as process-oriented approaches, and those

that use activity to address the performance itself, frequently defined as task-oriented approaches (Smits-Engelsman et al., 2018). In a review about the efficacy of motor interventions for children with DCD (Smits-Engelsman et al., 2013), the benefits for the motor performance of children with DCD over and above a lack of intervention were observed. However, task-oriented approaches were more effective than process-oriented approaches, yielding better motor competence for children with DCD. Concerning the gender effect on the efficacy of motor interventions for children with DCD, research is scarce, with only a few studies indicating equal outcomes of the effectiveness of programs on both boys and girls (Niemeijer et al., 2007; Sugden et al., 2003). For example, Niemeijer et al. (2007), using Neuromotor task training in a group of DCD seven-year-old children (20 males, 6 females), found an improvement in motor competence regardless of gender. However, gender differences and their importance for motor competence expression have been emphasized by several authors, such as Dos Santos et al. (2018) and Reyes et al. (2019). The authors found that children without DCD might possess fine motor skills, while Dos Santos et al. (2018) proved that inconsistent results of gross motor coordination occur with girls and Reyes et al. (2019) discovered the same tendency with boys.

Scientific evidence proves that interventions are effective in the short term to develop motor competence, as well as performance in emotional, cognitive, and other psychological aspects in DCD children (Yu et al., 2018; Smits-Engelsman et al., 2013; Niemeijer et al., 2007; Sugden et al., 2003; Dos Santos et al., 2018; Reyes et al., 2019; Hillier et al., 2007).

However, other authors, such as Nolan. (2005) found that girls might be superior to boys at developing postural control, with girls progressing to an ‘adult-like’ integrated open- and closed-loop strategy of controlling balance earlier than boys. These results were supported by Riach et al. (1994), Kirshenbaum et al. (2001), and Kolic et al. (2019). Nolan et al. (2005) also observed that greater balance ability and postural control were associated with Body Mass Index (BMI), with older female children and children with lower BMI being more likely to exhibit greater balance

ability and postural control. Therefore, Nolan et al. (2005) highlighted the need to study the sexes separately when investigating balance in children. Reys et al. (2019) supported these differences, in a study where they found that boys outperformed girls from 6 years of age to 9 years of age. In addition, children with increasing body mass index were less coordinated, while those who were stronger and more agile exhibited steeper trajectories of gross motor coordination with age.

Concerning children with DCD, Rodrigues et al. (2019) systematically analyzed the differences in motor performance between genders in studies that used only the MABC- 2 (Henderson et al., 2007). Their results revealed that gender differences in performance were consistent across studies, since boys demonstrated more success and ease in activities involving gross motor skills, and girls performed better in the activities involving fine motor skills. Differences in balance were not conclusive. Since few studies aimed to explore possible gender differences and the role of the environmental context in fundamental motor skill programs with children with motor problems (Bardid et al., 2013), there has been less research into whether such interventions are similarly efficient between genders of children with DCD. In this scenario, if boys and girls respond differently to motor intervention programs to overcome DCD, then motor programs must be adapted, considering the differences between genders, to maximize the reduction in movement difficulties for each. Taking into consideration that there are gender differences in motor competence and task-oriented approaches are more effective, the main goal of the current study is to study the effectiveness of a motor skill training program in children with DCD and analyze possible gender differences. Thus, the hypothesis was that participation in the intervention program would significantly improve the motor competence levels of all children, with boys and girls responding differently to motor intervention.

Methods

Participants

With the consent of the Department of Preschool Education of the Khorezm region (Uzbekistan), from the earliest periods of the COVID- 2019 rule mitigation period,

scientific research was launched among four kindergartens in the northwest region of Uzbekistan, the Urgench region. First, 63 children aged 4–6 years old with no indication of any neurological or physical impairment from these four kindergartens were tested with the MABC-2 (Henderson et al., 2007). Among the children evaluated with the MABC-2, those falling between the 5th and the 16th percentile (27 children) were selected and invited to participate in the intervention study (experimental group). However, during the pandemic time. access to one kindergarten was not accessible for intervention. Thus, we selected this kindergarten as a control group with 7 children. A total of 17 children were from the remaining kindergartens. It should be noted that 3 out of the 27 children (one of them from the experimental group and two of them from the control group) involved in the study could not participate in the post-test due to their parents' desire that they not attend kindergarten (Figure 1). Written parental consent was obtained.

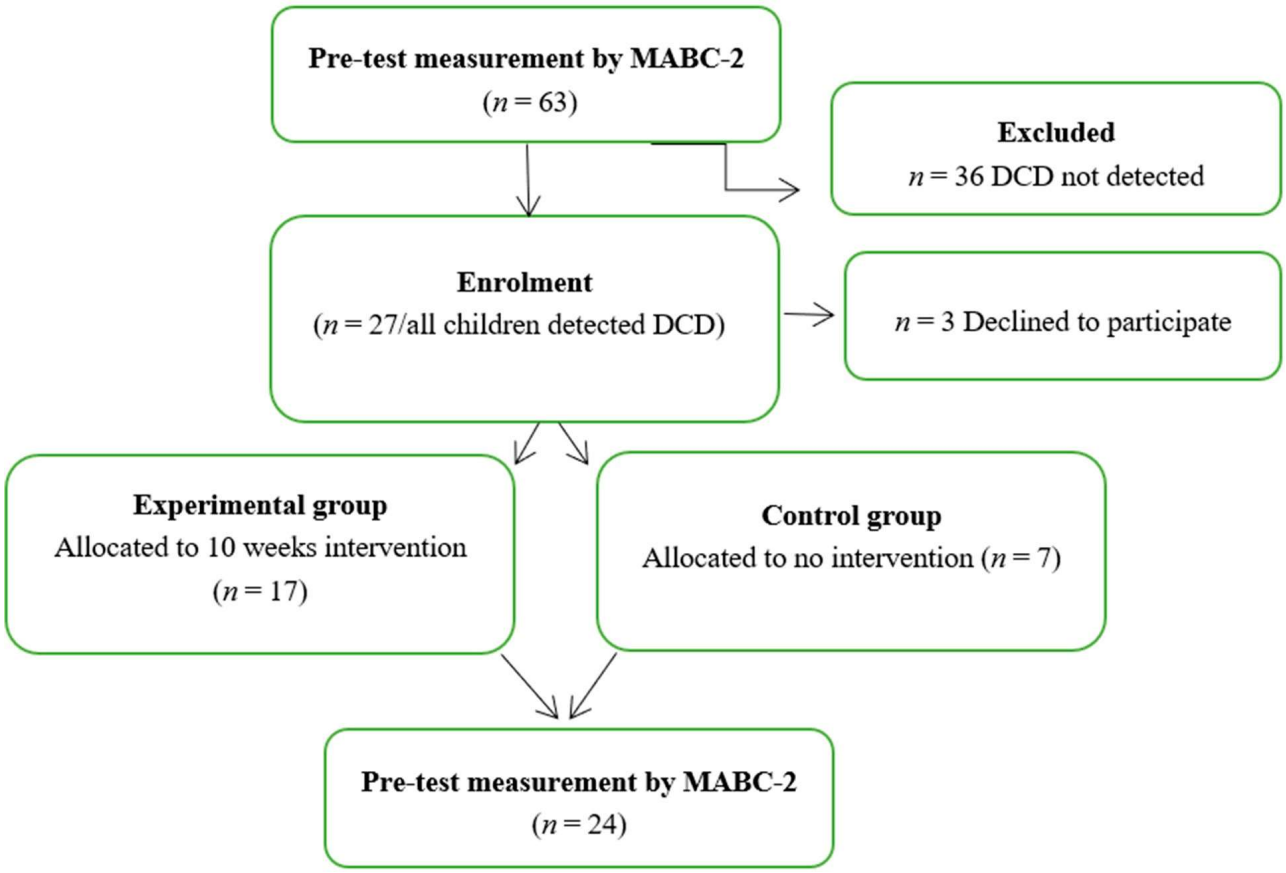


Figure 1. *CONSORT flow diagram.*

The inclusion criteria consisted of the children's performance falling between the 5th and the 16th percentile (probable DCD (Developmental Coordination Disorder)) or below the 5th (at risk of DCD) on the total MABC-2 (Movement Assessment Battery for Children, second edition) score and having not indicated any neurological or physical impairment. Descriptive statistics on gender, age, manual preference, and MABC-2 scores can be found in Table 1.

Table 1. Experimental and control groups. Characteristics of participants by age (years), sex (male; female), manual preference (right; left), and MABC-2 pre-test scores

	Experimental Group (n = 17)	**Control Group (n = 7)**
Age year, mean (SD)	5.47 ± 0.514	4.71 ± 0.756
Gender (m/f)	10/7	4/3
Manual preference (R/L)	15/2	5/2
MABC-2 Total Score	5.76 ± 1.39	5.29 ± 1.11

Instrument

The MABC-2 test was applied and executed following the MABC-2 manual in order to measure the effects of the training program on both groups (Henderson et al., 2007). MABC-2 is an appropriate instrument with which to assess the development of the motor competencies of preschool children, and acceptable overall evidence of its validity and reliability for age band one has been found (Griffiths et al., 2018; Serbetar et al., 2019). Smits-Engelsman et al. (2011) studied the psychometric properties and the confidence of the MABC-2 in 50 typical children (3 years of age) and concluded, based on the test-retest, that the test offers a good degree of confidence, even for three-year-old children, making it sensitive at detecting individual changes. Moreover, Smits-Engelsman et al. (2011) and Ellinoudis et al. (2011), using band 1 on 183 Greek children, suggested that the MABC-2 could be a valid and reliable tool to assess children aged 3 to 5 years of age with movement difficulties. Henderson et al. (2007) proposed the following cutoff points from the

test manual: ≤ 5% atypical motor performance, which indicates DCD; 6th to 15th percentile, which means r-DCD; and any percentile higher than 16%, which indicates TD. In pre-and post-tests, each child was assessed by the same tester and recorded on video.

Procedures

In the task-oriented approach, the focus was on training functional tasks, which included those that involved mainly body stability (e.g., standing) and those that required body transport (e.g., hopping, skipping, running, jumping, walking, and galloping) Miyahara et al. (2017). The children in the experimental group were involved for 45 min twice a week for ten weeks. The participants were divided into four groups, corresponding to the four kindergartens, and the number of participants in each group was 3–6 children. Each training session included two main components: an initial 5 min warm-up, and 40 min of motor skill training (group training is outlined in Table 2). All the children in the experimental group completed the intervention, and all the intervention sessions were videotaped. The DCD control group and the experimental group also performed their regular classroom activities, physical education classes, and physical activities as scheduled, but only the experimental group participated in any extra training for the duration of this research. The extra training replaced the daily walk during that 45 min and was designed and taught in the indoor facilities of each school by two graduates in PE (a PHD student and a master's degree student). They received an average of 15 h of training during the ten weeks. Due to various circumstances, such as kindergarten activities and dentist visits, several children missed one or more training sessions, which resulted in slightly different total training hours between the children in the experimental group (13.30 ± 1.02 h). Common motor problems experienced by children with DCD, such as poor agility, balance, core stability, and movement coordination, were addressed through a range of functional activities and exercises. The motor tasks were modified as the training continued to guarantee successful task execution while also offering a sufficient challenge to the child's motor ability.

Table 2. Motor skill training program. Examples of activities.

Domain	**Examples of Activities**
Manual Dexterity	Placing small beads on the side by plastic clamps Sorting and placing small products of different types with fingers Passing the lacing through the marked holes Hanging nuts on the bolts Hang the plastic clamps in the specified direction To tie clothing buttons Putting the buttons on the marked line Browsing a book and other similar game
Aiming and Catching	Catching three different balls (Robo-ball, tennis ball, football ball) Throwing three different balls to designated areas (Robo-ball, tennis ball, football ball) Bowling with twist Ping Pong Ball Catch (Get out those plastic red Solo cups and a few Ping-Pong balls) Bowling (Set up your bowling "lane" with some painter's tape and use plastic bottles or cups for pins) Different delays and other similar games
Balance	Walk on the marked line Picking up items "Night and morning" (when "night" is said, jump into a circle, and when "morning" is said, jump out of the circle) Book balance game (Holding a book on the head without dropping it) Different delays and other similar games

Data Analysis

One-way analysis of covariance (ANCOVA) was applied to examine differences in the post-test scores of all the MABC-2 domain variables between the intervention and control groups, controlling for pre-test scores (Geuze et al., 2015). The pre-test score of each domain variable was a covariant, the different groups were independent variables, and the post-test score was the dependent variable.

Next, the program effect was tested using a Wilcoxon test for repeated measure analysis in each group (EG and CG) and the Mann–Whitney was used to test gender differences within groups and moments.

The dependent variables included abilities in the domains of manual dexterity, aiming and catching, balance, and total MABC-2 scores.

The statistical analyses were performed using SPSS 26.0, and the statistical significance was assessed using an alpha level of 0.05. An estimate of the effect size for the intervention group, partial eta squared (ηp^2), was calculated for each dependent variable. According to Cohen's et al. (1988) guidelines, 0.0099 constitutes a small effect, 0.0588 a medium effect, and 0.1379 a large effect.

Results

The CONSORT flow diagram, illustrated in Figure 1, presents 63 children meeting the inclusion criteria. Of these, twenty-four children diagnosed with DCD by the MABC- 2 program were included in the study. There were no significant differences in perinatal and social factors or motor performance between the recruited children and the non-participants. The 24 recruited children with DCD were randomized to either the experimental group (n = 17; mean corrected age 5.47 ± 0.514; 10 males) or the control group (n = 7; mean corrected age 4.71 ± 0.756; 4 males).

From pre to post-intervention, all the children from the experimental group with probable DCD or at risk demonstrated no motor impairment after intervention. Nevertheless, in the control group, the majority remained with motor impairment and even regressed, with one falling above the 16 percentiles. In the second part of the study, the MABC-2 percentile of all the children in the experimental group exceeded the 16th percentile, but the children's performance in the control group remained virtually unchanged (Table 3).

Table 3. Number of children scoring in each MABC-2 percentile band at pre- and post-intervention.

The category of motor difficulty	Experimental Group (n = 17)		Control Group (n = 7)	
	Pre	**Post**	**Pre**	**Post**
No motor difficulty (MABC-2 >16th percentile)	0	17	0	1
At risk of DCD (from 6th–16th percentile)	11	0	3	1
Probable DCD (MABC-2 ≤ 5th percentile)	6	0	4	5

Program Effect

3.1.1. Manual Dexterity

The ANCOVA highlighted differences between groups in the post-test ($F_{(1, 20)} = 18.703$, $p < 0.001$; $\eta^2 = 0.471$) considering the pre-test values ($F_{(1, 20)} = 2.229$, $p = 0.150$; $\eta^2 = 0.096$) (see Table 4).

Table 4. Means and standard deviation for post-test MABC-2 domains by groups.

MABC-2	**Group**	**Mean ± SD**	***p***	***η2***
Manual Dexterity	Experimental group	7.76 ± 2.25	0.001	0.471
	Control group	4 ± 1.73		
Aiming and Catching	Experimental group	13.18 ± 2.24	0.003	0.317
	Control group	9.29 ± 3.35		
Balance	Experimental group	11.12 ± 1.96	0.920	0.626
	Control group	6.0 ± 1.63		
Total Test Score	Experimental group	81.6 ± 5.911	0.524	0.759
	Control group	51.43 ± 11.85		

The Wilcoxon test revealed for the EG statistically significant differences between moments ($z = 3.422$, $p < 0.001$) but not for the CG ($z = -1.890$, $p = 0.059$) (see Table 5).

Table 5. Experimental and Control groups. Results from MABC-2 domains at pre-and post-intervention.

		Experimental Group		Control Group	
MABC-2		**Mean ± SD**	***p***	**Mean ± SD**	***p***
Manual Dexterity	Pre-test	3.82 ± 1.18	0.001	4.86 ± 1.86	0.059
	Post-test	7.76 ± 2.25		4.00 ± 1.73	
Aiming and Catching	Pre-test	9.47 ± 2.80	0.002	8.26 ± 2.69	0.674
	Post-test	13.18 ± 2.24		9.29 ± 3.35	
Balance	Pre-test	8.00 ± 2.34	0.001	7.00 ± 2.30	0.399
	Post-test	11.12 ± 1.96		6.00 ± 1.63	
Total Percentile Rank	Pre-test	5.76 ± 1.39	0.001	5.29 ± 1.11	0.459
	Post-test	10.65 ± 1.53		4.71 ± 1.89	

The MABC-2 indicators improved in the post-test experiment group, but the indicators decreased from the first to the second moment in the control group.

3.1.2. Aiming and Catching

The ANCOVA highlighted differences between groups in the post-test ($F_{(1, 20)} = 9.734$, $p = 0.005$; $\eta^2 = 0.317$) considering the pre-test values ($F_{(1, 20)} = 0.245$, $p = 0.626$; $\eta^2 = 0.012$), (see Table 4). The Wilcoxon test revealed statistically significant differences between moments for the EG ($z = 3.160$, $p = 0.002$) but not for the CG ($z = 0.420$, $p = 0.674$) (see Table 5).

These effects indicated a positive overall intervention effect over time and different levels of ball skills between the groups of children.

3.1.3. Balance

The ANCOVA highlighted differences between groups in the post-test ($F(1, 20) = 35.140$, $p = 0.000$; $\eta^2 = 0.626$) considering the pre-test values ($F_{(1, 20)} = 0.039$, $p = 0.845$; $\eta^2 = 0.002$), (see Table 4).

The Wilcoxon test revealed statistically significant differences between moments for the EG ($z = 3.209$, $p = 0.001$) but not for the CG ($z = 0.843$, $p = 0.399$)

(see Table 5). The performance improved more in the experimental group than in the control group from the first to the second moment.

3.1.4. Total Test Score MABC-2

The ANCOVA highlighted differences between groups in the post-test ($F_{(1, 20)} = 66.093$, $p < 0.001$; $\eta^2 = 0.759$) considering the pre-test values ($F_{(1, 20)} = 1.129$, $p = 0.300$; $\eta^2 = 0.051$) (see Table 4).

The Wilcoxon test revealed statistically significant differences between moments for the EG ($z = 3.647$, $p < 0.001$) but not for the CG ($z = 0.740$, $p = 0.459$) (see Table 5). These results indicated a positive overall intervention effect over time, with the EG demonstrating an improved performance compared to the CG and the CG a decline in performance from the first to the second moment.

Gender Effect

The results of the Mann–Whitney test revealed no statistical differences between genders in both groups and moments (Tables 6 and 7).

Table 6. Pre-intervention. Gender effect in each group at MABC-2 domains.

		Experimental Group		**Control Group**	
MABC-2	**Gender**	**Mean ± SD**	***p***	**Mean ± SD**	***p***
Manual Dexterity	Male	3.90 ± 1.28	0.887	5.50 ± 1.73	0.400
	Female	3.71 ± 1.11		4.00 ± 2.00	
Aiming and Catching	Male	9.80 ± 2.48	0.536	8.50 ± 0.577	1.000
	Female	9.00 ± 3.36		8.00 ± 4.58	
Balance	Male	8.20 ± 2.39	0.669	6.75 ± 1.89	1.000
	Female	7.71 ± 2.43		7.33 ± 3.21	
Total Test Score	Male	58.6 ± 9.45	0.536	56.7 ± 4.57	0.629
	Female	56.2 ± 8.57		53.6 ± 8.08	

Table 7. Post-intervention. Gender effect in each group at MABC-2 domains.

		Experimental Group		Control Group	
MABC-2	**Gender**	**Mean ± SD**	***p***	**Mean ± SD**	***p***
Manual Dexterity	Male Female	7.80 ± 2.56 7.71 ± 2.56	0.813	4.00 ± 1.82 4.00 ± 2.00	1.000
Aiming and Catching	Male Female	12.9 ± 2.07 13.5 ± 2.57	0.669	9.25 ± 3.94 9.33 ± 3.21	1.000
Balance	Male Female	11.1 ± 1.96 11.1 ± 2.11	1.000	5.50 ± 1.91 6.67 ± 1.15	0.400
Total Test Score	Male Female	81.9 ± 7.18 81.1 ± 3.93	0.887	49.5 ± 16.00 54.0 ± 4.35	0.629

It was found during our study that the exposure rate equality of the intervention program administered to the children with DCD was equal for both girls and boys in both groups and in all variables ($p > 0.05$).

Discussion

The purpose of the present study was to analyze the effect of a motor skill training program on children with DCD considering their gender. As a result, the acquisition of motor skills was carefully monitored for ten weeks, and the effectiveness of the motor skill training program was assessed in a sample of children with different levels of DCD. This subject was also investigated by Farhat et al. (2016), Cacola et al. (2015), Hung et al. (2010), and Zanella et al. (2018), who studies support the use of a motor training program to increase motor competence in children with DCD. Our results indicated differences between the experimental group and the control group in all the motor competence measures, as in other studies with similar interventions with healthy (Nolan et al., 2005; Farhat et al., 2016), older children (McGlashan et al., 2017), and different genders (Dos Santos et al., 2018; Reyes et al., 2019). Importantly, our study found that, with the exception of children in the control group, all the children with DCD improved their total test scores, manual dexterity, aiming and catching, balance, and increased percentile after a 10-week

training period. Moreover, at the end of the study, it was found that not only in the MABC-2 program but also in interviews with parents and kindergarten teachers, positive changes were observed in the general physical activity of the children involved in the study. These findings suggest that a structured program of activities with an emphasis on the motor skills of manual dexterity, aiming and catching, and balance can benefit the motor competence of children with DCD, as has already been demonstrated in previous studies (Hung et al., 2010; Ferguson et al., 2013). When the MABC-2 battery was used to analyze the skills in terms of manual dexterity, improvements were seen in the intervention group, which could have been due to specific tasks being performed with this skill during the intervention. However, there were no improvements in this subscale in the control group, which could have been attributed to the fact that fine motor skills require a longer acquisition time (Smits-Engelsman et al., 2018). Regarding aiming and catching, the results indicate an increase in the score in each of the groups, but they were higher in the intervention group. These results agree with those of Yu et al. (2016) and Woods et al. (2017), which demonstrated that an intervention based on fundamental movement skills improves object control skills in pre-school children with DCD, discarding the idea that these skills are difficult to improve upon (Logan et al., 2011).

Another key finding of the study was that the aiming and catching skills of children with DCD can improve without intervention. This finding was also confirmed in other research studies (Yu et al., 2016; Wood et al., 2017). However, it should be mentioned that the improvement rate in the aiming and catching skills was higher in the intervention group than in the non-intervention control group.

Our findings reveal that in the experimental group, specific motor competence ori- entation, as taught by a specialist, exerted a beneficial influence on all MACBC-2 aspects. The individual results of the experimental group demonstrated that the 17 preschoolers improved in the total percentile of the MABC-2 battery to such an extent that they could be classified in a different performance category on this test and their clinical range could be changed to normal, according to the MABC-2 manual (Henderson et al., 2007). Our results demonstrate that the experimental

groups of children with lower scores on the total percentile obtained significant improvements to the point of falling within a normal motor competence range (percentile >16). Our results are in line with those of Farhat et al. (2016), which demonstrated that children with serious problems in motor competence, after a structured program, benefit more than those who are framed in higher percentiles and classified with normal motor competence (that is, their possibility of improvement is greater than that of their counterparts). Concerning gender, the main finding of our study is that the results of the post-intervention program were almost identical in boys and girls. Our results are not in line with those of Bardid et al. (2013) because they found that their intervention was gender-specific. These authors, using the TGMD-2, observed that boys and girls exhibited a similar gain in locomotor skills, but only the girls' object control skills benefited from the 10-week practice.

In this study, statistically significant gender differences were found between boys and girls. All the scores and percentages of the girls were higher than those of the boys, especially in object control skills, after the 10-week intervention; the results do not support those of some other investigations (Golding et al., 2013; Mathisen et al., 2016; Venter et al., 2015; Valentini et al., 2012), which indicate that boys generally achieve higher scores. These global differences with respect to gender could be due, in part, to the higher scores obtained by girls in manual dexterity (Kokštejn et al., 2017; Freitas et al., 2014; Psotta et al., 2012) and in balance (Kokštejn et al., 2017; Olesen et al., 2014), perhaps due to the practice of stereotyped activities, and different sports activities, between boys and girls. Therefore, preschool education classes should promote co-educational sports activities to try to eliminate these gender differences.

Conclusions

The most important finding indicated that the motor skill-training program exerts the same positive effect on both genders. Other results from this study demonstrated that a structured 10-week motor training program based on different motor skills

(e.g., manual dexterity, aiming, and catching) performed in one session of 40 min per week is more effective than traditional preschool. An education program for preschoolers with DCD led by a non-physical education teacher improves all of these skills and the overall percentile so that preschoolers who participate in intervention are no longer in the bottom percentile. This should be followed by five to one, in which they can be classified with normal motor competence. Therefore, these findings provide empirical evidence demonstrating the effectiveness of a structured motor skill training curricular program implemented in preschool education, focused on the result and not on the process.

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Empirical study – 2

Motor skill training Program Reinforces Crossing the Body's Midline in Children with Developmental Coordination Disorder

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Abstract

Midline crossing problems have been associated with children with atypical development. When compared to typical development (TD) children, they are less likely to cross the midline into contralateral space with their preferred hand. A motor skill training program is the most beneficial intervention for children with developmental coordination disorder (DCD). However, there is not enough information on how this intervention will affect crossing the midline. The goal of this study was to find out midline crossing behavior after an intervention program for children with DCD. The Movement Assessment Battery for Children (MABC-2) was used to assess motor coordination, and Bishop's card-reaching task measured the ability of children to cross the midline. The study included 48 right-handed children, 28 with TD and 20 with DCD (5.17 ± 0.70 years) from four preschools in the Khorezm region (Uzbekistan). Participants identified as having DCD were placed in an experimental group (EG: n = 15), receiving ten weeks of a motor skill training program, and a control group (CG: n = 5). Concerning midline crossing behavior before intervention, DCD children showed more contralateral and less midline right-hand use compared to TD children. After intervention, a significant group × position interaction was found between the EG and CG at positions 1 and 4, and between the EG and TD group at position 4. Concerning the midline reaching, fewer right-hand reaches were made by the EG group compared to the other two groups. The same could be seen at position 1 when compared to the CG group. It can be concluded that, after intervention, DCD children in the EG showed fewer right-hand reaches in the contralateral space, but they improved their right-hand reaches in the midline, showing a similar behavior to TD children.

Keywords: Midline crossing; developmental coordination disorder (DCD); motor skill training program; children; laterality

Introduction

The midline is a hypothetical line drawn through the center of human bodies. Crossing the body midline is the ability to move over spontaneously with a body part, such as the arms or legs, to reach across the body's center. The ability to cross the midline indicates that both sides of the brain are communicating, and that the child can coordinate both the left and right sides at the same time, which is required for learning skills and to perform movements efficiently (Ayers, 1971). Subsequently, crossing the midline is a necessary developmental milestone. This is because if the child learns to cross the midline, he/she will become more likely to use the preferred hand, and he/she will keep practicing every day or acquire sports skills more easily (Schilder, 1950). Moreover, the midline of the body has been credited with contributing to the formation of the spatial orientation, bilateral integration, body scheme, directionality, and laterality (Schilder, 1950; Stilwell, 1987), indicating the integration of the body's midline, which makes bilateral coordination possible (Smith, 1987). Postures of gross or body movements, such as standing upright, walking, turning, sitting, or lying, include both halves of the body, moving parallel to, on the opposite side of, or in a circular manner about the central axis of laterality (Stilwell, 1987). Additionally, it has been hypothesized that midline behavior plays an important part in the development of ego capabilities (Sherick et al., 1976; Goody et al., 1952). These researchers advanced the hypothesis that individuals orient themselves in a manner that is directly tied to their symmetrical structure and that all motions in space are similarly related to this symmetry around the midline.

A developmental trend has been observed in typically developing (TD) children from age 3 to age 8 while crossing the midline for unimanual movements; the number of midline crossings developed with age, with younger children showing a lower incidence of crossing the midline (i.e., doing more right-hand reaches into the right hemi space) (Smith, 1983; Serrien et al., 2021). Moreover, this trend was independent of gender and the handedness of the participants (Carlier et al., 2006). When taking into consideration the spatial position of the crossing behavior, midline

crossings happened more often near the middle of the body than in the mid-way and farthest positions (Carlier et al., 2006; Cermak et al., 1980; Pedersen et al., 2010).

Failure to participate in an adequate amount of midline behavior in early infancy is a forerunner of difficulties later in life, which, when interacting with other factors, unfold as disturbances in laterality, which may result in a learning disadvantage (Sherick et al., 1976). Midline crossing problems have been associated with children with atypical development, such as learning disabilities (Schilder, 1950; Smith, 1983; Michell et al., 1999; Murata et al., 2009), attention deficit hyperactivity disorder and/or autism spectrum disorder (Begum et al., 2020), Down syndrome (Groen et al., 2008), and developmental coordination disorder (DCD) (Hill et al., 1998; Smits-Engelsman et al., 2006). Results of these studies show that those children tended to make fewer midline crossing reaches, tended to be less ready to cross the midline into contralateral space with their preferred hand, and tended to be less consistent in their hand preference within and across activities. Furthermore, they showed deficits for tasks in the contralateral workspace. A kinematic investigation carried out by Smits-Engelsman et al. (2006) provides a rigorous measurement of children with and without DCD in both accuracy and speed when aim-directed movements were made across the midline. In contrast to expectations, this research discovered that DCD children were not preferentially impaired when making movements in a contralateral workspace, even though they were not as good as their peers overall. This supported the findings of Zoia et al. (2007) in a reaching task performed by children with and without DCD under normal and perturbed vision. Specifically, in children with DCD, Smits-Engelsman et al. (2006) proposed a general neuromotor deficit hypothesis, suggesting that these children have a weakness in movement initiation, and contralateral inaccuracy is added to their overall inaccuracy. These findings are supported by numerous studies (Goez et al., 2008; Freitas et al., 2014) that have established that children with DCD exhibit an unexplained inability to acquire necessary motor skills, such as maintaining balance or writing, despite the absence of any known medical condition or identifiable neurological disease. Performances of children with DCD tend to be slower, more

dependent on vision, and more variable than those of TD children (Biancotto et al., 2011). Nevertheless, for children with DCD, a motor skill training program can enhance the ability of their motor competence (Saidmamatov et al., 2021). Sherick et al. (1976) stated that external stimulation helps myelination, vascularization, and dendritic arborization in the brain; all of which are thought to be necessary for the brain to reach its genetic potential and work well. Moreover, multiple researchers have stated that hand preference may be associated with sensory–motor experience (Coryell et al., 1978; Nudo et al., 1996; Provins et al., 1997; Corbetta et al., 2002). Consequently, we hypothesized that a motor skill program would provide such stimulation, especially in midline crossing, because of the manual skills (manual dexterity and aiming and catching) activities proposed. Since a relationship has been reported between an inconsistency of using the preferred hand in children with DCD and less frequent use of the preferred hand in tasks requiring reaches across the midline, it was expected that a motor intervention program induces a more consistent handedness behavior expressed by more frequent midline crossing of the preferred hand. To our knowledge, there is no study that has compared midline crossing behavior after an intervention motor program. As a result, the purpose of this study was to investigate the impact of an intervention program on midline crossing behavior for children with developmental coordination disorder compared to typical development children.

Methods

2.1. Study Design

With a control group, a quasi-experimental design was used with pre- and post- test measurements.

2.2. Participants

A selected sample of children from 4 preschools in Urgench (a city in the Khorezm region of Uzbekistan) was recruited during September 2020. The sample comprised 48 right-handed children: 28 (14 male / 14 female) with TD, and 20 (12 male / 8

female) with DCD, aged between 4 and 6 years old. Children with learning difficulties or children with attention deficit disorder, prenatal complications, neurological disorders, or sensory problems, preterm infants, and children with epilepsy or other chronic diseases were not included in the study. As a result, none of the participants suffered from any neurological or physical issues. These data were gathered from the preschool records of the children, as well as feedback from their parents. A total of 28 TD children (14 male) had: (1) no evidence of functional motor problems as observed by their teacher; (2) no MABC-2 score at or above the 16th percentile; (3) no serious medical diagnosis reported by parents or relatives; and (4) no cognitive or intellectual impairment as reported by their teacher. On the other hand, seven children (four of them were male) appeared to perform the parameter for DCD. In DSM-5 (APA, 2013), they scored in the 5th percentile or lower on the MABC-2 (Criterion A), the teacher identified them as having a motor coordination problem (Criterion B), they were 3–6 years old (Criterion C), and their parents or relatives reported no significant medical condition that could affect motor performance, and their teacher confirmed the absence of intellectual or cognitive impairment (Criterion D). Thirteen children (eight male) fell between the 6th and 15th percentile, which means they were at risk for DCD. From these 20 DCD children, 15 children were randomly assigned to the experimental group (EG), and the remaining 5 children were assigned to the control group (CG). Prior to participation, the parents supplied verbal consent and the children provided informed consent. Through the permission given by parents and teachers, we selected 15 children in the EG to be engaged in a 10-week motor skill training program from October to December 2020 (Figure 1).

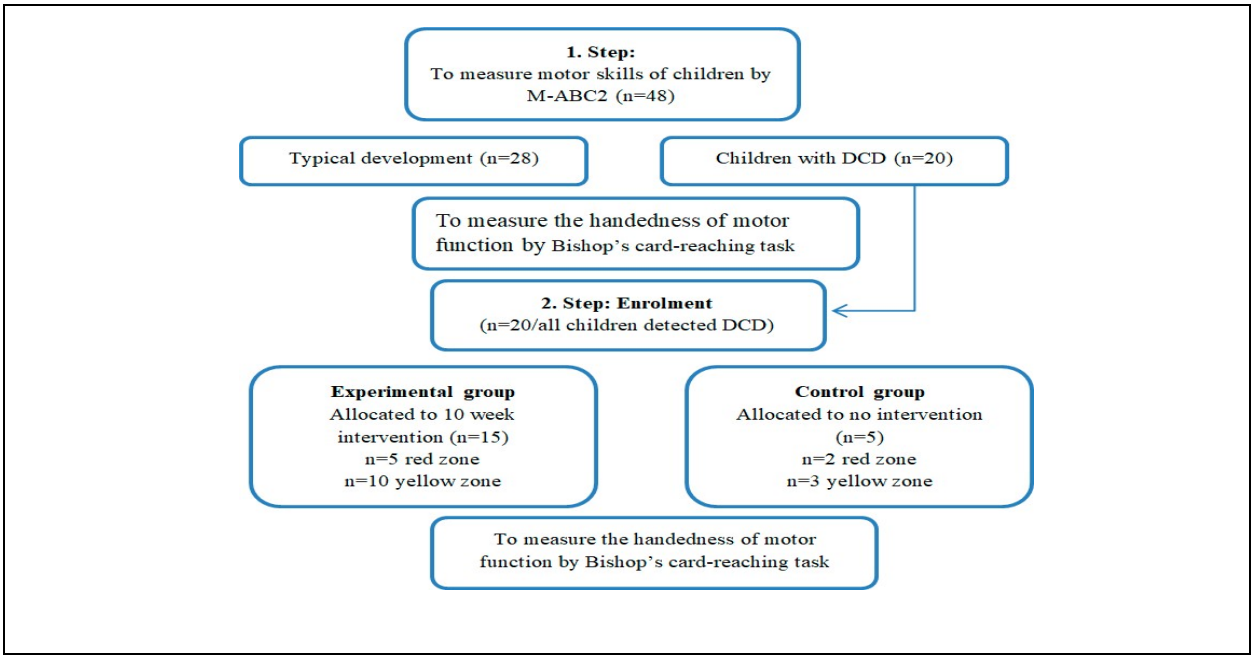


Figure 1. *CONSORT flow diagram.*

The approach provided in the MABC-2 was used to assess hand preference. A pen was placed on the table in front of the child, and he/she was asked to make a tiny drawing of a figure.

2.3. Instruments

The Movement Assessment Battery for Children—Second Edition (MABC-2) (Henderson et al., 2007) was used to evaluate DCD. Besides being one of the most common instruments applied in this domain, MABC-2 is an assessment tool that can easily be used in a school setting, being a valid and reliable instrument (Lander et al., 2016; Lander et al., 2017). Moreover, equal validity to the original UK version of the MABC-2 was shown in Greek, German, Japanese, and Thai studies (Wagner et al., 2011; Kita et al., 2016; Ellinoudis et al., 2011; Jaikaew et al., 2019). The MABC-2 test is designed to identify and describe impairments in the motor performance of children and adolescents from 3 to 16 years of age, divided into three age bands (3–6 years, 7–10 years, and 11–16 years). The test consists of children completing a series of eight fine and gross motor tasks divided into three subscales: manual dexterity, aiming and catching, and balance (Henderson et al., 2007).

Bishop's card-reaching task (Quantification of Hand Preference, QHP) was used to evaluate the crossing midline behavior. Bishop and her colleagues proposed a card-reaching test to determine hand preference in 1996 (Bishop et al., 1996). The test measures the degree and direction of hand preference in a task that allows participants to cross their body midline (Figure 2).

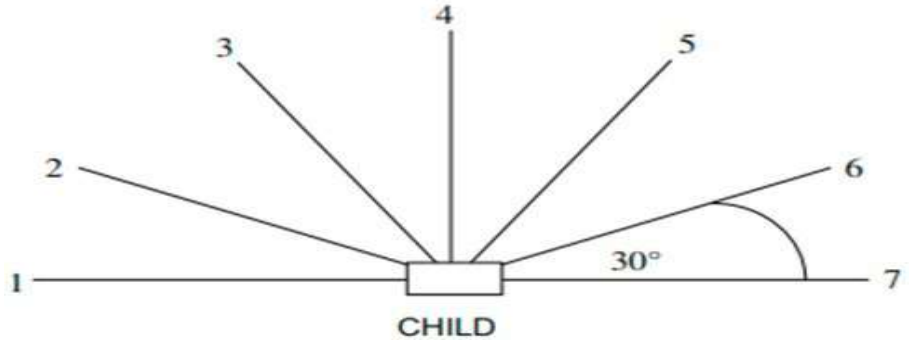


Figure 2. *Set up the task for the QHP. Position 4 = midline, child faces this. For right-handed participants, position 1–3 = contralateral; positions 5–7 = ipsilateral.*

Good metric qualities were found for the QHP (Bishop et al., 1996). The previous literature suggests that the QHP is a suitable measure of human handedness in children and adults. It should also be noted that the above instrument has been used by many researchers (Sherick et al., 1976; Goody et al., 1952; Pedersen et al., 2010; Goez et al., 2008; Saidmamatov et al., 2021; Doyen et al., 2002; Saidmamatov et al., 2022).

2.4. Procedures

Participants were intentionally allocated to a predetermined and unbalanced group. The reason for such imbalance was that since data were gathered in four kindergartens, children in one of the kindergartens were assigned to be the CG. As a result, the intervention program was carried out in each of the 3 remaining kindergartens (approximately 5 children in each) by two trained professionals. For ten weeks, children assigned to the EG participated in a 45 min, twice-weekly motor skill training program, with an average of 15 h of training. Each training session had two main parts: a 5 min warm-up and 40 min of working on motor skills. Detailed

information about the training sessions can be obtained elsewhere (Saidmamatov et al., 2021). All sessions were recorded with permission. All children continued to perform their physical education classes and regular classroom activities as scheduled. Moreover, in the EG, the motor intervention program replaced the daily walk of 45 min, an activity besides the physical education classes that all children performed in the indoor facilities of each school. During the study, enrolled children did not attend additional out-of-preschool sports. A variety of functional activities and exercises were used to improve common motor issues experienced by children with DCD, such as poor agility, balance, core stability, movement coordination, and ball skills. It is worth noting that exercises involving hand skills were performed with each hand and with both hands, enhancing uni- and bi-manual skills. As the training progressed, the motor tasks were modified to ensure successful task execution while also providing a sufficient challenge to the child's motor ability. The assessment in pre- and post-tests was carried out by the same professional and recorded on video.

2.5. Ethics

The research was approved by the Ethics Committee of Urgench State University (Code 12356), in accordance with the recommendations of the Declaration of Helsinki.

2.6. Statistical Analysis

When a card was reached with the right hand at positions 1, 2, and 3, the subject crossed the midline of the body, and position 1 extended into the contralateral hemi space, the furthest point to the left, with position 3 being the closest place to the midline. When a card was reached with the right hand in positions 5, 6, and 7, the children reached into the ipsilateral hemi space, with position 5 being the farthest point to the right, and position 7 being the closest to the body (see Figure 2).

Gender was included as a factor in preliminary analyses, but no significant effect was found for any of the variables analyzed; therefore, data from males and females

were pooled. Furthermore, as the number of participants was too small within each age group, with the majority being 5 years old, the age effect could not be analyzed. The hand use for the different groups at the 7 hemispace positions was analyzed by a multivariate analysis ANOVA. Following these analyses, a comparison between pre- and post-intervention was made by a non-parametric Wilcoxon test in each DCD group (EG and CG).

All statistical analyses were performed using SPSS software (SPSS v.25, IBM Corporation, New York, NY, USA). The statistical significance level was set at $p \leq 0.05$. Exact p values are provided. Post hoc comparisons were performed using the LSD (least small difference) procedure (Howell, 1997). When possible, the size of the statistical effects (partial eta-squared, abbreviated as ηp^2, which indicates the part of the variance explained by the factor with other non-error sources if the variance is partially led out) (Cohen, 1973) has been given.

Results

The results before the intervention, in terms of right-hand reaches (Table 1), indicate a main effect of group ($F_{(12,82)} = 3.514$, $p < 0.001$, $\eta p^2 = 0.340$), and a group x position interaction ($F_{(10,84)} = 4.167$, $p < 0.001$, $\eta p^2 = 0.332$). Post hoc comparisons revealed significant differences between the EG and TD group at position 3 ($p = 0.049$) and 4 ($p = 0.002$). At position 3, more right-hand reaches were made by the EG, and the opposite was observed at the midline, where the DCD group appeared less right-handed than the TD children.

Table 1. Results of right-hand reaches to the hemi space before intervention based on the group type. Number of participants, mean, and standard deviation values.

Group	**EG**		**CG**		**TD**	
N	**15**		**5**		**28**	
Position	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	0.67	1.18	0.80	1.10	0.32	0.82
2	0.47	1.10	0.00	0.00	0.39	1.00
3	1.27	1.49	0.40	0.89	0.50	1.04
4	1.87	1.25	1.89	0.70	2.71	0.54
5	2.87	0.52	3.00	0.00	2.93	0.38

6	3.00	0.00	3.00	0.00	2.93	0.40
7	3.00	0.00	3.00	0.00	2.93	0.40

Because of COVID-19, data from the TD group could not be collected after the intervention period, and only the DCD group could be reassessed. So, we decided to compare the results from the pre-intervention time of the TD group and the post-intervention of the DCD groups (experimental and control). The results of the comparisons between the groups, after applying the training program, are as follows (Table 2). A main influence of group was found ($F_{(10,82)} = 2.236$, $p = 0.023$, $\eta p^2 = 0.210$), as well as a group x position interaction ($F_{(8,86)} = 2.801$, $p = 0.008$, $\eta p^2 = 0.207$). Post hoc comparisons revealed significant differences between the EG and CG at position 1 ($p = 0.015$) and 4 ($p = 0.040$), and between the EG and TD group at position 4 ($p = 0.033$). Concerning the midline reaching, fewer right-hand reaches were made by the EG group compared to the other two groups. The same could be seen at position 1, when compared to the CG group.

Table 2. Results of right-hand reaches to the hemi space after intervention based on the group type. Number of participants, mean, and standard deviation values.

Group	**EG**		**CG**		**TD**	
N	**15**		**5**		**28**	
Position	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
1	0.00	0.00	1.00	1.40	0.32	0.82
2	0.00	0.00	0.00	0.00	0.39	0.99
3	0.20	0.77	0.40	0.89	0.50	1.04
4	2.20	1.08	3.00	0.00	2.71	0.53
5	3.00	0.00	3.00	0.00	2.93	0.38
6	3.00	0.00	3.00	0.00	2.93	0.38
7	3.00	0.00	3.00	0.00	2.93	0.38

A comparison between pre- and post-intervention in each DCD group, EG, and CG, was made. Results reveal that children in the CG were not different in pre- and post- test ($p > 0.050$). On the other hand, significant differences in the EG were found only in position 3 ($p = 0.020$), where, after intervention, fewer right-hand reaches were observed. The frequency of right-hand reaches was plotted for the

seven different spatial positions comparing pre- and post-intervention in the EG (see Figure 3).

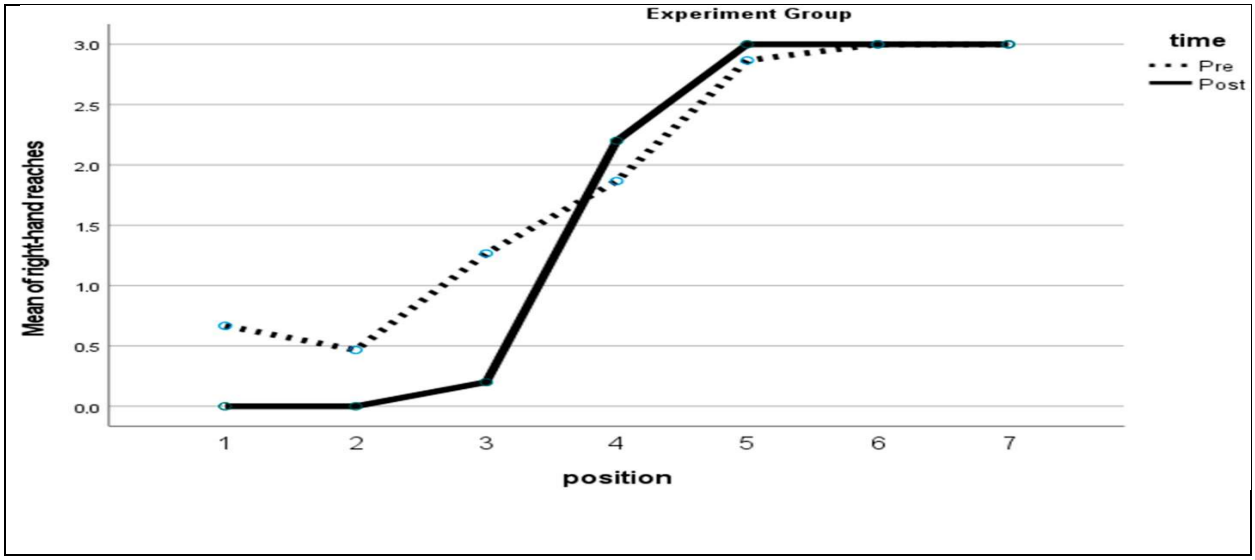


Figure 3. *Mean number of reaches as a function of the position of the card from the body midline in the EG. Ipsilateral hemi space: positions 5, 6, and 7; midline: position 4; and contralateral hemi space: positions 1, 2, and 3—see Figure 2.*

Discussion

The aim of this study was to investigate midline crossing behavior after an intervention program for children with DCD. For ten weeks, the acquisition and development of motor skills were meticulously applied, and the effectiveness of the motor skill training program for midline crossing was evaluated.

As expected, the results of this study indicate that the frequency of the right-hand use was dependent upon position in hemi space and the group. Typical development participants used the right hand primarily in ipsilateral space and the left hand to reach contralateral space. However, DCD children revealed a different behavior, showing less consistent right-hand use. While in position 3, the DCD group was more often willing to use the right hand, and then cross the hemi space, the opposite occurred in position 4 at the midline, where they exhibited a more inconsistent behavior. Within the TD children, the distribution of hand use in the hemi space indicated that almost all actions were carried out with the dominant hand in the ipsilateral hemi space, while only a few were performed with the dominant hand in the contralateral hemi space (Bryden et al., 2000). However, reaching into the

opposite hemi space contra laterally is widespread and may be a result of the development of hand preference (O'Regan et al., 2018). Namely, younger children have a weaker hand preference and are less likely to reach across the middle to grab an object, while older children use their preferred hand more and reach across the middle more often (Doyen et al., 2008). This stage of skill refining is necessary for creating a hand preference in childhood, supported by developed processing systems such as maturation of the interhemispheric pathways (Bishop et al., 1990). Concerning the DCD children, findings from this study do not support previous research with DCD children (Hill et al., 1998). This was because we noticed that the right hand was less used to cross the contralateral hemi space. The explanation for these opposite results may rely on the age effect, because in Hill et al. (1998), children were older than in this study. It could be said that reaching across the body's midline requires more complex motor programming than an ipsilateral reaching behavior. When faced with the choice of making a hard and a more complex movement with the preferred hand, children with poor motor skills will choose the easy movement, using the non-preferred hand in the contralateral hemi space. Another possible explanation was provided by Verfaellie et all. (1988) and Verfaellie et al. (1990) and later supported by Gabbard and Rabb [45]. The hemispheric bias hypothesis proposes a hemisphere (attentional) bias in favor of using the hand on the same side as the stimulus.

Another perspective proposed by Gabbard et al. (2000) is the kinesthetic hypothesis, which proposes that the individual recognized the biomechanical restrictions (e.g., degrees of freedom) involved in carrying out the task and programmed the pleasant and most efficient response by using the hand closer to the object. This hypothesis was supported by Vasconcelos et al. (2009), who found that fewer lateralized children seem to program hand selection based on biomechanical efficiency and proximity to the object to be grasped and not on motor dominance of the preferred hand, as more lateralized children do. Additionally, and according to Liedermen et al. (1983), manual midline crossing repeats a transition from extracellular to colossal control of interhemispheric communication and is,

therefore, a prerequisite for increasing a skilled dominant hand (Verfaellie et al., 1988; Verfaellie et al., 1990; Gabbard et al., 2000). Hand preference is a behavioral mirror of brain lateralization for handedness; it reveals how strongly a person prefers one hand over the other. In addition, and according to Smits-Engelsman et al. (2006), an alternative explanation for the clinical monitor is that impairments for activities in the contralateral workspace are more obvious in DCD children because these children already have a deficit, and contralateral inaccuracy is added to the overall inaccuracy (general neuromotor deficit hypothesis).

After intervention, DCD participants were more willing to use the left hand in contralateral space, and the difference was particularly evident in position 3. Additionally, differences at the midline position were found, where the DCD group appeared to be less right-handed than the TD group, but with an increase in the right-hand reaches, confirming results of other studies (Carlier et al., 2006; Groen et al., 2008). The willingness of using the left hand in contralateral space is in line with results from TD children (Carlier et al., 2006; Bryden et al., 2000), confirming that intervention programs seem to have an effect on the hemi space behavior and midline, showing that DCD children developed a more similar behavior to TD children.

So far, many researchers have tried using different intervention programs to develop motor skills in children with DCD. In a systematic review article, Saidmamatov et al. (2022) documented that motor skill training programs are very useful for children with DCD. Moreover, results are scientifically substantiated in another study (Saidmamatov et al., 2021) that postulated a 10-week motor skill training program develops motor skills in children with DCD, and also noted that DCD problems do not go away on their own. Going beyond the investigation of Saidmamatov et al. (2021), the present study concluded that a structured 10-week motor training program not only develops motor skills of children with DCD but also helps them to improve their midline crossing process. Additionally, those results partially support the hypothesis of many researchers that hand preference may be related to emotional–motor experience, along with the expected maturational

process (Coryell et al., 1978; Nudo et al., 1996; Provins et al., 1997; Corbetta et al., 2002). So, the results justify the initial research hypothesis that a motor skill program would provide external stimulation, especially in midline crossing, because of the manual skills (manual dexterity and aiming and catching) activities proposed. Moreover, the experiment provides new insight into the relationship between a motor skill training program and midline crossing.

Conclusions

It can be concluded from this study that right-handed children with DCD, after participating in a motor skills program, reinforced the handedness behavior and acquired the ability to form a left-handed working process in the contralateral space by engaging in an effective intervention program. Furthermore, results from this study demonstrate that by providing developmentally appropriate motor skills, such as crossing the midline of the body, through a structured motor training program, we can help young children build developmental readiness for competitive sports that rely on efficient cross-lateral processing speed.

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Empirical study – 3

Sustainability of a given ten-week motor skill training pro-gram for children with developmental coordination disorder

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Abstract

The aim of this research was to determine the sustainability of a given ten-week motor skill training program for children with developmental coordination disorder (DCD). Children with DCD in four kindergartens in the Khorezm region of Uzbekistan were selected to take part in the study. Participants were 24 children between 4 and 6 years old (5.25 ± 0.13 years), assigned to an intervention group (IG: 17 children; 10 boys) and a control group (CG: 7 children; 4 boys). The Movement Assessment Battery for Children (MABC-2) was used to assess motor competence pre-intervention, post-intervention, and retention test measurement after 18 months. The retention test results for the IG indicated a decline in all three motor domains of MABC-2. Despite this, the results that were acquired during the retention test came out to be better than the results that were achieved during the pre-test. At the same time, children who were allocated to the CG maintained their performance. The findings suggest that a preschool-based motor skill training program has the potential to increase motor skills in children with DCD. However, the positive benefits produced by the intervention may decrease over the course of time if the intervention is not continued.

Keywords: developmental coordination disorder (DCD); motor skill training program; MABC-2; retention-test 4.

Introduction

Developmental coordination disorder (DCD) is a deferment in motor skill development, particularly coordination of movements, making it difficult for the child to move and do routines that children do every day (APA, 2013). Moreover, the feelings of inadequacy accompanying a lack of motor coordination are typically strengthened through connections with peers (Gaines et al., 2008). Children with DCD may display decreased motivation to engage in physical activities as well as opportunities to improve motor skills and fitness, as Rivilis et al. (2011) formerly found. In addition to their motor impairments, they also display reduced levels of health-related physical activity. The literature has pointed out that children with movement impairments typically participate in less physical activity and physical exercise (Haga, 2009). If timely treatment is neglected, movement impairment symptoms persist in a large percentage of adults. Nevertheless, for children's and adolescents' healthy social and physical development, it is essential to spare time for recreational physical activity (Smits-Engelsman et al., 2018). Consequently, experts from a variety of fields, including pediatrics, occupational therapy, physiotherapy, and kinesiology, have paid considerable attention to DCD (Wilson et al., 2008). A variety of interventions focused on motor skill training programs have been developed by researchers and healthcare providers to overcome DCD. These programs are focused on physical activities and usual motor skills involving experiences directed to the development of fundamental motor competence. These programs are focused on physical activities and the development of fundamental locomotor motor skills (running, jumping, and walking), manipulative skills (aiming and catching), and balance skills (stabilization, rotation, static balance, and dynamic balance). Most researchers believe these activities improve children's movement quality and motor competence and reduce the difficulties of DCD (Smits-Engelsman et al., 2018; Adamchick et al., 2021; Navarro-Patón et al., 2021). In addition, studies have indicated that even short-term motor skill interventions can enhance other cognitive, psychological, and affective features in children with DCD (Yu et al., 2018). There have been several movement-based approaches regarding the design

of motor skill interventions for developmental coordination disorder, which are commonly classified into two broad categories: those that use movement to target underlying performance issues, commonly determined as process-oriented approaches, and those that utilize activity to address the performance itself, commonly determined as task-oriented approaches (Smits-Engelsman et al., 2018). In a study of the efficacy of motor interventions for children with DCD (Smits-Engelsman et al., 2013; Saidmamatov et al., 2022), the positive impacts of the intervention on the motor performance of children with developmental coordination disorder were observed. An analysis of the systematic reviews by Saidmamatov et al. (2022) and Rodrigues et al. (2019) reveals that many interventions have been given to children with DCD to develop their motor skills, and almost all of them have had a positive impact on children with DCD. The given intervention period by researchers typically ranged from 2 weeks (Cacola et al., 2016; Dunford et al., 2011) to 32 weeks (Straker et al., 2015). However, if we focus on Yu's et al. (2018) systematic review article, when the effectiveness of interventions that positively affected DCD children was examined after a certain time, some children's motor abilities, which had improved as a result of the intervention, had regressed to their earlier levels. For example, looking at research conducted by Hammond et al. (2014), a 1-month intervention program was able to improve the motor skills of DCD children, but after 2.5 months without intervention, the children's motor skills, tested again with the Bruininks–Oseretsky Test of Motor Proficiency Second Edition (BOT-2) equipment, returned to their previous state. Similar results were also observed in the studies of Sugden et al. (2003) and Wood et al. (2017). However, in other studies, a slightly different result was observed; that is, the results in the post-test were preserved in the follow-up moment (Fong et al., 2016; Miles et al., 2015; Noordstar et al., 2017; Dannenbaum et al., 2022; Norouzi et al., 2021; Capistran et al., 2016). In a small number of research studies, the motor skills of children with DCD improved from the post-test to the retention test (Coetzee et al., 2013). In order to verify the effectiveness of the given interventions, most of the follow-up tests were re-examined around 1 to 5 months after the end of the intervention program

(Fong et al., 2016; Miles et al., 2015; Noordstar et al., 2017; Dannenbaum et al., 2022). In the study of Coetzee et al. (2013), for example, the effectiveness of the intervention was re-examined two years after the post-test, and it was observed that the overall results of the MABC decreased over time. Based on the above data, we can say that the development of motor skills in children with DCD can be achieved through interventions given over a period of time. However, will the results achieved through the interventions given during a given period remain the same or decrease, and how will the passage of time affect children with DCD? The present study was an extension of our previous work and determined the sustainability of a given ten-week motor skill training program for children with DCD (Saidmamatov et al., 2021). We thought that motor skills learned during a certain period of intervention would likely go back to how they were before.

Methods

2.1. Study Design

The research is designed to evaluate whether or not post-test findings change over time. Therefore, the same children who were assessed at the post-test were reassessed 18 months later to determine the intervention's sustainability.

2.2. Participants

This study is a follow-up to a research project undertaken in 2020 (Saidmamatov et al., 2021). Children with DCD in four kindergartens in the Khorezm region of Uzbekistan were selected to take part in the project. Despite the a priori power calculation that had indicated that a sample size of 30 would provide a power of 0.9 to detect a 5-point difference in the MABC-2 total standard score (mean = 17 and standard deviation = 5) (Straker et al., 2011), from 63 children measured, only 24 children were eligible and participated in the study. The DCD children were between 4–6 years old (5.25 ± 0.13 years) and participated in the intervention group (IG: 17 children; 10 boys) and control group (CG: 7 children; 4 boys) in 2020. The pre-test and post-test have been previously published (Saidmamatov et al., 2021). In 2022,

they were again approached for participation in this retention test. Of this group, all 24 children were available for this retention test. The composition of these research parts is displayed in Figure 1.

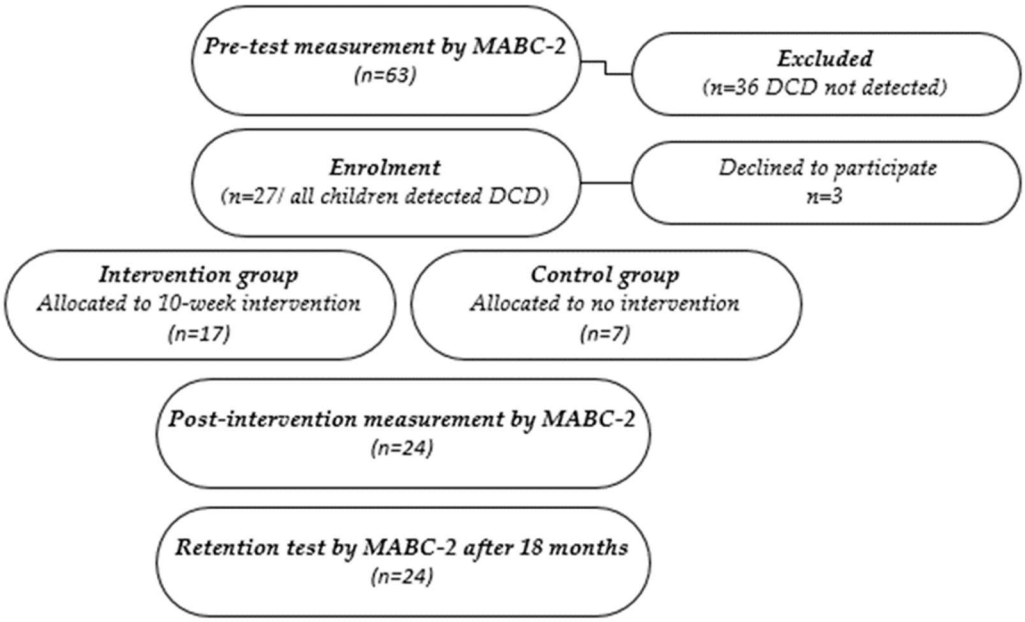


Figure 1. *Composition of these research parts of the study.*

The children were eligible to attend this study if they had not indicated any neurological or physical impairment.

2.3. Measuring Instruments

To see how the training program affected both groups, the MABC-2 test was given according to the MABC-2 manual (Griffiths et al., 2018). Details on how the test was performed are given elsewhere (Saidmamatov et al., 2022).

For age band one, sufficient evidence of validity and reliability has been revealed (Serbetar et al., 2019; Smits-Engelsman et al., 2011). Smits-Engelsman et al. (2011) studied the psychometric properties and the confidence of the MABC-2 in 50 typical children (3 years of age) and concluded, based on the test-retest, that even for three-year-olds, the test provides a high degree of confidence, making it sensitive to detecting individual changes. Moreover, Ellinoudis et al. (2011), using band 1 on 183 Greek children, advised that the MABC-2 could be a valid and reliable

tool to evaluate children aged 3 to 5 years of age with movement difficulties. Henderson et al. (2007) recommended the following cutoff points from the test manual: ≤5% atypical motor performance, which indicates DCD; 6th to 15th percentile, which means risk of developmental coordination disorder (r-DCD); and any percentile higher than 16%, which demonstrates typical development (TD). The pre-test–post-test was followed by a retention test in which each child was evaluated by the same person and recorded on video.

2.4. Intervention

Full details of this intervention are given in the article published by Saidmamatov et al. (2021). Children engaged in daily occupational activities until they were re-tested 18 months later.

2.5. Procedure

According to the Declaration of Helsinki, the research was approved by the Ethics Committee of Urgench State University (Code 12356). A meeting was organized with the principals of the respective schools, and the purpose and protocol of the study were explained to them. Written informed consent was obtained from the parents of each child before he/she was allowed to participate in the research. The purpose and procedures of the study were explained to each child before the beginning of the study. These children were evaluated regarding their DCD status.

2.6. Data Analysis

SPSS 26.0 was utilized to carry out the statistical analysis, and the statistical significance was evaluated using an alpha level of 0.05. The dependent variables included abilities in the domains of manual dexterity, aiming and catching, balance, and total MABC-2 scores, and for descriptive purposes, data were analyzed using means (M) and standard deviations (SD) and median. Preliminary analyses were performed, including gender as a factor, but no significant effect was found in any of the variables analyzed; therefore, data from both males and females were pooled.

The Mann–Whitney was used to test group (IG and CG) differences within the 3 moments. Next, a repeated measures ANOVA with adjustments for sphericity and Bonferroni corrections was utilized to identify whether the children's scores had changed significantly from baseline and whether any improvements following intervention were maintained after an 18-month retention test within the groups. Furthermore, an estimate of the effect size, by partial eta squared (ηp2), was calculated for each dependent variable. Cohen et al. (1988) 's guidelines say that an effect of 0.0099 is small, 0.0588 is medium, and 0.1379 is a large effect.

Results

3.1. Program Effect

In the retention test, only 6 children of the IG maintained their MABC-2 percentage above 16%. Children in the CG performed almost identically on all the three moments (pre-test, post-intervention, and retention test) (Table 1).

Table 1. Number of children scoring in each MABC-2 percentile band at pre-test, post-intervention, and retention test after 18 months.

Motor Difficulty Category	**Intervention Group (n= 17)**			**Control Group (n= 7)**		
	Pre	**Post**	**Retention**	**Pre**	**Post**	**Retention**
No motor difficulty (MABC-2 > 16th percentile)	0	17	6	0	1	1
At risk of DCD (from 6th – 16th percentile)	11	0	8	3	1	2
Probable DCD (MABC-2 ≤ 5th percentile)	6	0	3	4	5	4

3.2. Group Effect

Table 2 shows that there were no statistically differences between the two groups in all MABC-2 domains measured during the pre-test. However, statistically significant differences were evident in all the MABC-2 domains between the two groups in post-intervention after 10 weeks of intervention. Finally, in the retention test, again no statistically significant differences were found between the two groups on all the MABC-2 domains.

Table 2. Intervention and Control groups. Results from MABC-2 domains at pre-test, post-intervention, and retention test after 18 months.

Variables	Intervention group	**N**	Control group	**N**	***p***
	Mean ± SD		**Mean ± SD**		
Pre-test					
Total Score	5.76 ± 1.39 (6; 3-7)	17	5.29 ± 1.11(5; 4-7)	7	0,294
Manual Dexterity	3.82 ± 1.18 (4; 2-6)	17	4.86 ± 1.86 (6; 2-7)	7	0.171
Aiming & Catching	9.47 ± 2.80 (10; 5-15)	17	8.00 ± 2.70 (8; 3-12)	7	0.277
Balance	8.00 ± 2.34 (8; 4-12)	17	7.14 ± 2.19 (7; 4-11)	7	0,498
Post-intervention					
Total Score	10.64 ± 1.53 (11; 8-14)	17	4.71 ± 1.88 (4; 2-8)	7	< 0.001
Manual Dexterity	7.76 ± 2.25 (9; 4-12)	17	4.00 ± 1.73 (4; 2-6)	7	0.002
Aiming & Catching	13.17 ± 2.24 (13; 8-17)	17	9.28 ± 3.35 (8; 6-15)	7	0.017
Balance	11.11 ± 1.96 (11; 9-16)	17	6.00 ± 1.63 (6; 4-8)	7	< 0.001
Retention-test					
Total Score	8.47 ± 3.98 (7; 3-15)	17	6.43 ± 3.40 (5; 4-14)	7	0.075
Manual Dexterity	7.35 ± 3.44 (6; 3-13)	17	5.14 ± 2.19 (4; 4-10)	7	0.108
Aiming & Catching	9.82 ± 3.97 (9; 4-18)	17	9.57 ± 4.11 (8; 5-17)	7	0.822
Balance	9.29 ± 2.49 (9; 6-15)	17	7.57 ± 1.71 (7; 6-11)	7	0.076

3.3. Time effect

3.3.1. Manual Dexterity

Concerning MD, results have showed an effect of time [F (2, 21) =6.514, p=0.006, ηp2=0.383], and an interaction between time and group [F (2, 21) =12.363, p<0.001, ηp2=0.541], as can be seen on the Figure 2 below.

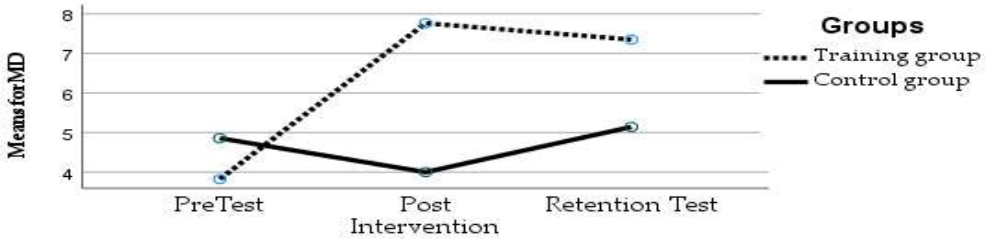


Figure 2. *Manual dexterity scores on the Movement Assessment Battery for Children (MABC-2) for both groups at time 1 (pre-test), time 2 (post-intervention), and time 3 (retention-test).*

A follow-up analysis revealed that the IG retained their performance after the retention test since there were no noticeable differences between the post-intervention period and the retention test (p > 0.050, post-intervention: 7.76 ± 2.25; retention test: 7.35 ± 3.44)

3.3.2. Aiming and Catching

As seen in Figure 3, the results revealed an effect of time [F (2, 21) =5.212, p=0.015, ηp2=0.332], and an interaction between time and group [F (2, 21) =2.897, p=0.077, ηp2=0.216].

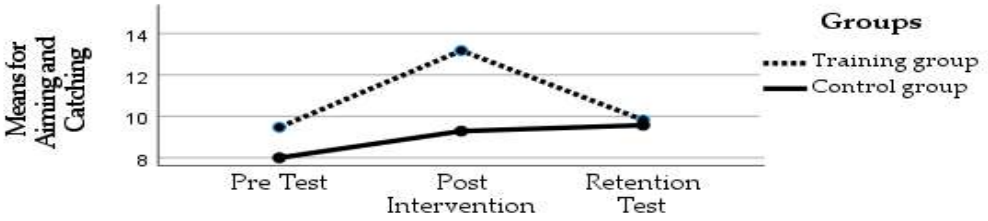


Figure 3. *Aiming and Catching scores on the Movement Assessment Battery for Children (MABC-2) for both groups at time 1 (pre-test), time 2 (post-intervention), and time 3 (retention-test).*

A decline was evident (post-intervention: 13.17 ± 2.24; retention test: 9.82 ± 3.97), but change over time needed to be analyzed within each group separately. In the IG, an improvement was found from the pre- to post-intervention, and a decline was seen from the post-intervention period to the retention test ($p < 0.050$) back to the initial scores. The CG maintained their performance (p>0,050).

3.3.3. Balance

The findings have demonstrated an effect of time [F (2, 21) =1.149, p=0.336, ηp2=0.099], and there was an interaction between time and group [F (2, 21) =6.673, p=0.006, ηp2=0.389] as can be shown in Figure 4.

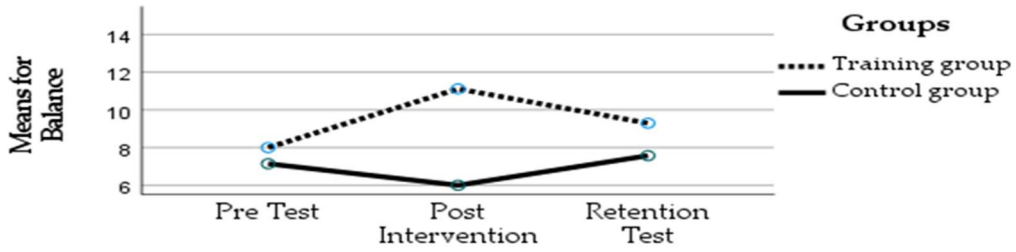


Figure 4. *Balance scores on the Movement Assessment Battery for Children (MABC-2) for both groups at time 1 (pre-test), time 2 (post-intervention), and time 3 (retention-test).*

The effect of time revealed a decline from Post-intervention (11.11 ± 1.96) to Retention-test (9.29 ± 2.49). Multiple analysis revealed that IG declined performance from post-intervention to the retention test evaluation, back to initial scores (p<0,050). The CG maintained the performance (p>0,050).

3.3.4. Total Test Score MABC-2

As seen in Figure 5, results of Total Score have indicated an effect of time [F (2, 21) =15.145, p<0,001, ηp2=0,591], and an interaction between time and group [F (2, 21) =23.108, p<0,001, ηp2= 0.688].

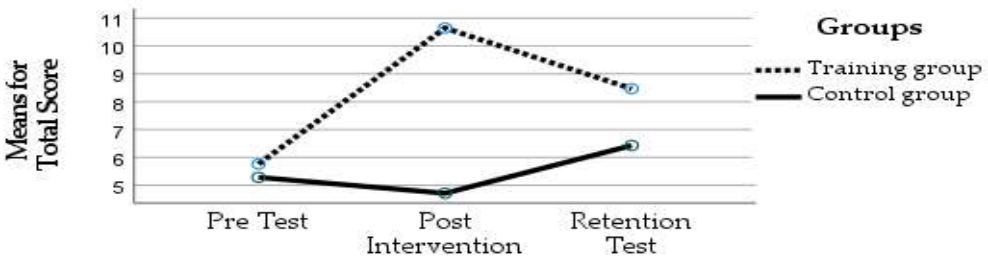


Figure 5. *Total test scores on the Movement Assessment Battery for Children (MABC-2) for both groups at time 1 (pre-test), time 2 (post-intervention), and time 3 (retention-test).*

Concerning Total Score, although there was a significant decline from the postintervention period to the retention test ($p < 0.050$, post-intervention: 10.64 ± 1.53; retentiontest: 8.47 ± 3.98), children in the IG were better than in the pre-test ($p < 0.050$). The CG maintained performance ($p > 0.050$). The retention test results for the IG revealed a decrease in the MABC-2 overall score. Even though this was the case, the retention test results were better than those of the pre-test.

Discussion

This research sought to determine whether or not post-test results were altered over time. Consequently, the same children who were evaluated at the post-test were reevaluated 18 months later to establish whether the allocated intervention was stable in the motor skill training program. Partly similar subjects were also investigated by Sugden et al. (2003), Wood et al. (2017), Fong et al. (2016), Capistran et al. (2016), and Coetzee et al. (2013), who assessed the sustainability of allocated intervention for children with DCD. Our findings revealed disparities between the intervention group and control group in all the motor competence measures in the three assessment parts, as in other studies (Wood et al., 2017; Fong et al., 2016). Importantly, our study found that the mean scores of the intervention groups' MABC-2 total score, manual dexterity, aiming, catching, and balance skills were considerably decreased after completion of the motor skill training program. This result partially supports the results of Sugden et al. (2003) and Wood et al. (2017), and based on the results of these studies, the effectiveness of interventions

for children with DCD may decline over time after the end of the intervention. Similar to Wood et al. (2017)'s findings, the results of the children's test dropped significantly from the post-intervention test to the retention test; nonetheless, these results were still superior to the pre-test results, demonstrating that the impact of the intervention is still present in the retention test, showing a more long-term effect. The findings of our research, on the other hand, contradict the conclusions of previous studies (Fong et al., 2016; Miles et al., 2015; Noordstar et al., 2017; Dannenbaum et al., 2022; Norouzi et al., 2021; Capistran et al., 2016). Nevertheless, this study differed from others (Sugden et al., 2003; Wood et al., 2017) because their retention tests were conducted after no more than 8 months, showing a short-term effect.

The research also shows that children with DCD may improve their aiming and catching abilities without intervention. This conclusion was also supported by other studies (Sugden et al., 2003; Wood et al., 2017). It is important to note, however, that the rate of development in aiming and catching abilities was greater in the intervention group than in the control group in the post-test and retention tests.

Another finding of the research was that following the intervention period, all children with DCD in the intervention group scored over 16% on the MABC-2 (Henderson et al., 2007; Cohen et al., 1988), indicating that their motor abilities improved as a result of the intervention. However, during the retention test, 18 months after the intervention, only six of seventeen children sustained beneficial improvements. According to these studies, the sustainability of the allocated intervention may not stay long. Therefore, interventions should be given to DCD children in a systematic and continuous manner, and frequent screening is recommended for children with DCD.

Conclusions

Concerning MABC-2 Total Score, although there was a significant decline from post-intervention to retention test, children in the IG performed better than in the

pre-test. The CG maintained performance. The retention test results for the IG revealed a decrease in the MABC-2 overall score. Even though this was the case, the retention test results were better than those of the pre-test. Future research should focus more on implementing intervention programs and evaluating their effects through post-tests and retention tests. Only in this way can we obtain more robust conclusions about the motor behavior changes of children with DCD after their participation in these programs, as well as observe changes in their behavior after a period without intervention. Thus, the reliability of the research will be much higher.

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Chapter IV

CONCLUSIONS AND FINAL CONSIDERATIONS

GENERAL CONCLUSION

As a general conclusion of this thesis, we argue that the field of DCD is too complex to be understood from only one perspective. Therefore, this study aimed to analyse the effects of a motor skills training program for DCD children in different domains related to both genders, midline crossing, and program sustainability. It is our intention to contribute to the deeper topic of DCD, thus enabling the development of scientific knowledge built up in the field. Consequently, the concluding remarks presented below represent a general and integrated analysis of the results of several studies presented throughout the dissertation.

PREVALENCE OF DCD AND GENDER

When gender was examined in the two studies, gender differences were found only in the first study (review study), showing that there is a difference in the prevalence of DCD between the two genders and that the overall prevalence of DCD is higher in boys than in girls.

MOTOR SKILLS TRAINING PROGRAM

The second study (empirical study 1) found that a structured 10-week motor training program based on different motor skills (e.g., manual dexterity, aiming, and catching) performed in one session of 40 min per week is more effective than traditional preschool. Also, the motor skill-training program exerts the same positive effect on both genders.

MIDLINE CROSSING

As expected, the results of this study (empirical study 2) indicate that the frequency of right-hand use was dependent upon the position in the hemi space and the group. Typical development participants used the right hand primarily in ipsilateral space and the left hand to reach contralateral space. However, DCD children revealed a different behaviour, showing less consistent right-hand use. While in position 3, the

DCD group was more often willing to use the right hand, and then cross the hemi space, the opposite occurred in position 4 at the midline, where they exhibited a more inconsistent behaviour. After the motor skills training program, DCD participants were more willing to use the left hand in contralateral space, and the difference was particularly evident in position 3. Additionally, differences at the midline position were found, where the DCD group appeared to be less right-handed than the TD group, but with an increase in the right-hand reaches.

It can be concluded from this study that right-handed children with DCD, after participating in a motor skills program, reinforced the handedness behaviour and acquired the ability to form a left-handed working process in the contralateral space by engaging in an effective intervention program. Furthermore, results from this study demonstrate that by providing developmentally appropriate motor skills, such as crossing the midline of the body, through a structured motor training program, we can help young children build developmental readiness for competitive sports that rely on efficient cross-lateral processing speed.

PROGRAM SUSTAINABILITY

The motor skills training program sustainability (empirical study 3) showed that the sustainability of the allocated intervention may not stay long. Therefore, interventions should be given to DCD children in a systematic and continuous manner, and frequent screening is recommended for children with DCD.

We finish our study by answering three pertinent questions:

Why was this study done?

- The majority of previous research focused on the difference in DCD prevalence between genders rather than the effectiveness of the intervention between genders.
- Moreover, there is not enough information on how this intervention for DCD will affect other skills such as crossing the midline.

- The vast majority of studies have focused only on post-intervention effectiveness, but little attention has been paid to the intervention's sustainability.

What did the researchers do and find?

- We found that there are differences between the two genders in the prevalence of DCD.
- The motor skill-training program exerts the same positive effect on both genders.
- Children with typical development and children with DCD were found to differ not only in the process of motor competence but also in crossing the midline, after the motor skill-training program.
- The effectiveness of the given motor skills training program has been found to decline over a period of time without intervention.

What do these findings mean?

- The motor skills of children with DCD do not improve without special interventions, so children with DCD should be involved in special treatment programs from the preschool period.
- According to these studies, the sustainability of the allocated intervention may not stay long. Therefore, interventions should be given to DCD children in a systematic and continuous manner, and frequent screening is recommended for children with DCD.

Table 1. Summary of the main findings addressing

Paper I - Motor skill training programs for children with developmental coordination disorder: Does gender matter? - Systematically review the available literature on the effect of a motor intervention program in children with DCD with a focus on gender differences. - The incidence of DCD is higher among boys than among girls. - Studies did not describe the gender effect in sufficient detail to help researchers and clinicians understand what it was about the treatment that made it equivalent.
Paper II - Ten-Week Motor skill training Program Increases Motor Competence in Children with Developmental Coordination Disorder. - To investigate the effect of a motor skill training program in children with DCD considering their gender. - Structured 10-week motor training program based on different motor skills performed in one session of 40 min per week is more effective than traditional preschool. - The motor skill-training program exerts the same positive effect on both genders.
Paper III - Motor skill training Program Reinforces Crossing the Body's Midline in Children with Developmental Coordination Disorder. - To find out midline crossing behavior after an intervention program for children with DCD. - Concerning midline crossing behavior before intervention, DCD children showed more contralateral and less midline right-hand use compared to TD children. - After intervention DCD children showed a similar behavior to TD children.
Paper IV - Sustainability of a Given Ten-Week Motor skill training Program for Children with Developmental Coordination Disorder. - To determine the sustainability of a given ten-week motor skill training program for children with developmental coordination disorder (DCD). - A preschool-based motor skill training program has the potential to increase motor skills in children with DCD. - The positive benefits produced by the intervention may decrease over the course of time if the intervention is not continued.

In the empirical articles that constitute this dissertation, it is important to point out some limitations that will serve to better control the development of future research.

The first one regards the fact that this study was not registered in any international registration system (study 1). Future research is needed to fully understand the role of gender in promoting motor and psychological performance in DCD children in the short and long term.

The second one regards study features and potential limitations. The period for determining the coordination ability of 63 children through the MABC-2 program coincided with the period when the COVID-19 quarantine restrictions were first released. Therefore, the sample size was small, and the group assignment in this quasi-experimental design was not completely random for logistical reasons (study 2 and study 3).

The third limitation of this study that needs to be considered is that, due to the COVID-19 period, we were unable to recruit more participants, especially in the control group. Participants were recruited from four kindergartens in the northwest region of Uzbekistan, specifically the Khorezm region, limiting the generalizability to other kindergartens (Studies 2, 3, and 4). Therefore, a larger number of participants should be used in future investigations. Moreover, considering the lack of significant differences between genders, it is likely that a larger group may have shown different findings with regard to the gender effect.

This study is the first in Uzbekistan to study the effects of a motor skills training program for children with DCD in preschools in Uzbekistan using the M-ABC test. Thus, we hope that these ideas and experiences will contribute to future studies of DCD on a regional scale.