Dissertation of Doctor of Philosophy

The characteristics of children with developmental coordination disorder and the effects of exercise intervention

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Abstract

Children with Developmental Coordination Disorder (DCD) have difficulties with physical activity as they lack in motor ability and tend to avoid or limit participation in physical activity due to accumulated negative experiences from previous physical activity participation. This is a significant issue in that physical inactivity of children with DCD may lead to physical fitness issues such as increased risk of cardiovascular disease or emotional and behavioral difficulties. Furthermore, children with DCD have difficulties in daily life that affect overall school life such as personal relationships, academic performance, etc. However, studies on DCD in South Korea are very limited. Thus, there is little evidence concerning characteristics and conditions of Korean children with DCD. Therefore, this dissertation aims to identify the feasibility of a translated DCD classification instrument to identify the characteristics of Korean children with DCD and the effect of exercise intervention and to suggest a program that may be practicable in practice. This dissertation specified these goals into three themes for the purpose: 1) Adaptation, reliability, and validity of the Korean version of Developmental Coordination Disorder Questionnaire 2007 (DCDQ-K), 2) Investigation of the difference in emotional and behavioral problems between children with DCD

and typically developed children, and 3) A study on the effect of fundamental motor skill-based excise program on motor performance and timing ability of children with DCD.

Results of this dissertation are as follows: first, Korean version DCDQ was completed using a systematic process. It has been identified that DCDQ-K is an applicable instrument to classify children with DCD. Second, children with DCD are at higher risk for internalizing problems, inattention/ hyperactivity, emotional symptoms index, and personal adjustment related scale compared to typically developed children. Third, children with DCD show lower health-related physical fitness, motor performance, and timing ability compared to typically developed children. It has been identified that these difficulties were improved through the 12-week fundamental motor skill-based exercise program.

According to the results presented in this dissertation and previous literatures, the overall conclusions and suggestions are as follows: emotional and behavioral problems as well as motor performance problems were identified among children with DCD in South Korea. The 12-week fundamental motor skill-based exercise program, designed as exercise intervention program to reduce these difficulties, was proved as effective. However, there is still a lack of applicable instruments available for early

identification of children with DCD in South Korea. Thus, it is suggested to develop possible solution for early identification of children with DCD in South Korea.

Key words: Developmental coordination disorder, DCDQ, emotional and behavioral problems, exercise intervention, timing ability

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I. Study Background

1. What is DCD?

Some children experience difficulties in physical activity due to the lack of motor skill and coordination ability, although they do not have any developmental disability or neurological problems (Wall, Reid, & Paton, 1990). The American Psychiatric Association (2013) diagnoses these children who have remarkably reduced coordination abilities, which lead to difficulties in daily life and poor academic achievement compared to typically developed children with the same chronological age, as Developmental Coordination Disorder (DCD). Previous researchers described the state of poor motor coordination ability with various terms, such as clumsy child syndrome (Gubbay, 1975), developmental dyspraxia (Dewey, 1995; Missiuna & Polatajko, 1995) perceptuo-motor dysfunction (Laszlo, Bairstow, & Bartrip, 1988), specific developmental disorder of motor function (World Health Organization, 1993), playground disability (Hay & Missiuna, 1998), minimal brain dysfunction (Clements, 1966), deficits in attention, motor control, and perception (DAMP) (Gillberg, 2003) and others. However, after the American Psychiatric Association's diagnostic manual introduced the term DCD at 1987 (Diagnostic and Statistical Manual of Mental Disorders, Third Edition)

(American Psychiatric Association, 1987), DCD has been used as a universal diagnosis in the field of motor coordination (Magalhães, Missiuna, & Wong, 2006).

The DSM-Ⅳ, the APA diagnostic criteria for DCD, suggests 4 criterion to diagnose DCD which are, (A) the person's performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence, (B) the disturbance in Criterion A significantly interferes with academic achievement or activities of daily living, (C) the disturbance is not due to a general medical condition and does not meet criteria for a Pervasive Developmental Disorder, and (D) if mental retardation is present, the motor difficulties are in excess of those usually associated with it. Although the DSM-Ⅳ suggests 4 significant criterion for diagnosing DCD, the Leeds Consensus and European Academy of Childhood Disability Guidelines recommend that the DSM-Ⅳ criterion would not be appropriate for children with an IQ below 70 (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012; D Sugden, Chambers, & Utley, 2006).

The DSM-Ⅳ criterion related to DCD have been discussed to be revised based on the consultation of experts and accumulated clinical and research knowledge, under Dr. David Sugden's initiative (Cairney, 2015a). A notable point of the revised diagnostic criteria for DCD within the DSM-Ⅴ is that children with Pervasive Developmental Disorder are not always excluded. Table 1 presents the criterion from both the DSM-Ⅳ and the DSM-Ⅴfor comparison.

Some children with DCD tend to show additional motor movements, such as unsupported choreiform movement or mirror movement. These excessive movements are considered a neurodevelopmental immaturity or neurological soft sign rather than neurological indisposition. The role of these symptoms in diagnosis within current literatures and clinical setting has not been clarified yet and, therefore additional evaluation is required (American Psychiatric Association, 2013)

Table 1. DSM-Ⅳ and DSM-Ⅴ Criteria for DCD

DSM-Ⅳ	DSM-Ⅴ
Criterion A: Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (e.g., walking, crawling, sitting), dropping things, "clumsiness", poor performance in sports, or poor handwriting	Revised Criterion A: The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness(e.g., dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g., catching an object, using scissors or cutlery, handwriting, riding a bike, or participating in sports).
Criterion B: The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living.	Revised Criterion B: The motor skills deficit in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g., self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.
Criterion C: The disturbance is not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and does not meet criteria for a Pervasive Developmental Disorder.	Revised Criterion C: Onset of symptoms is in the early developmental period.
Criterion D: If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it.	Revised Criterion C: The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g., cerebral palsy, muscular dystrophy, degenerative disorder).

2. How common is DCD?

The prevalence of DCD within children aged 4-11 has been reported as 5-6% (American Psychiatric Association, 2000; Gibbs, Appleton, & Appleton, 2007; Maeland, 1992). However, this result has a significant limitation because not all the research done in the field to address the prevalence of DCD has used the same DCD diagnostic criterion. Furthermore, not many studies reflect all DSM criterion for diagnosing DCD strictly (Cairney, 2015a).

Based on the DSM-Ⅴcriteria, DCD is more common in males than females, and gender ratio has been reported between 2:1 and 7:1 (American Psychiatric Association, 2013). However, this result has a limitation because of the sampling methods (Cairney, 2015a). Significantly more boys were provided as samples in clinical settings than girls, and gender ratio of the DCD group in general population samples has been reported as 1:1 (Cairney, Hay, Faught, Mandigo, & Flouris, 2005; Foulder-Hughes & Cooke, 2003; Skinner & Piek, 2001). Furthermore, a social prejudice that motor coordination problem of girls are not as significant as of boys acts on the gender imbalance of DCD (Gillberg, 2003; Taylor, 1990).

Previous researchers argued on the appropriate evaluation methods of each component of the DSM criteria and specific cut-offs of criterion (D Sugden et al., 2006). This is because applying diagnostic criterion, the evaluation methods of DSM criteria, and the cut-offs of criterion have a significant impact on the prevalence of DCD. Arguments on appropriate evaluation methods of diagnostic criterion are still being debated, but some studies suggest a strict epidemiological standard to measure the prevalence (Raghu Lingam, Hunt, Golding, Jongmans, & Emond, 2009).

Meanwhile, the European Academy of Childhood Disability developed clinical guidelines for the diagnosis, treatment and management of DCD (Blank et al., 2012). This was significantly meaningful in the field because it was the first guideline that used systematic and meta-analytic methods. Figure 1 presents a definition, assessment and treatment indication algorithm of children with DCD by the European Academy of Childhood Disability, and Table 2 presents a definition, diagnostic criteria, assessment and treatment indication.

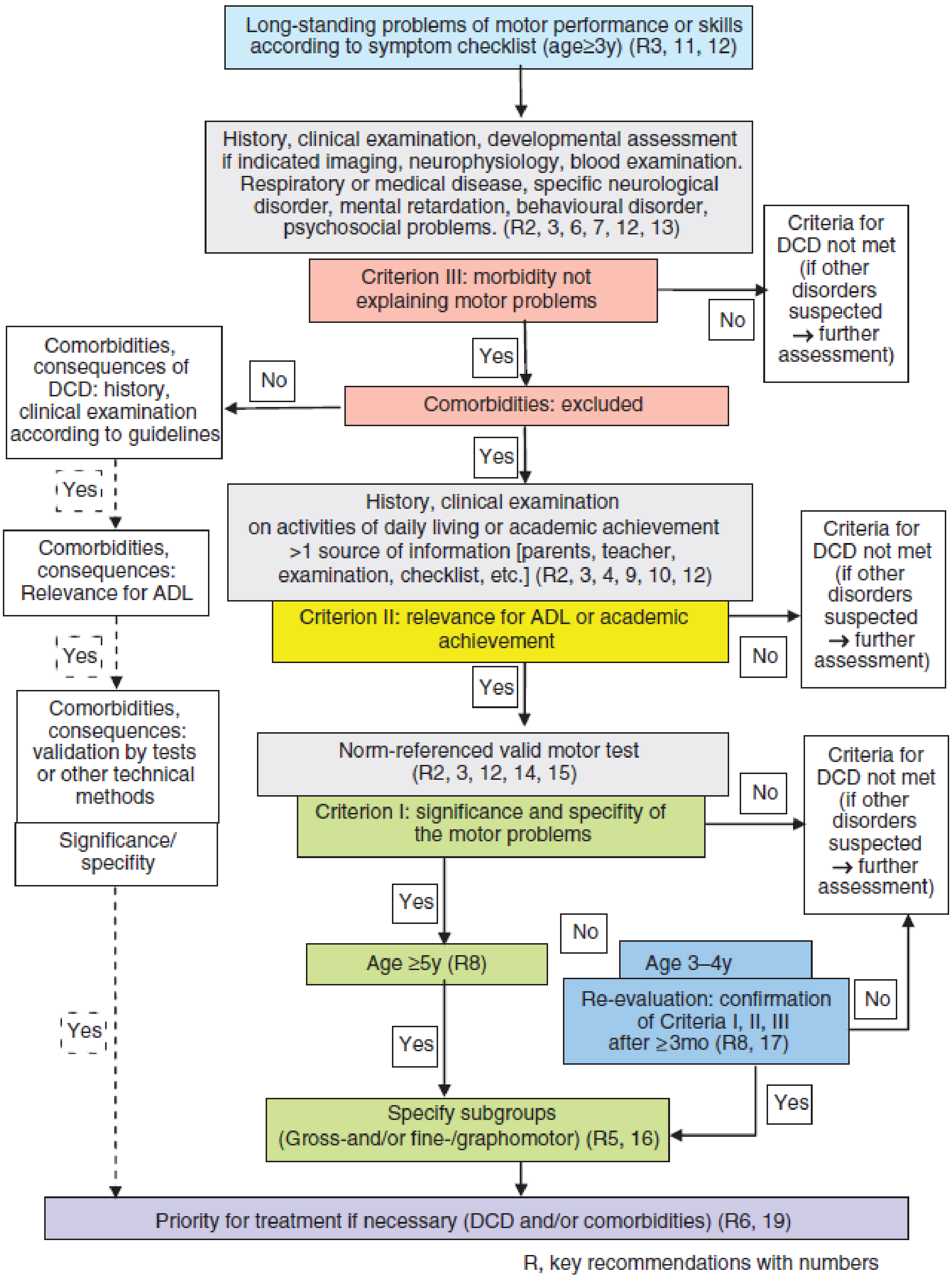

Figure 1. Definition assessment, treatment, indication algorithm (Blank et al., 2012)

Table 2. Definition, diagnostic criteria, assessment, treatment indication (Blank et al., 2012)

R1	The term developmental coordination disorder (DCD) should be used go refer to children with developmental motor problems in countries which adhere to the DSM Ⅳ-TR classification. In countries where International Classification of Diseases (ICD) 10 has legal status, the term specific developmental disorder of motor function (SDDMF) (F82, ICD 10) should be used	GCP++
R3	The diagnosis DCD (SDDMF) should be made within a diagnostic setting by a professional who is qualified to examine the specific criteria	GCP++
R2	Children with DCD (SDDMF) having performance deficits in specific areas of motor performance, e.g. gross motor dysfunctions or fine motor dysfucntion (manipulative skills) should be classified according to the ICD subgroups (gross motor dysfunction F82.0 or fine motor dysfucntion F82.1)	GCP++
R3	A dual diagnosis of DCD (SDDMF) and other developmental or behavioural disorders, e.g. autism spectrum disorder (ASD), learning disorders, attention-deficit -hyperactivity disorder (ADHD) should be given if appropriate	GCP++
R4	The onset of DCD (SDDMF) is usually apparent in the early years, but would not typically be diagnosed before 5y of age. If a child between 3 and 5y of age shows a marked motor impairment, even though there have been adequate opportunities for learning and other causes of motor delay have been excluded (e.g. deprivation, genetic syndromes, neurodegenerative diseases), the diagnosis of DCD (SDDMF) may be made based on the findings from at least two assessments performed at sufficiently long intervals (at least 3mo)	GCP++
R5	The use of questionnaires (e.g. DCDQ, Movement Assessment Battery for Children, 2nd version (M-ABC2) checklist) is not recommended for population-based screening for DCD	LOE 4 Level Aneg
R2	Criteria for diagnosis of DCD (SDDMF) Ⅰ. Motor performance that is substantially below expected levels given the child's chronological age and appropriate opportunities for skill acquisition Ⅱ. The disturbance in Criterion Ⅰ significantly interferes with activities of daily living or academic achievement Ⅲ. An impairment of motor coordination that is not solely explainable by mental retardation. The disturbance cannot be explained by any specific congenital or acquired neurological disorder or any severe psychosocial problem	GCP++
R6	Comorbidities should be carefully diagnosed and treated according to established clinical guidelines (e.g. ADHD, autism, dyslexia, specific language impairment)	GCP++

S1	Because of the high probability of comorbidity in DCD (SDDMF), disorders like ADHD, ASD, and learning disorder, particularly specific language disorder and in later age reading problems (e.g. reading comprehension) have to be checked by careful history taking, clinical examination and specific testing if possible according to existing clinical practice guidelines If there is any hint for interference (e.g. attentional problems) with objective motor testing the motor testing should be repeated, e.g. under medication or after other therapeutic intervention for attention problems	++
R7	Careful history taking is essential to support the application of Criteria Ⅰ,Ⅱ,Ⅲ. History should include following aspects 1. Parental report (GCP++) • Family history including DCD (SDDMF), comorbidities, environmental factors (e.g. psychosocial factors), neurological disorders, medical diseases, mental disorders, social condition of the family • Personal history including exploration of resources and possible aetiology, for example pregnancy, birth, milestones, achievements, social contacts, kindergarten, school (grades, levels), previous and present disorders, especially neroulogical disorders, sensory problems (previous assessments), accidents • History of the disorder (child) including DCD (SDDMF) and comorbidities and exploration of resources, activities of daily living (ADL) and participation, individual/personal factors, burden of disease, consequences of the DCD (SDDMF) • Exploration of problems: present level/deficits of motor functions, ADL, and participation 2. Teacher report (GCP++) • Motor functions, activities/participation, environmental factors/support systems, individual/personal factors (ICF) • School-based behaviour that bears on comorbidity for attentional disorders, autistic spectrum, learning disorders • Academic achievement 3. Views of the child should be taken into account (GCF++); child-adapted questionnaires (see above) may be useful, but cannot be generally recommended (GCP++)	GCP++
R8	Concerning Criterion Ⅲ: appropriate clinical examination with respect to medical, neurological and behavioural problems is necessary to verify that the disturbance is not due to a general medical, neurological, or behavioural condition	GCP++
S2	The clinical examination should include the following: • neuromotor status (exclusion of other movement disorders or neurological dysfunction); • medical status (e.g. obesity, hypothyreosis, genetic syndromes, etc.); • sensory status (e.g. vision, vestibular function); • emotional and behavioural status (e.g. attention, autistic behaviour, self-esteem); • cognitive function should there be a history of learning difficulties at school	GCP++

R9	Concerning Criterion II: the complete assessment should include consideration of activities of daily living (e.g. self-care and self-maintenance, academic ⁄ school productivity, pre-vocational and vocational activities, leisure, and play) and the views of the child, parents, teachers, and relevant others	GCP++
R10	Concerning Criterion II: it is recommended to use a validated questionnaire to collect information on the DCD (SDDMF)-related characteristics of the child from parents and teachers to support and operationalize Criterion II	GCP++
R11	Concerning Criterion II: questionnaires like the DCDQ-R or the M-ABC2 checklist may be recommended for use in those countries where the questionnaire is culturally relevant and standardized	LOE 2 Level B
R12	Concerning Criterion I: an appropriate, valid, reliable, and standardized motor test (appropriately norm-referenced) should be used	
R13	Concerning Criterion I: in the absence of a criterion standard test for establishing Criterion I, the M-ABC2 may be recommended (level of evidence (LOE) 2, level B). Where available, the Bruininks–Oseretzky Test of Motor Proficiency, second version (BOTMP-2) may also be recommended (LOE 2, level B). However, no German translation and standardization of the BOTMP-2 is currently available. In the absence of generally accepted cut-offs for identifying DCD (SDDMF), it is recommended that when using the MABC, or other equivalent objective measures, approximately the 15th centile for the total score (standard score 7 or less) should be used as a cut-off	LOE 2 Level B
R14	Based on the limitations of the available instruments, classification of specific domains of dysfunction (e.g. gross motor or fine motor dysfunction [ICD numbers F82.0 and F82.1]), can be made on the basis of clinical judgement The use of grossmotor or fine motor items of standardized assessmentsmay be recommended alongside observation and reports of difficulties across relevant gross motor or fine motor and ⁄ or graphomotor tasks The guideline group suggests the fifth centile cut-off of the fine motor subdimension (e.g. M-ABC2, BOTMP-2) be used for the diagnosis F82.1 if Criteria II and III are met If all Criteria I, II and III aremet and if finemotor function iswithin the normal range then the diagnosis F82.0 can bemade	GCP++
R15	Concerning Criteria I: for children between age of 3 and 5y, if the diagnosis is needed (e.g. for treatment purposes), a cut-off of less than the fifth centile is recommended for the total score on the M-ABC, or equivalent objective measures (see also R8)	GCP++

GCF++, good clinical practice (recommendation based on strog consensus:++, more than 95% of the participants; +, 75-95% of the participants of the nominative group ptocess). LOE, level of evidence; Aneg, strongly recommended that clinicians (do not) routinely provide the intervention/the assessment to eligible residents.

3. How is DCD different from TD?

Children with DCD experience difficulties in everyday tasks, including play, due to the motor coordination problems. (Cairney, 2015b). Moreover, children with DCD tend to feel difficulties and sometimes tend to avoid participating in physical activities due to their poor basic motor skills, which are essential to participate in play or sports (E. L. Hill, 2001). H. Polatajko (1999) argued children with DCD accumulate negative experiences from play and it leads them to avoid physical activities and participate in limited forms of play. Physical inactiveness of children with DCD caused by motor coordination problems negatively affect their physical health related to cardiovascular disease, and their unsuccessful play may cause psychosocial and behavioural difficulties (Piek & Rigoli, 2015).

Children with DCD are less physically active than typically developed children with the same chronological age (Cairney, Kwan, Hay, & Faught, 2012; Green et al., 2011), have high possibilities to be overweight and to become obese (Hay, Hawes, & Faught, 2004), have a high incidence of cardiovascular disease (Cairney et al., 2010), and have low health related fitness status (Cairney, Hay, Faught, Flouris, & Klentrou, 2007). Physical health problems of children with DCD are strongly associated with their physical inactiveness, and this is a major cause of cardiovascular disease such as obesity (Janssen & LeBlanc, 2010). The physical inactiveness of typically developing children tend to be caused by preferring inactive recreation such as screen based activities (i.e. playing computer games, watching TV, etc.) while the physical inactiveness of children with DCD is largely influenced by poor motor coordination, rather than by motivation or lack of interest in physical activity (Cairney, 2015b).

Hands and Larkin (2002) suggested a theory that low motor competence, low fitness and hypo-activity have an impact on each other among the growth process of children, and highlight the effects of low motor coordination on fitness and activity. Cairney (2015b) cited the Hands and Larkin (2002) continuous negative feedback loop in 2015, and mentioned how the low motor competence, low fitness and hypo-activity of children with DCD can increase the risk of poor cardiovascular health overtime (Figure 2).

DCD may not only affect physical problems, but also affect social inclusion and self-concept construction of children negatively (Skinner & Piek, 2001), and cause emotional and behavioral problems (Cantell, Smyth, & Ahonen, 1994). These problems persist into adolescence and adulthood, and cause incremental increases in various risk factors (Rasmussen & Gillberg, 2000). Therefore, the early identification of children with DCD is significant in order to provide effective intervention and to eliminate the risk factors in advance.

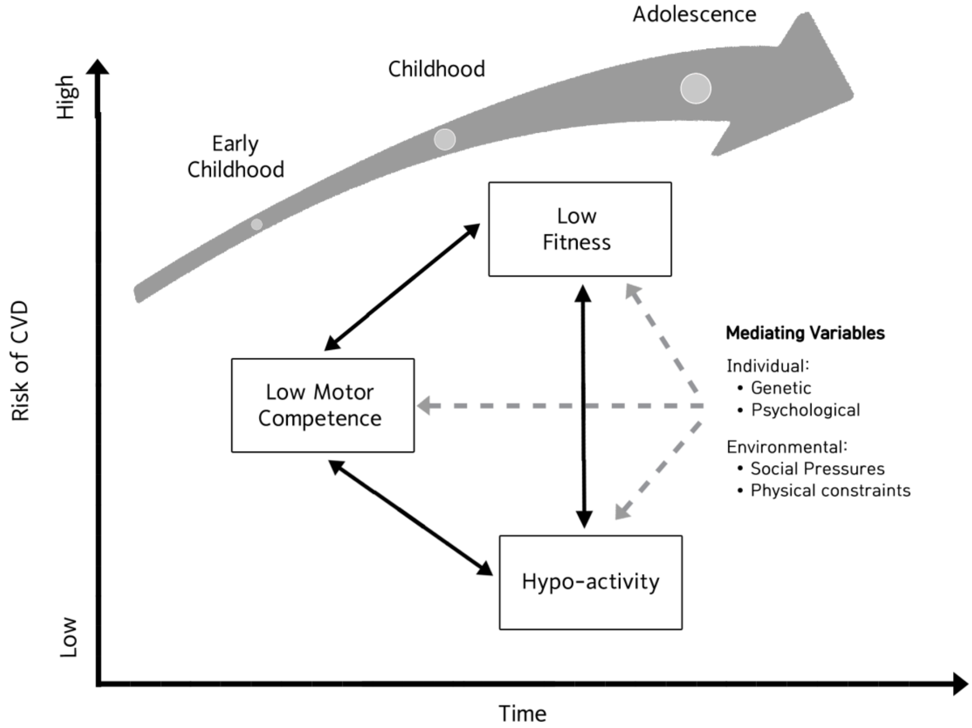

Figure 2. Continuous negative feedback loop over time (Cairney, 2015b; Hands & Larkin, 2002)

4. What is effective management for DCD?

Missiuna, Polatajko, and Pollock (2015) classify and suggest 4 levels of a DCD management scheme for children as follows: 1) Level 1: Management at a School/Population Level, 2) Level 2: Management at a Group Level, 3) Level 3: Management of Individual Children in Context, and 4) Level 4: Management of Individual Children who are Complex. This section will discuss each level of the DCD management scheme of children suggested by this study in detail (Missiuna et al., 2015).

Level 1: Management at a School/Population Level

Despite the high prevalence of DCD among school-age children, adequate preparation for children with DCD has not been developed yet, and thus, children with DCD are having negative experiences in school (Engel-Yeger & Hanna Kasis, 2010; Missiuna, Moll, King, King, & Law, 2007; Missiuna, Moll, Law, King, & King, 2006). It is significant to identify children with DCD early and to provide early intervention in order to minimize the problems of children with DCD. However, adequate actions are not taken in the educational arena due to the lack of recognition of children with DCD. Therefore, an improvement of teachers' and parents' perception of children with DCD and a reconstruction of educational curriculum for students who have poor motor ability are required as a first step.

Level 2: Management at a Group Level

At this level, children with DCD may have secondary health issues and academic failure due to their poor coordination ability, so children with DCD should be identified as early as possible (Missiuna, Rivard, & Bartlett, 2003). Early identification of DCD allows teachers and parents to share the characteristics of children with DCD in order to form appropriate environments for them (Missiuna et al., 2015). This may result in providing achievable tasks to children with DCD and avoiding repetitive unsuccessful experiences, and therefore, the role of teacher at this level is emphasized (Missiuna, Rivard, & Pollock, 2004). Generally, the Neurorehabilitation Training Toolkit (NTT), a therapeutic program which is being developed by Smits-Engelsman and colleagues that utilizes motor learning teaching principles, is recommended as an effective way to learn fundamental motor skills of children (Niemeijer, Schoemaker, & Smits-Engelsman, 2006; Niemeijer, Smits-Engelsman, & Schoemaker, 2007; M. Schoemaker & Smits-Engelsman, 2005; P. H. Wilson, 2005).

Level 3: Management of Individual Children in the Context

The motor impairment of children with DCD is a long-term problem, and the transfer of learning and generalization through intervention is difficult (Schmidt & Lee, 1988). Therefore, it is required to accept the difficulties of children with DCD and to provide an appropriate environment to easily participate in physical activities. Thus teachers are important in the process of establishing individualized plans for children with DCD, and strategies, such as “MATCH: Teacher can Modify the task, Alter their expectations, Teach strategies, Change the environment, and Help by understanding”, might be applied effectively (Missiuna et al., 2004).

Level 4: Management of Individual Children who are Complex

DCD is strongly associated with attention deficit hyperactivity disorder (ADHD), speech and articulation difficulties (specific language impairment), language-based learning disabilities and other difficulties (Dewey, Kaplan, Crawford, & Wilson, 2002; Gaines & Missiuna, 2007; Hill, 2001; Jongmans, Smits-Engelsman, & Schoemaker, 2003; Kadesjö & Gillberg, 1998; Piek & Dyck, 2004; Pitcher, Piek, & Hay, 2003; Rasmussen & Gillberg, 2000; Tervo, Azuma, Fogas, & Fiechtner, 2002; Webster, Majnemer, Platt, & Shevell, 2005). If these disabilities are accompanied with DCD, the negative effects can possibly be aggravated (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Rasmussen & Gillberg, 2000; Schoemaker & Kalverboer, 1994). Therefore, special intervention that considers the child's age, severity of the motor difficulties, evidence of secondary consequences and etc. is required in this case (Missiuna et al., 2015). At this level, the COOP (Cognitive Orientation to daily Occupational Performance) approach is used as an effective intervention for school-age children with DCD (Banks, Rodger, & Polatajko, 2008; Bernie & Rodger, 2004; Chan, 2007; Polatajko & Mandich, 2004; Rodger & Brandenburg, 2009; Rodger & Liu, 2008; Sangster, Beninger, Polatajko, & Mandich, 2005; David Sugden, 2007; Wilson, 2005).

Currently, an innovative service delivery model is being applied to manage children with DCD in Ontario, Canada (Missiuna et al., 2015). Within this model, occupation therapists provide related knowledge of DCD to teachers and parents, and construct a mutual cooperation system rather than provide the service directly. Thus, this cooperative work provides an appropriate environment for children with DCD to solve various problems (Figure 3).

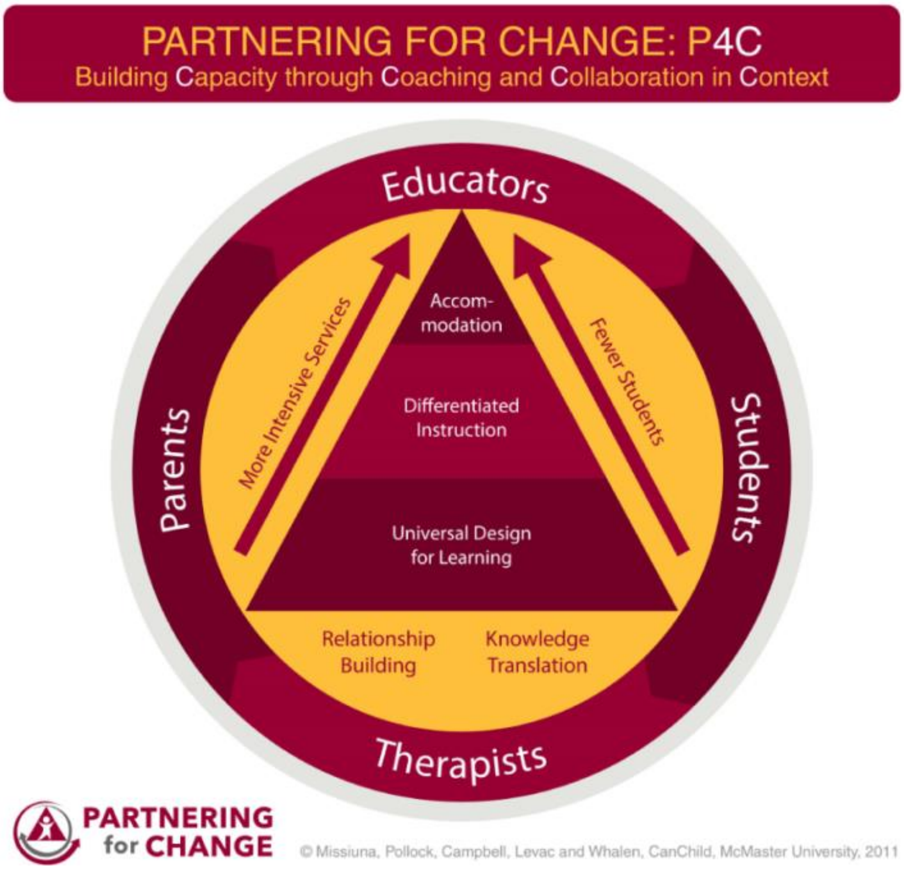

Figure 3. PARTNERING FOR CHANGE: P4C, Building Capacity through Coaching and Collaboration in Context

II. Research

In the present dissertation, three parts of experiments were investigated. The first study is to translate Developmental Coordination Disorder Questionnaire 2007 (DCDQ’07) in Korean and examine the reliability of DCDQ-K for possible application in diagnosis of DCD. The second study compared the children with and without DCD by evaluating their emotional and behavioral difficulties. The third study compared the children with and without DCD by measuring their body composition, health-related physical fitness, fundamental motor skill, and timing ability. Children with DCD participated in the fundamental motor skill-based exercise program for 12 weeks and then the resulting change was further analyzed.

1. Study I

Adaptation, reliability, and validity of the Korean version of developmental coordination disorder questionnaire 2007

2. Study II

Correlation between motor coordination skills and emotional and behavioral difficulties through comparison between children with developmental coordination disorder and typically developing children

3. Study III

Improving motor performance and timing ability in developmental coordination disorder via fundamental motor skill-based exercise

STUDY I

Adaptation, reliability, and validity of the Korean version of developmental coordination disorder questionnaire 2007

1. Introduction

The movement of humans has a regular pattern for fixed physical activities, and humans require a certain level of motor ability to participate in sport activities. In the field of education, educational activities are provided to enable school-aged children and adolescents' constant participation in physical activities. The educational activities help them learn motor skills. However, there are students who cannot participate in sport activities due to a lack of motor abilities or difficulties in learning motor skills. Some sport coaches call these students 'students with no motor talent' or 'students that lack motor functions' (Choi, 1998, 2003). They fail to consider the habitudinal abnormalities or the problems in perception and motor functions. They merely blame students for lacking individual effort (Yang & Kim, 2007; Yang & Tak, 2007).

Although they don't have developmental disorders or neurological problems, some students face difficulty participating in physical activities due to a lack of motor function and coordination abilities (Choi, 1998; Huh, 2011; Wall et al., 1990). According to the American Psychiatric Association, children who face difficulties in daily life and academic achievement compared to others of the same age because of significantly low coordination abilities are diagnosed with Developmental Coordination Disorder (DCD).

DCD is used as the most general term in research related to motor coordination (Choi & Kim, 2008; Magalhães et al., 2006).

Children with DCD, compared to others in the same age group, lack physical activities (Cairney et al., 2012; Green et al., 2011), are rated low in health-related physical fitness (Cairney et al., 2007), have a higher risk of becoming overweight or obese (Hay et al., 2004), and have a greater chance of developing cardiovascular disease (Cairney et al., 2010). DCD not only effects physical problems, but can also negatively influence children’s social integration and formation of self-concept (Skinner & Piek, 2001), and can cause emotional and behavioral problems (Cantell et al., 1994). These problems can continue throughout adolescence and adulthood, causing an increase in numerous risk factors (Rasmussen & Gillberg, 2000). Thus, identifying children with DCD at an early stage is essential to provide effective intervention and prevent future health risks.

Although DCD’s prevalence is reported to be 5–6% in general among children (American Psychiatric Association, 2013), many students with potentially dangerous DCD are not diagnosed with DCD due to a lack of awareness of DCD. The Movement Assessment of Battery for Children (M-ABC), a motor development evaluation tool, is used as the most suitable evaluation method to identify children with DCD in DCD related research. According to M-ABC measurement results, the lower 15% is diagnosed as children with a high danger of DCD and the lower 5% is diagnosed as children with DCD (Henderson, Sugden, & Barnett, 2007). However, in the case of measuring students with M-ABC, coordination abilities during daily life that corresponds to the A and B criteria of the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition, which is used as the DCD diagnosis standard, cannot be evaluated. Furthermore, there are limitations in the environment and time because the M-ABC requires an experienced evaluator to conduct a 30-40 minute motor development examination to a single subject.

Screening tools that allow teachers and parents to primarily evaluate a student's coordination abilities in daily life are being developed to supplement the weaknesses of the motor development examination. The representative questions in which teachers observe a student's school life and evaluate DCD related index as a DCD pretest of school-aged children are (1) Checklist of the Movement Assessment Battery for Children Second Edition (MABC-2) (Henderson et al., 2007), (2) Teacher Estimation of Activity Form (TEAF) (Faught et al., 2008), (3) Children Activity Scales for Teachers (ChAS-T) (S Rosenblum, 2006), and (4) Motor Observation Questionnaire for Teacher (MOQ-T) (Schoemaker, Flapper, Reinders-Messelink, & Kloet, 2008). The frequently used DCD Screen Tool in which parents evaluate DCD related index based on their observation of students' daily life are (1) The Developmental Coordination Disorder Questionnaire (DCDQ) (Wilson, Kaplan, Crawford, Campbell, & Dewey, 2000), and (2) Children Activity Scales for Parent (ChAS-P) (Rosenblum, 2006).

Research activities in Korea related to DCD evaluation tools are very insufficient. The adaptations of evaluation forms verified in foreign countries are not even conducted. In the case of domestic DCD related research, a standardized evaluation form to assess criteria B (low coordination ability's influence in daily life) of the DSM-5 has not been developed. That is why sport coaches use their subjective judgement to conduct M-ABC on students who have been primarily selected or to conduct a motor development examination on everyone without a primary selection process. Research that has diagnosed DCD considering every criteria of the DSM-5 in the process of identifying children with DCD is very limited. Most researches are identifying children with DCD only using M-ABC and limited to criteria A of the DSM-5 (Cho & Chung, 2009; Heo & No, 2009; No, 2014; No, Jo, Kim, An, & Kim, 2008; Park, 2010; Park & No, 2008). This is because verified Screen Tools that can simply evaluate coordination abilities related to daily life are not available.

The Developmental Coordination Disorder Questionnaire (DCDQ'07) that this research has adapted is a tool for parents to evaluate children's degree of coordination during daily life. It is an amendment by Wilson, Kaplan, Crawford, and Roberts (2007) in 2007 of the DCDQ developed in Canada in 2000. Regarding the factors related to coordination during daily life, this questionnaire is composed of (1) control during movement, (2) fine motor and handwriting, (3) general coordination and evaluates the degree of danger in DCD measuring 15 questions related to the factors with a five point scale. Although one cannot identify DCD with just this questionnaire, parents who know well the evaluation subject's characteristics can assess criteria B (difficulties in daily life due to low coordination ability) of DSM-5 in their student evaluation. The questionnaire's reliability and validity was verified by Wilson et al. (2009), and the questionnaire is used as a tool to primarily identify research subjects in large group research aimed at 5-15 year-old children.

2. Purpose of the study

The purpose of this research is to translate the DCDQ'07, which is used as a screening tool to identify children with DCD. It is also to verify the suitability of the translation and back translation, to verify the reliability, and to confirm the Korean version DCDQ's possibility of domestic application as a screening tool for DCD identification.

3. Method

3.1. Participants

This research conducted a questionnaire to 190 people who agreed to participate in the research among school parents whose children attend an elementary or middle school in Incheon Metropolitan city. The subjects were 36 men (18.95%) and 154 women (81.05%), of which were 93 female student parents (48.95%), and 97 male student parents (51.05%). Excluding the questionnaires of two school parents whose children were confirmed to have disabilities during the research process, a total of 188 people's questionnaires were analyzed.

3.2. Research tools

The DCDQ'07 that this research adapted is a tool for parents to evaluate their children's degree of coordination during daily life. It is an amendment by Wilson, Kaplan, Crawford, Roberts (2007) in 2007 of the DCDQ developed in Canada in 2000. This questionnaire is aimed at children ages 5-15 and has selected (1) control during movement, (2) fine motor and handwriting, and (3) general coordination as factors related to coordination during daily life. It is composed of 15 questions suitable to each factor as Table 3 shows. Each question is composed of a five point scale, and the sum of all questions’ scores can be used to evaluate the degree of danger of DCD.

Table 3. The subscale, item of DCDQ’07

Subscale	Item
Control during Movement	Throws ball, Catches ball, Hits ball/birdie, jumps over, Runs, Plans activity
Fine Motor / Handwriting	Writing fast, Writing legibly, Effort and pressure, Cuts
General Coordination	Likes sports, Learning new skills, Quick and competent, “Bull in shop”, Does not fatigue

3.3. Procedure

This research verified the suitability of the translation by translating the original DCDQ’07 into Korean. It also conducted back translation after the Translation Verification Committee carried out re-verification and completed the Korean version of DCDQ through the verification of the back translation. The research went through content validity verification to develop the Korean version of DCDQ and verified the internal consistency and test-retest reliability to establish the reliability of the tool

3.3.1. Translation and suitability verification

The translation was conducted after obtaining approval from Brenda N. Wilson, the director of the development of DCDQ’07, about the Korean translation and use. In the Korean translation of the DCDQ’07, one researcher and one holder of a master’s degree in English education who is proficient in both English and Korean participated. In the suitability verification, one elementary school teacher, one middle school physical education teacher who have both more than 10 years of education experience and one holder of a doctoral degree in motor development who has experience in more than a year of training in an English-speaking country participated. A sum of three people participated. The evaluators assessed the suitability of the Korean translation as Highly Unsuitable (1), Unsuitable (2), Average (3), Suitable (4), or Highly Suitable (5), and were made to write alternative words or syntax for the categories they marked as 2 or less (Highly unsuitable, unsuitable) along with the reasons why they were unsuitable. As a result, 5 out of 15 questions were evaluated as less than 2. With the original writer’s agreement, some words were revised, deleted, or replaced with another explanation considering cultural differences.

3.3.2. Translation verification committee’s re-verification

For the verification of the DCDQ’07 translated in Korean, three experts (one adapted physical education professor, one holder of a doctoral degree in motor development, one physical education teacher with more than 10 years of education experience) in related fields formed a translation verification committee. The members of the translation verification committee assessed the translated questionnaire's degree of suitability with Highly Unsuitable (1), Unsuitable (2), Average (3), Suitable (4), or Highly Suitable (5) and were made to write alternative words or syntax for the categories they marked as 2 or less (Highly unsuitable, unsuitable). As a result, 2 out of 15 questions were evaluated as less than 2 and the phrases were remodified with the help of the translation members.

3.3.3. Back translation and suitability verification

After receiving approval from the main author of DCDQ'07, an expert in English translation conducted back translation without looking at the original text. For the suitability verification of the back translation, native English speakers, two Americans and one Canadian, evaluated the similarity of the meanings between the original text and the back translation as Different (1), Slightly Different (2), Similar (3), Highly Similar (4), or Congruous/Equal (5), and were made to write the reasons for the categories they marked as 2 or less (Different, Slightly different). As a result, 2 questions received a score of less than 2 and therefore went through a re-verification procedure after revision so that every questions received a score of more than 3. Through this procedure, the Korean version of the DCDQ (DCDQ-K) was completed.

3.3.4. Content validity verification

30 Parents who have children attending elementary and middle schools were provided with the Korean version of the DCDQ (DCDQ-K) to verify the understanding of each question of the Korean version of DCDQ'07. The verification of the parents' understanding of each question used a five point scale (Not understood at all 1, Not understood 2, Average 3, Understood 4, Perfectly understood 5). It was decided to exclude the questions from revision if over 80% of the participants' answers scored over 3 and to submit the result to the translation verification committee otherwise.

The tool's CVI (Content Validity Index) was calculated to verify the content suitability of the 15 questions on the Korean version of DCDQ'07. After assigning the scale value of resources, which is gathered through a five point scale, so that 1 is .00, 2 is .25, 3 is .50, 4 is .75, and 5 is 1.00, the computation of the CVI was done by calculating the arithmetic mean of each question. The content validity index's cut-off score of this research was set to .83. In the questionnaire asking the suitability regarding the 15 questions, a sum of 6 experts in education (one elementary school teacher, one middle school physical education teacher, one sport instructor, one holder of a doctoral degree in motor development, one physical education professor, and one adapted physical education professor who all have more than 10 years of education experience) participated. The CVI for each question was calculated using a five point scale (Highly Unsuitable 1, Unsuitable 2, Average 3, Suitable 4, Highly Suitable 5) on the suitability of each question.

3.3.5. Reliability verification

Internal consistency and test-retest reliability examinations were conducted to verify the reliability of the Korean version of DCDQ (DCDQ-K). A questionnaire was given to 190 parents whose children attend an elementary or middle school for the internal consistency examination. Excluding the questionnaire of 2 school parents whose children were confirmed to have disabilities, a sum of 188 parent's questionnaires were analyzed. Among these people, 30 were tested repeatedly over a 2-3 week interval to analyze the test-retest reliability.

3.4. Data analysis

Descriptive statistical analysis was used to verify the understanding of the questions. The computation of CVI provided the arithmetic mean of each question by converting the score that was evaluated with a five point scale for each question to: 1 is .00, 2 is .25, 3 is .50, 4 is .75, and 5 is 1.00. The CVI's cut-off score of this research was set to .83 for analysis. Cronbach's α was computed to verify the internal consistency of the adaptation Korean version of DCDQ (DCDQ-K) and the Pearson correlation analysis was conducted to verify the test-retest reliability. The SPSS Version 21.0 program was used to conduct a statistical analysis on the data gathered in this research and the level of significance was set to .05.

4. Results

4.1. Content validity verification of the Korean version of DCDQ

4.1.1. Verification of the understanding of questions

Verification was assigned to 30 parents who have elementary or middle school children to verify the understanding of questions of the Korean version of DCDQ (DCDQ-K). The result of the verification of the understanding of questions for the Korean version of DCDQ is as shown in Table 2. The understanding of the questions of the Korean version of DCDQ was evaluated as 4 or more (Understood) in every question. Therefore, it did not reach the standard for revision (3 or less) and all of the questions were not modified.

4.1.2. Content validity index

As a result of calculating CVI to verify the content validity of the Korean version of DCDQ, the average score of all was .97, and the score of the 15 questions was distributed between .90 and 1.00. The CVI computation result of the Korean version of DCDQ is as shown in Table 4.

Table 4. Content validity of DCDQ-K

Subscale	No.	Item	CVI (n = 6)		Understanding of questions (n = 30)
			CVI values	SD	M ± SD
Control During Movement	1	Throws ball	1.00	.00	4.90 ± .31
	2	Catches ball	1.00	.00	5.00 ± .00
	3	Hits ball/birdie	1.00	.00	4.93 ± .25
	4	Jumps over	1.00	.00	4.87 ± .35
	5	Runs	1.00	.00	4.60 ± .50
	6	Plans activity	.96	.10	4.53 ± .62
Fine Motor/ Handwriting	7	Writing fast	1.00	.00	4.90 ± .31
	8	Writing legibly	1.00	.00	5.00 ± .00
	9	Effort and pressure	.96	.10	4.87 ± .35
	10	Cuts	.96	.10	4.90 ± .31
General Coordination	11	Likes sports	.96	.10	5.00 ± .00
	12	Learning new skills	1.00	.00	4.93 ± .25
	13	Quick and competent	1.00	.00	5.00 ± .00
	14	"Bull in shop"	.92	.13	4.46 ± .63
	15	Does not fatigue	.92	.13	4.60 ± .50

CVI, Content Validity Index

4.2. Reliability verification of the Korean version of DCDQ

4.2.1. Internal consistency

The Korean version of DCDQ's Cronbach's α value that was derived from 188 parents who have elementary or middle school children showed a value of .916 of internal consistency for every question. The internal consistency result of the Korean version of DCDQ (DCDQ-K) for each question is as show in Table 5.

Table 5. Cronbach's α of if item deleted DCDQ-K

Subscale	Item	Cronbach's α if item deleted
Control During Movement	1	.907
	2	.910
	3	.912
	4	.908
	5	.909
	6	.907
Fine Motor/ Handwriting	7	.912
	8	.909
	9	.909
	10	.907
General Coordination	11	.912
	12	.910
	13	.909
	14	.915
	15	.915

4.2.2. Test-retest reliability

The Korean version of DCDQ's test-retest reliability conducted over a 2-3 week interval involving 30 parents who have elementary or middle school children showed a Pearson correlation analysis result of .982, a high correlation. The Korean version of DCDQ's test-retest reliability result is as shown in Table 6.

Table 6. Test-retest reliability of DCDQ-K

(n = 30)

	Pearson correlation (r)
DCDQ-K	.982*

*Statistically significant difference ($p < .05$). DCDQ-K, the Korean version of Developmental Coordination Disorder Questionnaire

5. Discussion

This research translated DCDQ'07 for the development of the Korean version of DCDQ (DCDQ-K). It verified the suitability of the translation and back translation. Also, it conducted a verification of content validity and reliability to confirm the possibility of the Korean version of DCDQ's application in Korea as a primary evaluation tool for identifying DCD. As a result, a high score of understanding of questions and content validity index was computed during the translating process, and passed through an expert review. Also, the reliability verification showed a high level of internal consistency and test-retest reliability.

The translating procedure of DCDQ'07 is provided below: (1) translation based on the research of the evaluation tool translation preceded in the field of occupational therapy (Jung, Jung, Yoo, & Kang, 2015; Lim, Park, & Yoo, 2007), (2) verification of translation suitability, (3) Re-verification of the translation verification committee, (4) back translation, and (5) verification of back translation suitability. In the translation process of DCDQ'07, words were carefully translated in Korean considering the Korean sociocultural environment rather than a direct translation based on dictionary definitions to suitably translate an evaluation tool written in a different cultural area's language. This method was conducted in order to reduce the linguistic and cultural differences when applying an evaluation tool written in another language (Brislin, Lonner, & Thorndike, 1973; Candell & Hulin, 1986; Lim et al., 2007).

After DCDQ’07 was completely translated, translation suitability verification members were selected to verify the translated version, and the translation verification committee was organized to conduct the re-verification. The process was conducted to evaluate if the meaning of the original version was fully reflected in the translated version. For questions that were assessed inappropriately, modification was advised and reverification, after modification, was conducted. Back translation and suitability verification were also conducted to confirm the translation suitability of the translated version of DCDQ’07, especially to determine if the original writers’ intention was kept. As referred to the preceding evaluation tool translating research written in the field of occupational therapy, back translation and suitability verification are the only way to increase the validity of the evaluation tool by ensuring the consistency of the meanings, content, and concepts of the original version and the translated version (Jung et al., 2015; Van Widenfelt, Treffers, De Beurs, Siebelink, & Koudijs, 2005).

One should use the most similar word to the original text’s word in translation because a native language word that is semantically equal to the original text’s word doesn’t exist (Brislin et al., 1973; Lim et al., 2007). There was a difficulty in selecting words that precisely delivers the meaning of the original text's word or sentence during the procedure of translating the original text to Korean. Especially in the case of the idiomatic expressions in the original text, they were translated to idiomatic expressions that reflect Korean culture, and this became the cause of the low evaluated similarity in the back translation verification procedure. Translation was conducted with the judgement that providing consistency in semantic delivery is more important than using words grammatically (Lim et al., 2007; Sechrest, Fay, & Zaidi, 1972).

After the adaptation procedure of the DCDQ'07, content validity verification of the Korean version of DCDQ was conducted. In the case of the content validity verification, the verification of the understanding of questions conducted in Park and Yoo (2009) research was applied to 30 parents whose children attend an elementary or middle school. The CVI was computed by composing an education expert group to find out if the adapted questions were suitable in identifying children with DCD. As a result of the verification of the understanding of questions, all questions were evaluated as 4 or more (Understood), confirming that the school parents didn't have difficulty in understanding the questions. The score for the understanding of questions didn't reach the revision standard (3 or less) and thus were not modified. As a result of the CVI computation of the Korean version of the DCDQ, the entire average score was .97, and the scores of 15 questions were distributed between .90 and 1.00. The CVI score of all questions was computed higher than the cut-off score (.83) of the content validity index that this research set. Thus, the content validity was proven to be high without the deletion of questions. The cut-off score (0.83) of the content validity index that this research set referred to the recommendation from Polit and Beck (2006) research that more than .83 is the ideal level when more than six experts participate in CVI computation.

The Korean version of DCDQ may have limitations in precisely evaluating all the characteristics of children with DCD because it only conducted the content validity verification. However, it is judged that this limitation can be supplemented because the DCDQ’07 is an evaluation tool that has been adapted in eight languages and of which the validity and reliability has been verified. As a result of the questionnaire given to 287 children at the time the DCDQ’07 was developed, the sensitivity that judges children with DCD as children who are at high risk of DCD appeared high (85%) (Wilson et al., 2009). High validity was proven for the sensitivity, which evaluates children with DCD as a high-risk group, of DCDQ-Italian, an adaptation in Italy, was analyzed to be 88% (Caravale et al., 2015).

Internal consistency and test-retest reliability was computed to verify the Korean version of DCDQ's reliability. A questionnaire was given to 188 parents who have an elementary or middle school student for the internal consistency computation of the Korean version of the DCDQ. Cronbach's α value showed an internal consistency of .916 in all questions. It is judged that the internal consistency of this research shows a significantly high level of reliability because when judging the internal consistency's level of reliability, it is generally judged to be reliable if the Cronbach α value of all questions is more than .07. When comparing the internal consistency Cronbach's α value computed in DCDQ'07's adaptation and reliability research conducted abroad and this research's internal consistency, this research's internal consistency shows a similar level with DCDQ-FC .949 that was adapted in France and DCDQ-Italian .89 that was adapted in Italy (Caravale et al., 2015; Martini, St-Pierre, & Wilson, 2011). Furthermore, this research shows that the Korean version of DCDQ is composed of questions that can measure Korean children's characteristics related to DCD because it shows a similar level of reliability with the DCDQ'07's internal consistency value (.94) at the time when it was developed (Wilson et al., 2009).

This research repeatedly conducted a survey to 30 parents who have elementary or middle school students over a period of 2 to 3 weeks to verify the reliability, and computed the test-retest reliability. The test-retest reliability of the Korean version of DCDQ is computed through the Pearson correlation analysis, and as a result, showed a very high correlation of .982. When comparing the result with other results of the adaptation of DCDQ'07 and the test-retest reliability of reliability study conducted in other countries, it demonstrated higher reliability than DCDQ-FC .952 adapted in France and DCDQ-Italian .88 adapted in Italy (Caravale et al., 2015; Martini et al., 2011). This result is judged as evidence that the Korean version of DCDQ can be used as a reliable evaluation tool to apply in domestic research.

STUDY II

Correlation between motor coordination skills and emotional and behavioral difficulties through comparison between children with developmental coordination disorder and typically developing children

1. Introduction

Children without developmental disorders or neurological problems might still face difficulties in physical activities due to a lack of motor and coordination skills (Wall et al., 1990). The American Psychiatric Association (2000) suggests those children as developmental coordination disorder (DCD) and it means that DCD face difficulties in everyday life and academic achievements due to a significant lack of coordination skills and showed poor motor coordination compared with others in the same age. Previous studies have diagnosed conditions featuring diminished motor coordination skills including clumsy child syndrome (Gubbay, 1975), developmental dyspraxia (Dewey, 1995; Missiuna & Polatajko, 1995), specific developmental disorder of motor function (World Health Organization, 1993), and deficits in attention, motor control, and perception (DAMP) (Gillberg, 2003). Recent research related to motor coordination has used the terminology, DCD as the most general diagnosis (Magalhães et al., 2006).

Children with DCD face difficulties in activities of daily living due to motor coordination problems (Cairney, 2015a). Children with DCD also experience difficulties in participating in physical activities or physical education classes and show a tendency to avoid these activities because they are not fully developed the basic motor skills to participate in play or sports

(Hill, 2001). As children with DCD accumulate negative experiences in activities from plays or PE classes, they might tend to avoid physical activities and participation in play activities only to a limited extent (Polatajko, 1999). Inactivity of children with DCD that occurs from motor coordination problems diminishes their physical health related to cardiovascular disease. Children's inactivity also leads to the development of psychosocial and behavioral difficulties because children with DCD fail to participate in play, which is important in establishing social relationships during childhood (Piek & Rigoli, 2015).

DCD could be a first negatively influence to their physical problems and secondary problems, such as social integration and establishment of self-conception (Skinner & Piek, 2001), also causing emotional and behavioral problems (Cantell et al., 1994). Motor skill impairment dangerously influences psychosocial outcomes, such as anxiety during childhood and adolescence (Sigurdsson, Van Os, & Fombonne, 2002; Skinner & Piek, 2001). Furthermore, even pre-school age children who lack motor skills feel greater anxiety and depression than the same-aged children who are not lack of motor skills (Piek, Bradbury, Elsley, & Tate, 2008). Problems of children with DCD might continue throughout adolescence and adulthood, causing the increase of various danger factors (Rasmussen & Gillberg, 2000). Therefore, discovering DCD children's emotional and behavioral problems in an early stage is very critical for their future development.

Motor performance greatly influences children's psychosocial development and is an important factor in explaining various psychosocial problems in early stage of life span (Heuvel, Jansen, Reijneveld, Flapper, & Smits-Engelsman, 2016). Children with DCD have noticeably more prevalent depression, withdrawn behavior, and anxiety compared to those of the same age (Cairney, Veldhuizen, & Szatmari, 2010; Dewey et al., 2002; Pratt & Hill, 2011; Tseng, Howe, Chuang, & Hsieh, 2007). Internalizing and externalizing behaviors are prevalent for their typical developing (Dewey et al., 2002; Tseng et al., 2007). Although previous research has been limited on motor problems and emotional/behavioral research for pre-school age children (Piek, Barrett, Smith, Rigoli, & Gasson, 2010), a recent study (King-Dowling, Missiuna, Rodriguez, Greenway, & Cairney, 2015) on this age group reported a significant relationship between motor difficulties and emotional-behavioral problems.

Only few studies related to emotional-behavioral problems in DCD have been conducted because of the limitation. First, it targeted children sampled from clinical environments based on information written by parents and teachers. Second, data were obtained from school environments based on what DCD children were aware of. Research related to emotion and behavior problems in of Asian children with DCD is also lacking and research related to

South Korean children’s motor coordination skills and emotion/behavior problems has not been carried out. Although the results indicate that DCD is not affected by cultural or social differences, emotional/behavioral problems due to differences in motor coordination skills in Asian children might differ because the influence of social and cultural environments cannot be removed. Therefore, it is important to know the emotional/behavioral problems children in lower grades of elementary school have compared to others of the same age in South Korean schools (where awareness DCD is insufficient).

2. Purpose of the study

The purpose of this research is to investigate the differences in emotional and behavioral problems of DCD and TD children, and the interrelationship between children's motor coordination skills and emotional, behavioral problems for elementary students from grades 3.

3. Method

This study was conducted with the approval of the Seoul National University Institutional Review Board (approval No. 1603/001-028). Informed consent for participation was obtained from all children, parents, and relevant school officials.

3.1. Participant

288 children (148 boys, 140 girls) from South Korean grade 3 (8-9 years old) children were asked to participate voluntarily from one of three elementary schools randomly selected and located in city, South Korea. As a result of screening 288 participants based on DSM–V standards, 46 participants (30 boys, 16 girls) were classified as DCD risk patients and 242 participants (118 boys, 124 girls) were classified as TD. Of these, 30 participants (15 boys, 15 girls) were classified as probable DCD group with total MABC-2 < 67 and 30 participants (15 boys, 15 girls) were classified into TD group with a score ≥ 68. Among the 30 participants in the probable DCD group, 4 severe DCD children (2 boys, 2 girls) with total MABC-2 ≤ 56 (lower 5%) were included. The emotion and behavior testing comprised 15 males and 15 females. To exclude the influence of gender between groups, this study placed 15 boys and 15 girls for each group and used the KBASC-2, SRP-C

(Ahn, Ebesutani, & Kamphaus, 2014) to gather information about the emotions and behaviors of the participants.

DCD diagnosis was established based on 4 criteria described in the *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition (American Psychiatric Association, 2013): total MABC-2 score < 67 (bottom 15%); Developmental Coordination Questionnaire 2007 (DCDQ'07) score < 55 (Wilson, Kaplan, Crawford, & Roberts, 2007), as a parental report describing the level of ADL coordination of the child; difficulty in learning or fulfilling school assignments, as described by the teachers; and no physical or neurological deficit, as reported by the parents and confirmed based on health records. An overview of the characteristics of the study participants is provided in Table 7.

Table 7. Characteristics of the participants

Characteristic	DCD group (n = 30)	TD group (n = 30)	*p* -value
Age (years)	8.76±0.29	8.80±0.39	-
Sex (boys, girls)	15, 15	15, 15	-
Manual dexterity score	21.45±3.77	31.30±5.22	.000**
Aiming and catching score	11.70±2.78	17.96±4.09	.000**
Balance score	28.75±3.66	31.45±2.96	.003**
Total MABC-2 score	61.90±5.26	80.71±5.88	.000**

**Statistically significant difference ($p < .01$). DCD, Developmental Coordination Disorder; TD, Typically Developing; MABC-2, Movement Assessment Battery for Children, second edition

3.2. Emotional and behavioral difficulties

3.2.1. KBASC-2, SRP-C

The Korean Behavior Assessment System for Children, Second Edition, Self-Report of Personality, Children Form (KBASC-2, SRP-C) and the South Korean standardized version of The Behavior Assessment System for Children, Second Edition, Self-Report of Personality, Children Version (Reynolds & Kamphaus, 2004) is multi-dimensional mental health screening inspection that provides comprehensive information on the problematic behavior patterns based on the self-perception and attitude toward others of children aged 8-11 years (Ahn et al., 2014). KBASC-2 and SRP-C provide validity index, general measure, and scale scores, and measure personality traits and positive adaptive skills comprehensively in the screening process of emotional symptoms and problematic behaviors and in the evaluation of adaptive resilience, which is useful in evaluating the prognosis in counseling and psychotherapy. KBASC-2, SRP-C's reliability and validity were verified by Ahn, Ebesutain, Kamphaus (2014) and used as a tool for evaluating children's emotions and behaviors in the South Korea elementary school environment.

3.2.2. KBASC-2 validity index

KBASC-2, SRP-C provides F,, L, V indices, response type index, and a consistency index to confirm test result validity. The F index evaluates the possibility that children respond to the test questions too negatively. The L index (the ‘Faking good’ index) evaluates the possibility that children respond biased toward what is considered socially desirable. The V index evaluates the possibility that children answer ‘yes’ due to negligence, lack of understanding of the question, uncooperative attitude in the evaluation process. The response type index distinguishes tests that can decrease the validity of the inspection results due to the participant’s negligent response. Consistency index distinguishes cases of different answers to questions that show similar responses.

3.2.3. KBASC-2 general criterion

General criterion score is useful to summarize the entire test and to make an extensive conclusion on the various types of personality traits and emotional, behavioral problems. The general criterion of KBASC-2 and SRP-C is comprised of school problems, internalizing problems, inattention/ hyperactivity, emotional symptoms index, and personal adjustment. Excluding the personal adaptation general criterion evaluating positive adaptation skills, a score of 60-69 is in the range of ‘high’ on the subclinical level, and a score ≥70 is in the range of ‘very high’ on the clinical level. In the personal adaptation general measure a score of 31-40 is in the range of ‘low’ on the subclinical level, and a score ≤30 is in the range of ‘very low’ on the clinical level.

3.2.4. KBASC-2 scales

Individual scale has the highest accuracy of the interpretation of this examination result and by confirming the scale T score, the problems that a student has can be understood specifically. The scale corresponding to the general criterion is shown in Table 8.

Table 8. Composites and scale of KBASC-2, SRP-C

Composites	**Scale**	**Composites**	**Scale**
School problems	Attitude to school	Emotional symptoms index	Social stress
	Attitude to teacher		Anxiety
Internalizing problems	Atypicality		Depression
	Locus of control		Sense of inadequacy
	Social stress		Self-esteem
	Anxiety		Self-reliance
	Depression	Personal adjustment	Relations with parents
	Sense of inadequacy		Interpersonal relations
Inattention/ Hyperactivity	Sense of Inattention		Self-esteem
	hyperactivity		Self-reliance

3.2.5. KBASC-2 implementation

The KBASC-2, SRP-C examination was implemented for 30-40 minutes after the counseling teacher established a rapport with the participating children and after sufficiently explaining the purpose of the examination. To minimize the influence of environment, the examination was progressed in a quiet, controlled counseling office under 1:1 supervision of the counseling teacher. Although the KBASC-2, SRP-C is a test for a student to fill in alone, the few children who could not read or understand the content of the test received the help of the counseling teacher to fill in the test. After conducting the test, two cases of children whose validity index exceeded the permissible range occurred; the test was conducted one week later. Also, this research only analyzed results with validity index inside the permissible range.

3.3. Statistical analysis

The independent *t*-test was used to assess the differences between the groups of children with normal development and those with DCD. The correlations between motor coordination skill and emotional and behavioral difficulties were analyzed using Pearson's correlation coefficient. All data were presented as mean ± standard deviation. All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

Differences were considered significant for p .05.

4. Results

4.1. Difference of school problems, internalizing problems, inattention / hyperactivity, and emotional symptoms index in children with DCD and TD children

The difference of children with DCD and TD children's school problems, internalizing problems, inattention/hyperactivity, emotional symptoms index participating is shown in Table 9. Compared to TD children, children with DCD showed significantly high scores in internalizing problems ($p<.01$), inattention/hyperactivity ($p<.01$), and emotional symptoms index ($p<.01$) among the KBASC-2's general measure. Compared to TD children, DCD children showed significantly high scores in locus of control ($p<.05$), the scale of internalizing problems and depression ($p<.01$), sense of inadequacy ($p<.01$), and sense of inattention ($p<.01$). The clinical level, subclinical level, and normal range distribution of children in the area of school problems, internalizing problems, inattention/hyperactivity, emotional symptoms index are shown in Table 10.

Table 9. Comparison of school problems, internalizing problems, inattention/ hyperactivity, and emotional symptoms index in children with DCD and TD children

Scale		DCD group (n = 30)	TD group (n = 30)	*p* -value
School problems	Attitude to school	46.93±9.74	47.50±10.68	.831
	Attitude to teacher	46.86±6.18	45.26±7.13	.357
	School problems	46.50±7.37	45.93±9.16	.793
Internalizing problems	Atypicality	44.60±3.95	44.60±4.30	1.000
	Locus of control	48.33±9.19	43.80±5.68	.025*
	Social stress	45.66±7.59	42.83±6.51	.126
	Anxiety	47.63±6.36	44.73±6.20	.079
	Depression	51.26±11.94	43.60±5.71	.002**
	Sense of inadequacy	50.46±8.24	44.96±7.24	.008**
	Internalizing problems	47.86±7.30	43.36±5.54	.009**
Inattention/ hyperactivity	Sense of Inattention	49.86±6.53	43.33±7.79	.001**
	hyperactivity	48.50±5.84	46.50±5.60	.181
	Inattention/ hyperactivity	49.10±5.90	44.46±6.01	.004**
Emotional symptoms index		49.30±8.72	42.33±6.34	.001**

*Statistically significant difference (*p* <.05). **Statistically significant difference (*p* <.01). DCD, Developmental Coordination Disorder; TD, Typically Developing

Table 10. Proportion of subclinical score of school problems, internalizing problems, inattention/ hyperactivity, and emotional symptoms index in children with DCD and TD children

Scale		DCD group (n = 30)			TD group (n = 30)		
		Clinical	Subclinical	Normal	Clinical	Subclinical	Normal
School problems	Attitude to school	2	1	27	2	4	24
	Attitude to teacher	0	2	28	0	2	28
	School problems	1	1	28	2	2	26
Internalizing problems	Atypicality	0	0	30	0	0	30
	Locus of control*	1	2	27	0	0	30
	Social stress	0	1	29	0	2	28
	Anxiety	0	1	29	0	2	28
	Depression*	5	1	24	0	0	30
	Sense of inadequacy*	0	5	25	0	4	26
	Internalizing problems*	0	4	26	0	0	30
Inattention/ hyperactivity	Sense of Inattention*	0	1	29	0	2	28
	hyperactivity	0	1	29	0	0	30
	Inattention/ hyperactivity*	0	2	28	0	0	30
Emotional symptoms index*		1	4	25	0	0	30

DCD, Developmental Coordination Disorder; TD, Typically Developing, *, variable showed significant difference between DCD and TD (*p* <.05)

4.2. Difference of personal adjustment in children with DCD and TD children

Differences in personal adjustment of DCD and TD children are as shown in Table 11. Compared to TD children, DCD children personal adjustment (p<.01) among KBASC-2's general criterion was significantly low. Compared to TD children, DCD children had a significantly low degree of personal adjustment, which was obtained by measures including relationships with parents (p<.05), interpersonal relationships (p<.01), self-esteem (p<.01), and self-reliance (p<.01). Children's clinical level, subclinical level, and distribution of normal range are as shown in Table 12.

Table 11. Comparison of personal adjustment in children with DCD and TD children

Scale		DCD group (n = 30)	TD group (n = 30)	*p* -value
Personal adjustment	Relations with parents	51.90±6.62	55.73±7.35	.038*
	Interpersonal relations	50.46±10.86	56.53±3.44	.005**
	Self-esteem	50.80±9.02	57.46±5.80	.001**
	Self-reliance	47.16±10.96	53.50±8.58	.016*
	Personal adjustment	49.83±9.42	57.93±6.33	.000**

*Statistically significant difference (p <.05). **Statistically significant difference (p <.01). DCD, Developmental Coordination Disorder; TD, Typically Developing

Table 12. Proportion of subclinical score of personal adjustment in children with DCD and TD children

Scale		DCD group (n = 30)			TD group (n = 30)		
		Clinical	Subclinical	Normal	Clinical	Subclinical	Normal
Personal adjustment	Relations with parents*	0	1	29	0	1	29
	Interpersonal relations*	1	5	24	0	0	30
	Self-esteem*	1	5	24	0	0	30
	Self-reliance*	1	8	21	0	2	28
	Personal adjustment*	0	7	23	0	0	30

DCD, Developmental Coordination Disorder; TD, Typically Developing, *, variable showed significant difference between DCD and TD (*p* <.05)

4.3. Correlation between the motor coordination skills and school problems, internalizing problems, inattention / hyperactivity, and emotional symptoms index

Analyses results of the correlation between the motor coordination skills and school problems, internalizing problems, inattention/ hyperactivity, emotional symptoms index of the children participating in the research are shown in Table 13. The MABC-2 composite percentile score of children showed a significant correlation with internalizing problem behavior ($r=-.382$, $p<.01$), inattention / hyperactivity disorder ($r=-.409$, $p<.01$), and emotional symptoms index ($r=-.483$, $p<.01$), which are the general measures of the KBASC-2. Also, the MABC-2 composite percentile score of children showed a significant negative correlation with the locus of control ($r=-.305$, $p<.05$), anxiety ($r=-.269$, $p<.05$), depression ($r=-.468$, $p<.01$), and sense of inadequacy ($r=-.446$, $p<.01$), which are the scales of internalizing problem behavior, and with attention problems ($r=-.478$, $p<.01$), which is the scale of inattention / hyperactivity disorder.

Table 13. The association of MABC-2, school problems, internalizing problems, inattention/hyperactivity and emotional symptoms index

Variables		total MABC-2 score	*p* -value
School problems	Attitude to school	-.054	.680
	Attitude to teacher	-.180	.168
	School problems	-.111	.398
Internalizing problems	Atypicality	.091	.489
	Locus of control	-.305	.018*
	Social stress	-.158	.229
	Anxiety	-.269	.038*
	Depression	-.468	.000**
	Sense of inadequacy	-.446	.000**
	Internalizing problems	-.382	.003**
Inattention/ hyperactivity	Sense of Inattention	-.478	.000**
	hyperactivity	-.171	.192
	Inattention/ hyperactivity	-.409	.001**
Emotional symptoms index		-.483	.000**

*Statistically significant difference (p <.05). **Statistically significant difference (p <.01). MABC-2, Movement Assessment Battery for Children, second edition

4.4. Correlation between the motor coordination skills and personal adjustment

Results of the analysis of the correlation between the motor coordination skill and personal adjustment of the children participating in the research are shown in Table 14. The children's MABC-2 composite percentile score showed a significant positive correlation with personal adjustment ($r=.474$, $p<.01$), the general criterion of KBASC-2. Moreover, the children's MABC-2 composite percentile score showed a significant positive correlation with relation with parents ($r=.282$, $p<.05$), interpersonal relations ($r=.349$, $p<.01$), self-esteem ($r=.360$, $p<.01$), and self-reliance ($r=.409$, $p<.01$), which are all scales of personal adjustment.

Table 14. Association of MABC-2 and personal adjustment

Variables		total MABC-2 score	*p* -value
Personal adjustment	Relations with parents	.282	.029*
	Interpersonal relations	.349	.006**
	Self-esteem	.360	.005**
	Self-reliance	.409	.001**
	Personal adjustment	.474	.000**

*Statistically significant difference ($p<.05$). **Statistically significant difference ($p<.01$). MABC-2, Movement Assessment Battery for Children, second edition

5. Discussion

This research was conducted to verify the correlation between motor coordination abilities; difference in emotion, problematic behaviors and emotional, behavioral problems based on the presence of DCD. It was conducted with children located in South Korean schools. As a result of analyzing the emotion, problematic behavior of 8-9 year old children, based on the presence of DCD, using the KBASC-2, SRP-C, a significant difference existed in internalizing problems, inattention/hyperactivity, the emotional symptoms index, and the personal adjustment scales. The result of verifying the correlation between children's motor coordination abilities and emotional, behavioral problems showed a significant negative correlation with internalizing problems, inattention/hyperactivity, the emotional symptoms index, and the composite scale of the KBASC-2, SRP-C, and a significant positive correlation with the personal adjustment.

Children who have problems with motor ability control seem to have been damaged self-esteem. The negative experiences of being excluded from sports activities that occupy a significant part of healthy school age development further intimidate these children (Jongmans, Smits-Engelsman, et al., 2003). Children with DCD face difficulties with social participation and face teasing and harassment more than typically developing children because they have characteristics of physical awkwardness or clumsiness (Cairney, Rigoli, & Piek, 2013). Children with DCD face a decrease in self-worth (Skinner & Piek, 2001) and difficulty in interpersonal relationships as social isolation deepens (Piek, Baynam, & Barrett, 2006). These problems negatively influence children with DCD's, leading to them internalizing problems such as depression and anxiety (Campbell, Missiuna, & Vaillancourt, 2012; Hill, Dunn, Dunning, & Page, 2011). These internalizing problems that are discovered during childhood tend to continue until adolescence (Shaffer et al., 1985).

In this research, children with DCD had significantly high in locus of control, depression, sense of inadequacy, and the subscales of internalizing problems, compared to TD children. Furthermore, although children with DCD do not show a significant difference in social stress and anxiety compared to TD children, a significant difference was discovered in the emotional symptoms index which is composed of social stress, anxiety, and depression. These differences are similar to those seen in research where parents (Dewey et al., 2002; R. Lingam et al., 2012) and teachers (Heuvel, Jansen, Reijneveld, Flapper, & Smits-Engelsman, 2016) evaluated the psychosocial problems of children with DCD. These differences are also identical to results found in precedent research (Campbell et al., 2012; Missiuna et al., 2014) that reported the relationship between motor coordination and depression in school-aged children.

In this research, children with DCD showed a significant difference in relations with parents, interpersonal relations, self-esteem, self-reliance, and subscales of personal adjustment, compared to TD children. This result shows that 8-9 year old Korean children with DCD face difficulties with developing amicable relationships, with not only friends at school but also with parents at home, compared to TD children. It also shows that they do not have positive feelings about themselves and have low confidence in their decision-making. These results are in line with precedent research that shows that the motor coordination difficulties of children with DCD cause peer relation difficulties (Missiuna et al., 2007; Poulsen, Ziviani, & Cuskelly, 2006) and cause not only mental health problems but also emotional problems (Piek, Dworcan, Barrett, & Coleman, 2000; Skinner & Piek, 2001) such as depression (Kadesjö & Gillberg, 1998; Rasmussen & Gillberg, 2000) and anxiety (Sigurdsson et al., 2002).

In this research, children with DCD were shown to be at higher risk of not only internalizing problems but also suffering from inattention/ hyperactivity, compared to TD children. This is judged to be because DCD has a coexistence rate of 50% with ADHD and has several common clinical characteristics such as inattention and hyperactivity (Fliers et al., 2010). The inattention and hyperactivity of children with DCD can be common characteristics with ADHD and can also be distinct characteristics of DCD.

Rather, they can be symptoms of the children's discouragement as a result of, a lack of writing academic achievement, due to a disability in fine motor control (Song & Jung, 2011). However, these symptoms in children with DCD must be accepted as distinct from children with ADHD because these characteristics do not show in all children with DCD. Moreover, early intervention must be considered for children with DCD who show inattention and hyperactivity because in longitudinal research (Cantell, Smyth, & Ahonen, 2003; Hadders-Algra, 2002; Rasmussen & Gillberg, 2000) that focused on problems in motor development, the authors showed that show that negative emotions can be caused by inattention, academic problems, etc.

In this research, the claim that children with DCD are more at risk than TD children is limited. The measured average T-score of the children with DCD in the areas of internalizing problems, inattention/ hyperactivity, emotional symptoms index, and personal adjustment scale are within the normal range that the KBASK-2, SRP-C provides. However, the DCD group showed a significant difference compared to the TD group in this research. Compared to the TD group, in which there are no children at risk in the subclinical level, there were four children in internalizing problems, two in inattention/hyperactivity, five in the emotional symptoms index, and seven in the personal adjustment scale who were found to be at risk at the subclinical level in the DCD group. Thus, it is judged that children with DCD are at a higher risk in the emotional, behavior field compared to TD children.

In this research, the total MABC-2 score showed a significant negative correlation with the internalizing problems, inattention/ hyperactivity, emotional symptoms index, and the composite scales of the KBASC-2, SRP-C, and showed a significant positive correlation with the personal adjustment scale. These results are in line with research that reported the relationship between motor skill impairment and risk factors for poor psychosocial outcomes (Sigurdsson et al., 2002; Skinner & Piek, 2001). Regardless of the presence of DCD, emotional, behavioral problems decrease as motor coordination ability increases, showing how significant motor coordination is during childhood. Through these results, it has been confirmed that motor coordination ability is a very significant factor in developing relationships with friends at Korean schools. Therefore, the need for school level intervention measures for children who face difficulty with motor coordination should be discussed.

Although some results show that the DCD does not arise from cultural or social environment's influence, the social, cultural environment's influence during childhood cannot be excluded. Korean society is influenced by Confucianism culture in which women's participation in sports activities is not looked upon well. Therefore, female children not participating in physical activities are not considered as big of a problem as male children. In this research, although significant differences of emotional, behavioral problems based on gender were not found, men were evaluated as being at a higher risk compared to women, different from the research of Campbell et al. (2012). Furthermore, except for the two female children with DCD who were evaluated to be at a risk level higher than or equal to the subclinical level on the personal adjustment scale, the rest of the children with DCD who were evaluated to be at risk higher than or equal to the subclinical level were all male children. With only these results, it cannot be concluded that Korean male children with DCD are more highly influenced by emotional, social problems compared to female children with DCD. However, the possibility that gender differences exist based on cultural influence can be accepted and additional discussion through further research is required.

In Korea, interest and understanding of DCD is insufficient because DCD is not considered disability under the current law. For this reason, DCD related research in South Korea is limited and research concerning the emotional, behavioral problems of children with DCD has not been conducted. Through this research, that was attempted in Korea for the first time, emotional, behavioral problems of Korean children with DCD were confirmed. This research confirmed that Korean children with DCD not only face difficulties in physical activities but also suffer from emotional, behavioral problems. Therefore, the Korean field of education must demand measures to devise proper educational environments that consider the characteristics of children with DCD.

PART III

Improving motor performance and timing ability in developmental coordination disorder via fundamental motor skill-based exercise

1. Introduction

The diagnosis of Developmental Coordination Disorder (DCD) is established in children who experience difficulty performing activities of daily living (ADL) and acquiring motor skills because of lack of coordination ability rather than a neurological deficit (American Psychiatric Association, 2013). While most children achieve typical motor development by school age, 5–6% of children experiences DCD symptoms (poor, slow, and less precise movement), with a predominance in boys (American Psychiatric Association, 2013; Gibbs, Appleton, Appleton, 2007; Maeland, 1992).

Because children with DCD lack basic motor abilities essential to participate in play and sports activities, they accumulate negative experience and eventually tend to avoid such activities (Hill, 2001; Polatajko, 1999), resulting in negative effects on cardiovascular-related health outcomes (Cairney, 2015b), higher incidence of overweight status or obesity (Hay, Hawes, & Faught, 2004), higher prevalence of cardiovascular disease (Cairney et al., 2010), and reduced health-related fitness compared to that of their peers (Cairney, Hay, Faught, Flouris, & Klentrou, 2007). Furthermore, DCD may negatively affect aspects of the child's social inclusion and self-concept formation (Skinner & Piek, 2001), potentially leading to emotional and behavioral problems (Cantell, Smyth, & Ahonen, 1994). Therefore, early recognition of health-related problems is crucial for minimizing risk factors and facilitating effective intervention in children with DCD.

The Movement Assessment Battery for Children-2 (MABC-2), is a standardized tool for evaluating motor development in children aged 3–16 years, and can be applied to assess skill, which is required for diagnosing DCD (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). Such evaluations have confirmed the remarkably reduced manual dexterity, aim, catching ability, and balance in children with DCD (Henderson, Sugden, & Barnett, 2007). However, using MABC-2 alone for evaluating the motor skills of children with DCD remains challenging Logan, Robinson, Rudisill, Wadsworth, and Morera (2014) evaluated the motor performance of school-aged children using MABC-2 and the Test of Gross Motor Development-2 (TGMD-2), a general tool for basic motor skill assessment, in 3–10-year-old children (Ulrich, 2000). Upon comparing the results, they found partial correlation between MABC-2 and TGMD-2 scores in relation to the motor performance of the same child, but with different absolute values of the MABC-2 and TGMD-2 scores. These previous findings suggest that MABC-2 and TGMD-2 evaluate different aspects of motor competence (Logan et al., 2014), and neither tool is sufficient on its own for judging the level of fundamental motor skills in children with DCD. A more precise approach is therefore desirable for accurate assessment of fundamental motor skill level and effective exercise intervention.

While exercise training is commonly used to improve the motor skills of children with DCD (Niemeijer, Smits-Engelsman, & Schoemaker, 2007; Peens, Pienaar, & Nienaber, 2008; Pless, Carlsson, Sundelin, & Persson, 2000; Polatajko, Mandich, Miller, & Macnab, 2001; Schoemaker, Niemeijer, Reynders, & Smits-Engelsman, 2003), research in this direction has focused on elaborate and limited movements such as handwriting (Jongmans, Linthorst-Bakker, Westenberg, & Smits-Engelsman, 2003) rather than coordination, which did not allows for a complete evaluation of motor skills (Jongmans et al., 2003). Some researchers have evaluated both coordination and fundamental motor skills of children with DCD and reported improved motor performance in sports-related activities but these findings cannot be generalized because no control groups were (Niemeijer, Schoemaker, & Smits-Engelsman, 2006). Therefore, the present study aimed to evaluate the exercise intervention-induced change in motor performance assessed using MABC-2 and TGMD-2 in children with DCD.

Children with DCD have difficulty participating in both physical activities and ADL (American Psychiatric Association, 2000; May-Benson, Ingolia, & Koomar, 2002). ADL performance relies on continuous movement within appropriate reaction time and reasonable time span in a given circumstance (Ben-Pazi, Kukke, & Sanger, 2007; Missiuna, Rivard, & Bartlett, 2003; Rao, Mayer, & Harrington, 2001). Thus, timing ability plays an important role in developing motor skills and achieving satisfactory functional performance (Buhusi & Meck, 2005; Johnston, Burns, Brauer, & Richardson, 2002; Rao et al., 2001). However, during variable and continuous motor tasks, timing ability relies on the interaction of motor and cognitive function (Diamond, 2000; Wassenberg et al., 2005), which is impaired in children with DCD, leading to reduced timing ability (Hamilton, 2002; Kaplan, Dewey, Crawford, & Wilson, 2001; Mandich, Buckolz, & Polatajko, 2003) and, subsequently coordination (Ben-Pazi et al., 2007; Mackenzie et al., 2008). However, since previous studies focused on evaluating discrete movement or measuring sequential movement in a specific limb or part of a limb, their findings cannot be generalized to ADL performance (Schaal, Sternad, Osu, & Kawato, 2004; Van Waelvelde et al., 2006; Zelaznik, Spencer, & Ivry, 2002). Therefore, the present study aimed to evaluate timing ability using an Interactive Metronome® (IM) for continuous monitoring of the hand, foot, and bilateral limbs during various movements (Bartscherer, Bartscherer, & Dole, 2005).

Cairney, Hay, Faught, Mandigo, and Flouris (2005) suggested that recruiting children with DCD from an educational environment might provide different results than those noted in children recruited form the clinical environment. Furthermore, previous studies typically focus on a single parameter related to physical health, motor performance, or timing ability. Therefore, the present study aimed to investigate parameters related to physical health, motor skills, and timing abilities in children with DCD recruited from an educational environment, and to compare such parameters with those noted among children with normal development.

As delayed motor development persists into adolescence or adulthood in over half of children diagnosed with DCD, appropriate early intervention should be provided (Cantell et al., 1994; Christiansen, 2000), which typically involves occupational therapy, physiotherapy, medical treatment, diet, and education and etc. are considered to develop intervention (Smits-Engelsman et al., 2013). Such interventions and can established within the school environment (Jongmans et al., 2003; Niemeijer et al., 2006) with the benefit of high accessibility and the possibility to consider the individual characteristic of each child via cooperation with the teachers. An individualized DCD specific learning environment can also be implemented as an after-school curriculum (Kimball, 2002). Therefore, the present study established a 12-week fundamental motor skill-based exercise program as an after-school program to assess the training-induced change in body composition and health-related physical fitness of children with DCD.

2. Purpose of the study

The present study aimed to compare body composition, health-related physical fitness, motor performance, and timing ability of 8-9-year-old children with and without DCD, recruited from an educational environment. We also sought to evaluate the changes in motor performance, motor ability, and timing ability among children with DCD who participated in a 12 week fundamental motor skill-based exercise program.

3. Method

3.1. Participants

The study enrolled 312 elementary school students (158 boys, 154 girls) aged 8-9 years old, who had not received any previous clinical treatment to address DCD symptoms. The children were classified into a DCD group (n = 55; 32 boys, 23 girls) and a non DCD group (n = 257; 126 boys, 131 girls). Only those children who agreed to undergo further measurements (body composition, health-related physical fitness, motor performance, and timing ability) were included in the final analysis (n = 40; 22 boys, 18 girls). Children with DCD were randomly assigned to either the intervention group (n = 10; 6 boys, 4 girls), or the control group (n = 10; 6 boys, 4 girls).

DCD diagnosis was established based on 4 criteria described in the *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition (American Psychiatric Association, 2013): total MABC-2 score < 67 (bottom 15%); Developmental Coordination Questionnaire 2007 (DCDQ'07) score < 55 (Wilson, Kaplan, Crawford, & Roberts, 2007), as a parental report describing the level of ADL coordination of the child; difficulty in learning or fulfilling school assignments, as described by the teachers; and no physical or neurological deficit, as reported by the parents and confirmed based on health records. An overview of the characteristics of the study participants is provided in Table 15.

Table 15. Characteristics of the 40 school children included in the final analysis

Characteristic	DCD group (n = 20)	Non-DCD group (n = 20)	*p*-value
Age (years)	8.54±0.34	8.73±0.35	-
Sex (boys, girls)	12, 8	10, 10	-
Manual dexterity score	21.93±3.76	31.33±5.13	.000**
Aiming and catching score	11.75±2.55	18.25±3.72	.000**
Balance score	28.45±3.76	31.78±3.13	.004**
Total MABC-2 score	62.13±4.72	81.35±6.17	.000**
Total MABC-2 (%)	10.95±4.47	53.85±16.86	.000**

**Statistically significant difference ($p < .01$). DCD, Developmental Coordination Disorder; MABC-2, Movement Assessment Battery for Children, second edition

3.2. Fundamental motor skill-based exercise program

The 12-week fundamental motor skill-based exercise program proposed in the present study (Table 2) was designed to develop locomotor skills, object control, and balance. Exercises involving locomotor skills included running, galloping, sliding, leaping, hopping, and jumping. Object control exercises involved basic movements typically used in soccer, basketball, and baseball. Balance exercises comprised of walking along a line, standing on one foot, and jumping on one foot.

The proposed program was developed while considering the effective intervention activity plan presented by Kimball (2002) and team at the CanChild research centre of McMaster University. This learner-oriented program provided assignments of suitable levels and assigned a maximum of three children per teacher to facilitate teacher-learner interaction. The program used various teaching materials and aids to create an environment suitable for children with DCD. A specially-trained physical education teacher helped the children focus on the assignment in a positive class environment.

The exercise program consisted of 60-min exercise sessions performed 3 days a week (Monday, Wednesday, and Friday) for 12 weeks. The sessions, which were incorporated in the after-school curriculum, involved 4 to 6 children training under the supervision of two skilled physical education teachers. The classes were conducted in the elementary school’s gymnasium. During the study period, the children in the intervention group participated in the after-school exercise program, while the children in the control group attended only the physical education classes included in the regular curriculum.

Table 16. Overview of the 12-week fundamental motor skill-based exercise program

Activity (duration)	Weeks 1–4	Weeks 5–8	Weeks 9–12
War-up (10 min)	1. Rhythm activities (basic movement) 2. Joint exercise and stretching	1. Rhythm activities (applied movement) 2. Joint exercise and stretching	1. Rhythm activities (complete movement) 2. Joint exercise and stretching
Exercises to locomotor skills (10 min)	1. Run: Running to the hoop while swinging the arms and legs 2. Gallop: Passing over the hoop with a galloping step 3. Hop: Jumping with one foot to passing over the hoop	1. Running, galloping, and hopping practice 2. Leaping: Running to the hoop and jumping over it with hurdle movement 3. Jumping: Consecutively jumping with two feet over an obstacle 4. Sliding: moving horizontally along a line	A) Movement skill practice using obstacles - 1. Running, galloping, hopping 2. Leaping, jumping, sliding B) Consecutive movement skill motion without obstacles 1. Running, galloping, hopping 2. Leaping, jumping, sliding
Exercises to improve object control skills (25 min)	Basketball-based exercise: 1. Rolling the basketball forward like a bowling ball 2. Bouncing the basketball in place and while walking 3. Chest pass(throwing and catching) 4. Overhand pass 5. Basketball game	Soccer-based exercise: 1. Kicking the ball with the top of the foot 2. Soccer dribbling in place and while walking 3. Soccer passing and trapping 4. Soccer game	Baseball-based exercise: 1. Overhand throw 2. Holding a bat and swinging 3. Throwing and catching the ball 4. Hitting a non-moving ball 5. Baseball game
Exercises to improve balance (10 min)	1. Walking along the line 2. Standing on one foot 3. Jumping on one foot (five hops) and keeping balance 4. Keeping balance while walking back and forth on a board	1. Walking along the line 2. Standing on one foot with eyes closed 3. Jumping on one foot (five small hops) and keeping balance 4. Keeping balance while walking back, forth, and sideways on a board	1. Walking on a balance beam 2. Standing on one foot with eyes closed 3. Consecutively jumping on one foot and keeping balance in various settings 4. Keeping balance while walking back, forth, and sideways on a board
Cooling down (5 min)	1. Joint exercise and stretching	1. Joint exercise and stretching	1. Joint exercise and stretching

3.3. Body composition

Body composition was measured in at a university facility. The children were instructed to sit quietly for 30 min. Subsequently, height, weight, and waist circumference were measured using an extensometer, body weight scale, and measuring tape, respectively. Body composition was measured in a carefully selected area of the lower limb, and analyzed using standard software (QDR for Windows, Hologic, USA).

3.4. Health-related physical fitness

Cardiorespiratory fitness, muscle strength, muscle endurance, flexibility, and body fat percentage were evaluated as descriptor of health-related physical fitness. Measurements were performed using the Physical Activity Promotion System (PAPS), which is typically applied to assess physical fitness among Korean elementary school, middle school, and high school students.

Cardiorespiratory fitness was measured during a 15-m shuttle run test performed in a group with 4 participants who were asked to run towards marked spots. If the participant failed to reach the marked spot, a warning was provided; the shuttle run measurement was terminated at the second failure. The test results were reported, and the participants were instructed to perform cool-down exercises.

Hand grip strength was measured by using a digital hand-grip dynamometer (TKK-5401, TAKEI, Japan). The participants were asked to stand and assume a neutral position of the arm and wrist. Measurements were performed twice in both the right and left hand, and the mean value was reported for each side. The strength of the lower limbs was measured using an isokinetic dynamometer (Humac Norm, CSMi, USA). Before starting the test, the participants were required to perform two to five light contractions as practice. After 10 s of rest, the participants performed five repetitions of knee extension at 60°/sec. Following a 2–5 min rest, the participants completed fifteen repetitions of knee extension at 180°/sec. The muscle strength in the lower body was measured using a digital jump measurement instrument (TKK-5406, TAKEI, Japan) during a Sargent jump test. The measurement was taken only if the participant landed on the measuring board after the vertical jump, with their feet at shoulder width. The Sargent jump test was performed twice, and the best record was reported.

Muscle endurance was measured during a curl-up test. The participants were asked to bend their knees at 90° and perform one curl-up every 3 seconds. The total number of curl-ups that each participant could perform uninterruptedly was reported.

Flexibility was measured by using digital sit-and-reach measuring instrument (DW-782, DAEWOO, Korea) during a sit-and-reach test. The participants were asked to assume a sitting position, straighten their leg and arms, lean forward, and maintain this position for at least three seconds. The sit-and-reach test was performed twice, and the best record was reported.

Finally, body fat percentage was measured using dual-energy X-ray absorptiometry.

3.5. Motor performance

3.5.1. Fundamental motor skills

Fundamental motor skills were assessed using TGMD-2 (Ulrich, 2000), which evaluated object control skills (hitting, throwing, catching, kicking, dribbling, and underhand rolling of a ball) and locomotor skills (running, galloping, sliding, leaping, hopping, and jumping). The participants first watched a demonstration of each of 12 motor skill tests, and subsequently performed one practice trial and two evaluation trials. The entire process was video-recorded, and the motor skill performance was analyzed by three TGMD-2-certfied researchers. The raw scores for object control skills and locomotor skills were classified and reported, and subsequently converted to standardized scores.

3.5.2. Motor coordination skills

Motor coordination skills were evaluated using MABC-2 (Henderson et al., 2007) in terms of manual dexterity, ball skills, and static and dynamic balance for age band-2, which is designed for children aged 7–10 years. The evaluation, which took approximately 30–40 minutes, was performed by a trained evaluator who followed to procedure described in the MABC-2. All evaluations were conducted as one-to-one interactions. The raw MABC-2 score was normalized for age and presented as a percentile. While the general recommendation is to establish the DCD diagnosis for MABC-2 scores of 5% or less (American Psychiatric Association, 2000), a cutoff or 15% is generally used in experimental and clinical research (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001).

3.6. Timing abilities

Timing ability was evaluated using the IM (IM Pro 9.0), which was designed to activate the central nervous system and is used to evaluate and train children and adults with nerve disorders associated with reduced cognitive and motor function. Timing abilities were measured for the hand, foot, and bilateral performance during 14 tasks (1, both hands; 2, right hand; 3, left hand; 4, both toes; 5, right toe; 6, left toe; 7, both heels; 8, right heel; 9, left heel; 10, right hand/left toe; 11, left hand/right toe; 12, balance on right foot; 13, balance on left foot; 14, repeat both hands). According to the IM manual, timing ability is classified and evaluated for performance each hand, each foot, both hands simultaneously, both feet simultaneously, hand and foot on the same side of the body, and hand and foot on opposite sides of the body (bilateral performance). However, as there is significant overlap on these definitions, the present study used a set of modified evaluation criteria (Rosenblum & Regev, 2013) that assess timing ability for hand performance (tasks 1, 2, 3, and 14), foot performance (tasks 4, 5, 6, 7, 8, 9, 12, and 13), and bilateral performance (tasks 10 and 11).

The participants performed each of the 14 tasks by using their hand to tap a sensor attached to their hand or thigh, or by using their foot to tap a sensor mat in response to a metronome sound. For the motor tasks included in the evaluation, the expected response time varied between 0 and 44.554 s, depending on the complexity of the task and the participant's ability to react effectively and efficiently to the metronome sound, with good timing ability corresponding to lower response time. The measurement was performed according to a standardized, 15-session protocol, as described in the IM manual (Hill, Dunn, Dunning, & Page, 2011).

3.7. Study design

This study was conducted with the approval of the Seoul National

University Institutional Review Board (approval No. 1603/001-028). Informed consent for participation was obtained from all children, parents, and relevant school officials.

The study proceeded in four main steps: (1) DCD screening, (2) pre-intervention evaluation, (3) exercise intervention, (4) post-intervention evaluation. In the first stage, the recruitment proposal and the DCDQ'07 were sent to each household in cooperation with the school in order to obtain consent for participation and an assessment of ADL performance. Subsequently, 312 children aged 8–9 years (158 boys and 154 girls) completed the MABC-2 (Henderson et al., 2007) in the classroom after school. Additionally, the students' health records were examined, and the parents and teachers were interviewed in order to identify children with DCD. In the second stage (pre-intervention), a set of children (DCD group, 20 children; non-DCD group, 20 children) who had agreed to undergo further measurements visited the university laboratory for evaluation of body composition and timing abilities. Health-related physical fitness and motor performance were evaluated in the school's gymnasium two weeks later. In the third stage (exercise intervention), the children in the exercise group (10 children with DCD) participated in the 12-week fundamental motor skill-based exercise program implemented as an after-school activity. During the same period, the children in the control group (10 children with DCD) did not participate in any exercise program except for the regular physical education curriculum available at their school. In the final stage (post-intervention), the evaluation procedure was repeated.

3.8. Statistical analysis

The independent *t*-test was used to assess the differences between the groups of children with normal development and those with DCD. The correlations between motor coordination skill and body composition, health-related physical fitness, motor performance, and timing abilities were analyzed using Pearson's correlation coefficient. The effects of the exercise program were assessed using the two-way repeated measures ANOVA. All data were presented as mean ± standard deviation. All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Differences were considered significant for p .05.

4. Results

4.1. Body composition and DCD

Children with normal development (non-DCD group) were compared against children with DCD (DCD group) in terms of height, weight, body mass index (BMI), waist circumference, bone mineral content (BMC), fat mass, lean mass, and lean BMC (Table 17). While children with DCD had significantly higher fat mass, while other variables did not differ significantly between the DCD and non-DCD groups.

Table 17. Parameters describing body composition in children with normal development or developmental coordination disorder (DCD)

	DCD group (n = 20)	Non-DCD group (n = 20)	*p*-value
Height (cm)	130.18±5.08	130.61±4.66	.782
Weight (kg)	30.15±6.07	28.15±4.51	.246
BMI (kg/m^2)	17.65±2.46	16.44±2.13	.108
WC (cm)	60.58±7.60	57.69±5.19	.169
BMC (g)	985.35±108.91	996.85±88.19	.716
Fat mass (g)	9222.16±2998.50	6626.00±1987.66	.003**
Lean mass (g)	18985.65±3236.45	19534.85±3137.32	.589
Lean BMC (g)	32471.01±57729.26	20531.74±3196.74	.362

**Statistically significant difference (p <.01). BMI, body mass index; WC, waist circumference; BMC, bone mineral content

4.2. Health-related physical fitness and DCD

In terms of health-related physical fitness (Table 18), children with DCD had significantly poorer results of 15-m shuttle run and curl-up test, indicating reduced cardiorespiratory fitness and muscle endurance, respectively. Other parameters of health-related physical fitness did not show significant differences between the DCD and non-DCD groups.

Table 18. Health-related physical fitness in children with normal development or developmental coordination disorder (DCD)

Component	Test item	DCD group (n = 20)	Non-DCD group (n = 20)	*p*-value
Cardiorespiratory fitness	15m shuttle run	23.40±11.66	37.15±10.18	.000*
Muscle strength and endurance	Hand grip strength	9.73±1.60	9.73±2.21	.994
	Leg strength	36.00±7.65	36.60±8.41	.815
	Sargent jump	26.65±5.97	29.05±4.45	.158
	Curl-up	5.95±5.17	16.45±12.94	.002**
Flexibility	Sit and reach	1.25±8.53	5.02±7.01	.135
Body composition	% Fat	31.02±4.82	24.10±4.15	.000**

*Statistically significant difference (p <.05). **Statistically significant difference (p <.01)

4.3. Fundamental motor skills and DCD

Regarding fundamental motor skills differences (Table 19), children with DCD showed significantly poorer scores for object control and locomotor skills compared to those noted in normal development

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Table 19. TGMD-2 scores in children with normal development or developmental coordination disorder (DCD)

Component		DCD group (n = 20)	Non-DCD group (n = 20)	*p*-value
Locomotor Skills	Run	5.20±1.10	5.85±0.745	.035*
	Gallop	4.00±1.29	5.75±1.33	.000**
	Hop	6.05±1.98	8.45±1.87	.000**
	Leap	5.15±1.18	5.50±0.68	.260
	Horizontal jump	4.50±2.14	5.05±1.31	.334
	Slide	4.80±2.72	6.95±1.27	.003**
	Locomotor score	29.70±6.54	37.55±3.05	.000**
Object control skills	Hitting a stationary ball	5.85±1.98	8.05±1.63	.000**
	Stationary dribble	1.30±1.55	5.65±1.81	.000**
	Catch	3.75±0.44	4.20±0.61	.012*
	Kick	4.30±1.75	7.25±1.33	.000**
	Overhand throw	2.70±2.17	5.90±1.99	.000**
	Underhand roll	2.05±1.23	3.45±0.82	.000**
	Object control score	19.95±6.25	34.50±5.20	.000**
Total score		49.65±10.81	72.05±6.02	.000**

*Statistically significant difference (p <.05). **Statistically significant difference (p <.01). TGMD-2, Test of Gross Motor Development, second edition

4.4. Timing abilities and DCD

In terms of timing abilities (Table 20), children with DCD showed significantly higher mean response times in several IM test, indicating reduced timing abilities for hand (tasks 1, 3, and 14), foot (tasks 4 and 7), and bilateral performance (tasks 10 and 11).

Table 20. Mean response time (RT, ms) in children with normal development or developmental coordination disorder (DCD)

Component	Test item	DCD group (n = 20)	Non-DCD group (n = 20)	*p*-value
Hands	1. Both hands	143.95±98.75	75.15±36.21	.006**
	2. Right hand	136.20±122.87	82.20±33.11	.065
	3. Left hand	134.70±78.99	69.55±44.09	.003**
	14. Repeat both hands	158.75±69.22	114.20±48.84	.024*
	Mean RT hands	143.40±74.68	85.27±33.84	.003**
Feet	4. Both toes	127.75±64.74	72.20±29.22	.001**
	5. Right toe	170.60±86.84	131.45±74.62	.135
	6. Left toe	174.30±77.65	149.20±84.85	.335

	7. Both heels	164.95±92.53	86.60±30.08	.001**
	8. Right heel	166.85±80.25	169.55±99.28	.925
	9. Left heel	206.90±111.27	175.50±87.57	.328
	12. Balance right foot	208.65±99.51	166.20±87.54	.160
	13. Balance left foot	202.45±94.14	194.20±103.91	.794
	Mean RT feet	177.80±63.87	143.11±35.25	.040*
Bilateral	10. Right hand/Left toe	196.80±91.32	127.20±40.82	.004**
	11. Left hand/Right toe	198.70±95.93	105.30±42.31	.000**
	Mean RT bilateral	197.75±85.21	116.25±35.14	.000**
Total	Mean RT	170.82±57.04	122.75±28.50	.002**

Timing ability was measured using an interactive metronome. *Statistically significant difference (p <.05). **Statistically significant difference (p <.01).

4.5. Association between motor coordination skill and physical parameters

We found that the total MABC-2 scores were significantly associated with fat mass, body fat percent, and the results of the 15-m shuttle run, Sargent jump, curl-up, fundamental motor skill, and timing ability test, as determined by the Pearson's correlation analysis. However, we did not observe any significant relationship between total MABC-2 scores and height, weight, BMI, waist circumference, BMC, or results of the hand-grip strength, leg strength, and sit-and-reach test in either the DCD group or the non-DCD group.

Table 21. Association of MABC-2 total score with body composition, physical fitness, fundamental motor skill, and timing ability

Variable		MABC-2 score	*p*-value
Body composition	Height (cm)	.094	.564
	Weight (kg)	-.124	.448
	BMI (kg/m2)	-.205	.205
	WC (cm)	-.170	.294
	BMC (g)	.171	.290
	Fat mass (g)	-.404	.010**
Physical fitness	15-m shuttle run	.468	.002**
	Hand grip strength	.159	.328
	Leg strength	.121	.456

	Sargent jump	.348	.028*
	Curl-up	.506	.001**
	Sit and reach	.195	.228
	% Fat	-.550	.000**
Fundamental motor skill	Locomotor score	.683	.000**
	Object control score	.784	.000**
	TGMD-2 total score	.819	.000**
Timing ability	Mean RT hands	-.504	.001**
	Mean RT feet	-.351	.026*
	Mean RT bilateral	-.536	.000**
	Mean RT	-.511	.001**

MABC-2, Movement Assessment Battery for Children, second edition; BMI, body mass index; WC, waist circumference; BMC, bone mineral content; TGMD-2, Test of Gross Motor Development, second edition; RT, response time, IM

*Significant correlation between MABC-2 total score and other factors (*p* <.05).

**Significant correlation between MABC-2 total score and other factors (*p* <.01).

4.6. Effect of exercise intervention on body composition in DCD

Among the children with DCD who participated in the exercise program, significant change between the beginning and end of the program was noted in terms of height, weight, BMI, WC, BMC, and fat mass (Table 22). The same parameters showed significant change among children with DCD who did not participate in the exercise program. No significant difference was noted when considering the simultaneous effect of exercise intervention and time.

Table 22. Effects of exercise intervention on body composition in children with developmental coordination disorder

	Group	Pre-intervention	Post-intervention	Group	Time	Time × Group
Height (cm)	Ex (n = 10) Con (n = 10)	129.79±5.89 130.58±4.42	132.79±6.06** 132.76±4.58**	*F* = .026 *P* = .874	*F* = 121.621 *P* = .000	*F* = 3.048 *P* = .098
Weight (kg)	Ex (n = 10) Con (n = 10)	30.65±6.95 29.65±5.39	31.98±7.60* 31.01±5.41**	*F* = .119 *P* = .735	*F* = 34.780 *P* = .000	*F* = 0.004 *P* = .948
BMI (kg/m^2)	Ex (n = 10) Con (n = 10)	17.98±2.59 17.31±2.42	17.91±2.82 17.52±2.35**	*F* = .221 *P* = .644	*F* = .444 *P* = .514	*F* = 1.789 *P* = .198
WC (cm)	Ex (n = 10) Con (n = 10)	61.31±9.14 59.86±6.12	61.93±9.97 60.50±6.39*	*F* = .161 *P* = .693	*F* = 1.923 *P* = .183	*F* = 0.000, *P* = .983
BMC (g)	Ex (n = 10) Con (n = 10)	1009.60±125.23 961.10±89.72	1061.20±130.72** 991.00±93.14**	*F* = 1.443 *P* = .245	*F* = 49.878 *P* = .000	*F* = 3.536 *P* = .076
Fat Mass (g)	Ex (n = 10) Con (n = 10)	8595.24±3205.06 9849.08±2799.15	10166.71±4181.79** 11207.16±2875.99**	*F* = .615 *P* = .443	*F* = 41.097 *P* = .000	*F* = 0.218 *P* = .646
Lean Mass (g)	Ex (n = 10) Con (n = 10)	19691.26±3723.78 18280.04±2672.11	19441.54±3459.54 17911.84±2780.58	*F* = 1.073 p=.314	*F* = 4.905 *P* = .040	*F* = 0.180 *P* = .676

The exercise intervention group (Ex) and control group (Con) each included 10 children.
BMI, body mass index; WC, waist circumference; BMC, bone mineral content; *Significantly different from pre-intervention in the same group ($p < .05$). **Significantly different from pre-intervention in the same group ($p < .01$). †Significant difference between the groups for the same time point ($p < .05$).

4.7. Effect of exercise intervention on health-related physical fitness in DCD

In the exercise intervention group, significant change was noted in terms of body fat percentage and the results of the 15-m shuttle run, hand-grip strength, Sargent jump, curl-up test, and sit-and-reach test (Table 23). On the other hand, in the control group, significant change was noted only in terms of body fat percentage. Significant difference was noted when considering the simultaneous effect of exercise intervention and time regarding the results of the 15-m shuttle run, hand-grip strength, Sargent jump, curl-up, and sit-and-reach tests.

Table 23. Effect of exercise intervention on health-related physical fitness in children with developmental coordination disorder

Component	Test item	Group	Pre-intervention	Post-intervention	Group	Time	Time × Group
Cardiorespiratory fitness	15m shuttle run	Ex (n = 10) Con (n = 10)	17.3±8.44 29.5±11.54	45.50±14.56** 29.20±7.19	*F* = .187 *P* = .671	*F* = 29.928 *P* = .000	*F* = 30.356 *P* = .000 †
Muscle strength and endurance	Hand grip strength	Ex (n = 10) Con (n = 10)	9.82±1.79 9.65±1.48	11.12±1.90* 9.78±1.20	*F* = 1.198 *P* = .288	*F* = 10.409 *P* = .005	*F* = 6.968 *P* = .017 †
	Leg strength	Ex (n = 10) Con (n = 10)	34.00±8.30 38.00±6.78	33.20±7.51 38.30±6.32	*F* = 2.038 *P* = .171	*F* = .151 *P* = .702	*F* = 0.730 *P* = .404
	Sargent jump	Ex (n = 10) Con (n = 10)	25.50±3.34 27.80±7.82	34.70±9.21* 29.20±7.19	*F* = .319 *P* = .579	*F* = 11.570 *P* = .003	*F* = 6.265 *P* = .022 †
	Curl-up	Ex (n = 10) Con (n = 10)	4.10±5.32 7.80±4.54	16.10±10.01** 8.0±4.08	*F* = .925 *P* = .349	*F* = 12.138 *P* = .003	*F* = 11.355 *P* = .003 †
Flexibility	Sit and reach	Ex (n = 10) Con (n = 10)	1.80±9.19 0.70±8.28	4.90±6.68** 1.0±7.33	*F* = .506 *P* = .486	*F* = 12.028 *P* = .003	*F* = 8.157 *P* = .010 †
Body composition	% Fat	Ex (n = 10) Con (n = 10)	28.61±4.51 33.44±3.96	31.61±6.03** 35.83±3.31**	*F* = 4.745 *P* = .043	*F* = 32.552 *P* = .000	*F* = 1.039 *P* = .321

The exercise intervention group (Ex) and control group (Con) each included 10 children.
*Significantly different from pre-intervention in the same group ($p < .05$). **Significantly different from pre-intervention in the same group ($p < .01$). †Significant difference between the groups for the same time point ($p < .05$).

4.8. Effect of exercise intervention on motor coordination and fundamental motor skills in DCD

In the exercise intervention group, significant change was noted both regarding motor coordination (aiming and catching, balance, and total MABC-2 scores in both absolute and percental values) and fundamental motor skills (locomotor skill, object control skill, and total TGMD-2 scores) (Table 24). On the other hand, in control group, significant change was noted only in terms of fundamental motors skills (object control skill and total TGMD-2 scores). Significant difference was noted when considering the simultaneous effect of exercise intervention and time regarding all aspects of motor coordination (MABC-2 scores) and fundamental motor skills (TGMD-2 scores).

Table 24. Effect of exercise intervention on motor coordination and fundamental motor skills in children with developmental coordination disorder

Scale		Group	Pre-intervention	Post-intervention	Group	Time	Time × Group
MABC-2	Manual dexterity score	Ex (n = 10) Con (n = 10)	22.10±5.17 21.75±1.73	25.05±2.70 22.65±1.65	*F* = 1.815 *P* = .195	*F* = 3.894 *P* = .064	*F* = 1.104 *P* = .307
	Aiming and catching score	Ex (n = 10) Con (n = 10)	12.30±2.62 11.20±2.48	16.70±3.26** 11.70±2.21	*F* = 8.033 *P* = .011	*F* = 21.849 *P* = .000	*F* = 13.841 *P* = .002 †
	Balance score	Ex (n = 10) Con (n = 10)	27.70±3.30 29.20±4.22	32.10±3.87** 28.60±4.44	*F* = .397 *P* = .537	*F* = 5.500 *P* = .031	*F* = 9.522 *P* = .006 †

	Total MABC-2 score	Ex (n = 10) Con (n = 10)	62.10±4.25 62.15±5.39	73.85±6.19** 62.95±6.20	*F* = 6.013 *P* = .025	*F* = 30.082 *P* = .000	*F* = 22.900 *P* = .000 †
	Total MABC-2 (%)	Ex (n = 10) Con (n = 10)	10.40±4.14 11.50±4.95	34.00±18.67** 13.10±6.13	*F* = 7.298 *P* = .015	*F* = 19.922 *P* = .000	*F* = 15.184 *P* = .001 †
TGMD-2	Locomotor score	Ex (n = 10) Con (n = 10)	30.90±6.33 28.50±6.86	42.10±2.47** 28.00±6.14	*F* = 12.549 *P* = .002	*F* = 25.249 *P* = .000	*F* = 30.189 *P* = .000 †
	Object control score	Ex (n = 10) Con (n = 10)	21.30±7.22 18.60±5.12	36.70±4.42** 21.50±5.33*	*F* = 13.805 *P* = .002	*F* = 159.219 *P* = .000	*F* = 74.287 *P* = .000 †
	TGMD-2 total score	Ex (n = 10) Con (n = 10)	52.20±11.59 47.10±9.90	78.80±5.57** 49.50±9.37*	*F* = 18.815 *P* = .000	*F* = 113.854 *P* = .000	*F* = 79.283 *P* = .000 †

The exercise intervention group (Ex) and control group (Con) each included 10 children.
MABC-2, Movement Assessment Battery for Children, second edition; TGMD-2, Test of Gross Motor Development, second edition; *Significantly different from pre-intervention in the same group ($p < .05$). **Significantly different from pre-intervention in the same group ($p < .01$). †Significant difference between the groups for the same time point ($p < .05$).

4.9. Effect of exercise intervention on timing ability in DCD

In the exercise intervention group, significant change was noted for the response time during tasks assessing hand, foot, and bilateral performance (including the mean response time for all IM-based tasks) (Table 25). A similar trend of change was noted in the control group. Significant difference was when considering the simultaneous effect of exercise intervention and time regarding response time during exercises assessing hand, foot, and bilateral performance (including the mean response time for all IM-based tasks).

Table 25. Effect of exercise intervention on timing ability in children with developmental coordination disorder

Component	Group	Pre-intervention	Post-intervention	Group	Time	Time × Group
Mean RT hands	Ex (n = 10) Con (n = 10)	138.12±59.90 148.67±90.14	104.15±52.75* 139.67±81.31*	*F* = .518 *P* = .481	*F* = 14.971 *P* = .001	*F* = 5.056 *P* = .037 †
Mean RT feet	Ex (n = 10) Con (n = 10)	201.33±79.31 154.27±33.06	147.72±63.23* 150.18±34.99**	*F* = .952 *P* = .342	*F* = 7.711 *P* = 5.681	*F* = 5.681 *P* = .028 †
Mean RT bilateral	Ex (n = 10) Con (n = 10)	215.35±88.09 180.15±82.93	157.30±59.60** 173.50±81.54**	*F* = .076 *P* = .786	*F* = 19.945 *P* = .000	*F* = 12.588 *P* = .002 †
Mean RT	Ex (n = 10) Con (n = 10)	185.27±68.79 156.37±40.91	136.64±56.34** 150.51±40.40**	*F* = .110 *P* = .744	*F* = 16.382 *P* = .001	*F* = 10.096 *P* = .005 †

The exercise intervention group (Ex) and control group (Con) each included 10 children.
RT, response time; *Significantly different from pre-intervention in the same group ($p < .05$). **Significantly different from pre-intervention in the same group ($p < .01$). †Significant difference between the groups for the same time point ($p < .05$).

4.10. Determinants of motor coordination skill progression in DCD

The Pearson's correlation analysis indicated that the rate of change in total MABC-2 score was associated with the rate of change in the results of the hand-grip strength and curl-up tests, fundamental motor skills (locomotor skill, object control skill, total TGMD-2 scores), and mean response time in IM-based tests evaluation bilateral performance (Table 26). However, we did not observe any significant relationship between the rate of change in total MABC-2 score and the rate of change in other variables.

Table 26. The association between the change in MABC-2 score and the change in body composition, physical fitness, fundamental motor skill, and timing ability in children with developmental coordination disorder

Variable		ΔMABC-2 score	*p*-value
Body composition	ΔHeight (cm)	.269	.251
	ΔWeight (kg)	-.042	.860
	ΔBMI (kg/m^2)	-.177	.454
	ΔWC (cm)	.060	.801
	ΔBMC (g)	.266	.114
	ΔFat mass (g)	.114	.631
Physical fitness	Δ15m shuttle run	.265	.259

	ΔHand grip strength	.513	.021*
	ΔLeg strength	-.182	.442
	ΔSargent jump	.265	.259
	ΔCurl-up	.614	.004**
	ΔSit and reach	.276	.239
	Δ% Fat	.317	.173
Fundamental motor skill	ΔLocomotor score	.537	.015*
	ΔObject control score	.753	.000**
	ΔTGMD-2 total score	.687	.001**
Timing ability	ΔMean RT hands	-.114	.632
	ΔMean RT feet	.020	.932
	ΔMean RT bilateral	-.584	.007**
	ΔTotal RT	-.102	.670

MABC-2, Movement Assessment Battery for Children, second edition; BMI, body mass index; WC, waist circumference; BMC, bone mineral content; TGMD-2, Test of Gross Motor Development, second edition; RT, response time

*Significant correlation between ΔMABC-2 score and rate of change for other factors (*p* <.05).

** Significant correlation between ΔMABC-2 score and rate of change for other factors (*p* <.01).

5. Discussion

The present study involved Korean school children aged 8-9 years old and was conducted to estimate the effect of DCD on health-related physical fitness, motor performance, and timing ability, as well as to determine whether an exercise program tailored for motor skill improvement can help alleviate DCD symptoms. We found that DCD was indeed associated with significantly poorer indicators of health-related physical fitness, motor performance, and timing ability, which improved significantly following participation in the 12-week fundamental skill-based exercise program.

In the first stage of our study, we examined 312 students (158 boys, 154 girls) enrolled in the second or third grade of a Korean elementary school. We determined that 55 children (32 boys, 23 girls) showed symptoms potentially indicative of DCD with (MABC-2 total score ≤15%) and 8 children (5 boys, 3 girls) showed symptoms characteristic to DCD (MABC-2 total score ≤5%). The prevalence of DCD in our sample was 2.56%, which is smaller than the 5–6% prevalence reported in the general population (American Psychiatric Association, 2000). MABC-2, which is recognized as the most appropriate evaluation tool for identifying DCD, has rarely been used to assess the prevalence of DCD in Korea. While it is difficult to generalize our findings to the Korean population, we note that Kim (2016) also reported that, in Korea, symptoms potentially indicative of DCD are noted in five of every 100 children, while symptoms characteristic of DCD are noted in one of every 100 children. Taken together, these results suggest that South Korea has a lower prevalence of DCD compared to those reported in Sweden, Greece, or Singapore (Kadesjö & Gillberg, 1998; Tsiotra, Nevill, Lane, & Koutedakis, 2009; Wright & Sugden, 1995).

Children's physical fitness has important implications in relation to development (Cairney et al., 2007). Health-related physical fitness is been considered an important factor for the healthy development of children with DCD (Li, Wu, Cairney, & Hsieh, 2011), as both longitudinal and cross-sectional studies have indicated that such children have poorer health-related physical fitness compared to that of children with normal development (Schott, Alof, Hultsch, & Meermann, 2007; Tsai, Chen, Li, & Wu, 2006; Tsiotra et al., 2009). Indeed, we also found a significant difference in terms of body fat percentage and the results of the 15-m shuttle run and curl-up tests. However, we found no difference regarding BMI and muscle strength. We believe that this discrepancy is at least partially related to the fact that the children who participated in the present study were relatively younger than those included in previous studies. The MABC-2 score threshold considered to indicate DCD may also play a role in the perceived differences.

An appropriate balance between motor ability and motor skill is required for children to skillfully participate in sports activities (Logan et al., 2014). In the case of children with DCD, learning motor skills can be difficult compared because their motor ability is lower than that of children with normal development. Indeed, we found that children with DCD showed lower locomotor skill, object control skill, and total score for TGMD-2. The difference between the DCD and non-DCD groups was less pronounced in terms of locomotor skills (29.70 versus 37.55) than in terms of object-control skills (19.95 versus 34.50). This is because, compared to motor tasks, manipulation tasks are more complicated and require coordination ability.

Moreover, following the IM-based test, we found that children with DCD had poorer reaction time in hand, foot, and bilateral performance. The most pronounced difference was noted for task 11 (bilateral performance), which is consistent with the findings of Rosenblum and Regev (2013). These results demonstrate that children with DCD face difficulty in reacting to auditory signals and simultaneously carrying out designated movements, and this difficulty is more pronounced for tasks involving symmetrical movement because higher coordination ability is required for such tasks. Our findings are in agreement to previous observations (Volman, Laroy, & Jongmans, 2006; Whitall et al., 2006) that children with DCD have slower motor reaction to auditory stimulus. Whitall et al. (2006) attributed the cause of this phenomenon to a deficit in auditory processing associated with DCD.

We aimed to not only estimate the difficulties faced by Korean school children with DCD, but also to develop a motor intervention program that facilitates the acquisition of basic motor skills within the school environment. Compared to children with normal development, children with DCD generally have less physical, psychological, and social confidence (Cairney, Hay, Faught, & Hawes, 2005), and find participating in physical activities challenging because of the difficulty in performing movements that require coordination. This situation eventually leads them to avoid physical activities altogether (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996), which increases the risk of hypokinetic diseases and behavioral problems (Piek, Baynam, & Barrett, 2006; Skinner & Piek, 2001). As a result, the deficit in age-specific motor performance might even increase with time.

It remains unclear whether the motor deficit noted in children with DCD is innate or represents a result of the lack of appropriate educational activity. However, evidence from both the present and previous studies indicates that children with DCD can improve motor ability via appropriate exercise intervention. Therefore, improvement in ADL functional performance is indeed possible. For young children in particular, development of fundamental motor skills can promote participation in physical activities involving play and sports. We developed our 12-week intervention program with these principles in mind, and showed that second and third graders with DCD can gain basic motor skills via a fundamental skill-based exercise program implemented as an after-school curriculum.

As others have observed (Schott et al., 2007; Tsai et al., 2006; Tsiotra et al., 2009), we also found that children with DCD have poorer indicators of health-related physical fitness. However, these indicators improved after participation in the 12-week fundamental skill-based exercise program, most likely because of the increased participation in physical activities, which is expected to have positively influenced cardiorespiratory fitness, muscle strength, muscular endurance, and flexibility. However, the percentage of body fat increased significantly in children from both the exercise intervention group and the control group, which is likely related to the fact that diet was not restricted during the study period, and the participants were going through a major developmental growth phase.

We found that, compared to children with normal development, children with DCD showed poorer performance in tasks requiring locomotor and object-control skills, which differs from the results of Willoughby and Polatajko (1995) but is consistent with those of Yu et al. (2016). Moreover, the locomotor and object-control skills improved as they participated in the fundamental skill-based exercise program. Notably, at the end of the exercise program, the performance of children with DCD in terms of locomotor and object-control skills actually exceeded the values noted for children with normal development (Table 6). This finding suggests that the fundamental skill-based exercise program was effective in improving the motor skills of children with DCD, which is in agreement with the findings of Yu et al. (2016), who showed that fundamental motor skill training supported by error-reduced learning was effective in children with DCD.

We found that the MABC-2 score, which evaluates the motor coordination ability of children with DCD, improved after participation in the 12-week fundamental skill-based exercise program, in agreement with the results of precedent studies reporting an improvement in coordination ability after motor intervention (Farhat et al., 2015; Ferguson, Jelsma, Jelsma, & Smits-Engelsman, 2013; Hillier, McIntyre, & Plummer, 2010). Most notably, in five of the ten children with DCD (MABC-2 score ≤ 15%), the symptoms reduced to the point that these children would no longer be considered at risk (MABC-2 score >15%). While it is difficult to conclude that DCD symptoms can fully resolve within 12 weeks of motor intervention, as the DCD group included only children with symptoms potentially indicating DCD, this possibility cannot be ignored, because the MABC-2 score of the lower 5% of children with DCD that participated in this study has been enhanced from 52.5 score (MABC-2 score $\leq$ 5%) to 72 score (MABC-2 score >15%).

While participation in the 12-week intervention program was associated with increased MABC-2 scores for aiming, catching, and balance, no meaningful change was noted for manual dexterity. This is likely related to the fact that exercises specifically focused on improving fine motor skills were not included in our fundamental skill-based exercise program. Such limitations should be considered when applying the proposed exercise program in children with DCD if the immediate goal is to improve fine motor skills.

The reasons behind the success of our fundamental skill-based exercise program can be found in the provision of education environments for children with DCD and the task-oriented class method (Kimball, 2002). Specifically, the program included physical activities tailored for children with DCD, was integrated with their regular education environment, limited the number of children in each session so that each student may have sufficient interaction with the teacher. Furthermore, although the nature and difficulty of the tasks were decided beforehand, the supervising teacher was allowed to modify these parameters based on the individual response of each child. By observing their own success in various tasks, children with DCD earned confidence in their motor skills, which motivated them to continue training and effectively helped improve motor performance (Hillier et al., 2010; Yu et al., 2016).

III. Conclusion

This graduate thesis was carried out to develop a screening tool that would identify children with DCD and to find out the motor intervention effect and characteristics of children with DCD. The following is a summary of the three research results conducted to achieve the purpose of the research.

1. Study I

This research translated DCDQ'07 for the development of the Korean version of DCDQ (DCDQ-K). It verified the suitability of the translation and back translation. Also, it conducted a verification of content validity and reliability to confirm the possibility of the Korean version of DCDQ's domestic application as a primary evaluation tool for identifying DCD. The average CVI of the Korean version DCDQ that 6 education experts evaluated showed a high level of .97. As a result of the questionnaire given to 188 parents who have elementary or middle school children, the internal consistency of all questions showed a high level of .916. Moreover, the test-retest reliability of DCDQ-K showed a high correlation of .982. The Korean version of DCDQ was completed through a systematized research method, and therefore the Korean version of DCDQ, which is verified by the content validity and reliability test, can be used as a primary evaluation tool for the identification of domestic children with DCD.

2. Study II

This research was conducted to verify the difference of emotional, behavioral problems between children with DCD and TD children and to clarify the correlation between children's motor coordination abilities and emotional, behavioral problems. As a result of conducting the KBASC-2, SRP-C with 30 children with DCD and 30 TD children, children with DCD showed significantly higher risk of internalizing problems, inattention/hyperactivity, the emotional symptoms index, and the personal adjustment scale compared to TD children. As a result of analyzing the correlation between the results of the MABC-2 score, which evaluates motor coordination abilities, and the KBASC-2, SRP-C, which evaluates emotional, behavioral problems, internalizing problems, inattention/hyperactivity, and emotional symptoms index showed negative correlations and the personal adjustment scale showed a positive correlation. Because 8-9 year old Korean children with DCD, attending Korean elementary schools, have a high possibility of developing emotional, behavioral problems, solutions that can decrease related risk factors should be created.

3. Study III

This research was conducted to clarify the effect of motor intervention on the body composition, health-related physical fitness, motor performance, and timing ability of children with DCD. Participation in the 12-week fundamental motor skill-based exercise program was associated with a positive change in all parameters evaluated, suggesting that a dedicated after-school program may be effective in improving the daily lives of children with DCD even without further intervention such as occupational therapy. At the national level, our findings are encouraging and warrant the development of education policies and solutions to ensure healthy school lives for children with DCD.

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국문초록

발달성 협응장애 아동의 특성 및 운동 중재 효과에 관한 연구

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발달성 협응장애 아동은 운동능력이 부족하기 때문에 신체활동에 어려움을 느끼며, 신체활동에 참여하면서 부정적인 경험이 축적되어 신체활동을 기피하거나 제한적으로 참여하게 된다. 발달성 협응 장애 아동의 비활동성은 심혈관 질환의 발병 가능성을 높이는 증상과 같은 신체적 건강 문제뿐만 아니라 정서적, 행동적 문제를 야기할 수 있다. 발달성 협응장애 아동은 일상생활에서 기본적인 활동에도 어려움을 가지고 있으며 이는 교우관계, 학업성취도 등에 영향을 미쳐 학교생활 전반에 있어 어려움을 겪는다. 그러나 국내에서는 발달성 협응장애에 대한 연구가 매우 제한적으로 실시되어 국내 아동의 발달성 협응장애 아동의 특성 및 실태에 대한 근거가 부족한 실정이다. 따라서, 본고에서는 발달성 협응장애를 선별할 수 있는 평

가 도구를 번안하여 국내 적용 가능성을 알아보고, 발달성 협응장애 아동의 특성 및 운동 중재 효과를 확인하여 현장에서 적용할 수 있는 프로그램을 제시하고자 하였다. 본고에서는 이를 세 가지 주제로 구체화하여 다음과 같이 연구를 진행하였다. 1) Developmental Coordination Disorder Questionnaire 2007의 번안 및 신뢰도 연구, 2) 발달성 협응장애 아동과 일반 아동의 정서, 행동 문제의 차이 및 상관성 연구 3) Fundamental motor skill-based exercise program 이 발달성 협응장애 아동의 운동 수행 능력과 타이밍 능력에 미치는 영향 연구

본 연구의 결과는 다음과 같다. 첫째, 한글판 DCDQ (DCDQ-K)는 체계화된 연구 방법을 통해 완성되었으며, 내용 타당도 및 신뢰도 검사를 통해 검증된 한글판 DCDQ(DCDQ-K)는 국내 발달성 협응장애 아동의 선별을 위한 1차적 평가 도구로 활용될 수 있는 것으로 나타났다. 둘째, 발달성 협응장애 아동은 일반 아동에 비하여 내면화 문제행동, 주의력 결핍/과잉 행동, 정서증상 지표, 개인적 적응과 관련된 척도에서 위험이 높은 것으로 나타났다. 셋째, 발달성 협응장애 아동은 일반 아동에 비하여 건강관련 체력, 운동 수행 능력, 타이밍 능력이 부족한 것으로 나타났다. 이러한 발달성 협응장애 아동의 어려움은 12주간 운동 중재 활동(Fundamental motor skill-based exercise program)을 통하여 향상되는 것으로 나타났다.

본 연구 결과와 기존의 선행 연구들의 보고를 종합해 보았을 때, 결론 및 제언은 다음과 같다. 국내 발달성 협응장애 아동은 운동 수행 능력뿐만 아니라 정서, 행동의 문제가 나타나고 있었다. 이를

해결하기 위한 중재 활동으로 12주간 방과 후 운동 프로그램 (Fundamental motor skill-based exercise program) 참여는 효과적인 중재 방법 임을 확인하였다. 그러나 발달성 협응장애 아동의 조기 선별을 위한 국내에서 적용 가능한 평가 도구는 부족한 실정이고 이를 해결할 수 있는 방안이 앞으로 마련되어야 할 것이다.

주요어: 발달성 협응장애, DCDQ, 정서 행동 문제, 운동 중재, 타이밍 능력
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