[Paper]

Poor Motor Coordination in Japanese Children with Developmental Dyslexia

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Abstract

To clarify the relationship between poor motor coordination and learning and cognitive impairments in Japanese children with developmental dyslexia (DD), we investigated these characteristics with a battery of learning and cognitive tasks. The subjects were 46 children with DD (32 males and 14 females; age: 6.9–12.7 years). Ten children had autism spectrum disorder (ASD), and 28 had attention-deficit/hyperactivity disorder (ADHD). We defined children as having poor motor coordination based on the results of the Japanese version of the Developmental Coordination Disorder Questionnaire (DCDQ-J). Eleven children were judged to have poor motor coordination, and all of these were diagnosed with developmental coordination disorder (DCD): therefore the rate of DCD in children with DD was 24%. There was a significant difference between the DCD and Non-DCD groups in the Eye-hand Coordination General Index of the Wide-range Assessment of Vision-related Essential Skills (WAVES). Through logistic regression analysis, comorbidity of ASD and PSI of the WISC-IV was found to have a significant relation with DCD, but the results of learning tasks associated with reading and writing were not significantly related to DCD. This study does not support the theory that motor coordination is directly related to reading ability in children with DD. Although there was no significant relation with the products of the writing tasks, the DCD group is thought to have poorer handwriting speed and accuracy and therefore requires more reasonable accommodation tailored to their characteristics. We propose that poor motor coordination in children with DD is a symptom associated with comorbid ASD and/or DCD.

Keywords: developmental dyslexia, developmental coordination disorder, autism spectrum disorder, Japanese version of the Developmental Coordination Disorder Questionnaire (DCDQ-J), Wide-range Assessment of Vision-related Essential Skills (WAVES)

1. Introduction

Developmental dyslexia (DD) is defined by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as a specific learning disability caused by neurological impairment (American Psychiatric Association, 2013). The International Dyslexia Association defines DD as characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities, and these difficulties typically result from a deficit in the phonological component of language (International Dyslexia Association, 2025). Various factors besides phonological impairment have been proposed as contributing factors to the pathophysiology of DD. For example, the involvement of an attentional mechanism (Shaywitz and Shaywitz, 2008), visual magnocellular deficit (Stein et al., 2000), deficits in detecting rapidly presented or rapidly changing sensory stimuli (Tallal, 2000), and cerebellar dysfunction (Nicolson et al., 2001) have been proposed as the pathophysiological basis of DD. DD is often comorbid with other neurodevelopmental disorders such as autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD), which can cause variations in the cognitive characteristics of DD.

Developmental coordination disorder (DCD) is characterized by severely impaired motor ability, including fine and gross motor skills, postural control, and movement coordination. The diagnosis of DCD is made by a clinical integration of the patient's history (developmental and medical), physical examination, school or workplace reports, and individual assessments using psychometrically sound and culturally appropriate standardized tests (American Psychiatric Association, 2013). The prevalence of DCD in children aged 5 to 11 years is thought to be 5 to 6% (American Psychiatric Association, 2013), which is almost as high as that of ADHD. Children with DCD can have handwriting deficits, and cause impaired academic achievement (Biotteau et al., 2019). DCD leads to impaired functional performance in activities of daily living, and can cause poor self-esteem and sense of self-worth, emotional and/or behavior problems.

Previous studies have suggested that cerebellar dysfunction is one of the important neural substrates of DCD. Similarly, cerebellar dysfunction has been reported as one of the neural bases of DD. As reading requires the integration of visual, auditory, motor, and language systems, it is mediated by network-interconnected brain regions. It has been reported that the left hemispheric language network, including the occipitotemporal region, is involved in the orthographic processing of word forms; that the temporoparietal region plays a role in visuo-auditory association and phonological processing; and that the inferior frontal gyrus is important for articulation (Pugh et al., 2001). These regions are thought to be closely connected with the cerebellum (Kujala et al., 2007). Additionally, the cerebellum is probably involved in various aspects of reading, including eye movements, language processing and spatial processing, working memory, and skill acquisition and automaticity (Peterson & Pennington, 2012; Stoodley & Stein, 2013). In typically developing readers, neuroimaging studies have revealed that the cerebellum is an important part of the reading network (Fulbright et al., 1999; Alvarez & Fiez, 2018).

As poor motor coordination is observed in many children and adults with DD, Nicolson and Fawcett proposed the cerebellar deficit hypothesis of DD (Nicolson & Fawcett, 1990; Nicolson et al., 1999). They also argued that the deficit in automaticity and procedural learning system via cortico-cerebellar language circuits could account for the specific impairments in DD (Nicolson & Fawcett, 2007; Nicolson & Fawcett, 2011). Accordingly, it has been suggested that motor coordination and reading ability are closely interconnected within the neural network (Nicolson et al., 2001; O'Hare & Khalid, 2002).

While it is recognized that the cerebellum is involved in the reading process in typically developing readers, the theory that motor coordination is directly related to reading ability in children with DD has been questioned. In a relatively recent study on the relationship between motor coordination and reading ability, as well as structural differences of the cerebellum using MRI between adults with and without DD, no significant relationships were found between motor coordination and reading ability, and structural differences of the cerebellum between the two groups were not observed (van Oers et al., 2018). In summary, various hypotheses have been proposed regarding the close relationship between motor coordination and reading ability, but no clear conclusion has been established.

For Japanese children with DD, no reports have been made on the relationship between motor coordination and learning abilities such as reading and writing, and both the prevalence of DCD in Japanese children and its comorbidity rate in children with DD are still unclear. The aim of the present study was to clarify how poor motor coordination affects Japanese children with DD and the relationship between motor coordination and learning and cognitive abilities associated with reading and writing.

In this study, "motor coordination" is refers to motor ability, such as fine and gross motor skills, postural control, and coordinated movement. The term "poor motor coordination" encompasses these impairments and is also commonly used in previous studies.

2. Subjects and Methods

2.1 Subjects

The subjects of this study were 46 school-aged children (32 males and 14 females; age:6.9-12.7 years), who were diagnosed with DD at the Department of Child Neurology, Okayama University Hospital. The diagnosis of DD was undertaken by one of the authors [M.O] using the DSM-5 criteria and the diagnostic procedure of DD in accordance with the 2010 Japanese Practical Guidelines for the Diagnosis and Treatment of Specific Developmental Disorders (Inagaki et al., 2010). This study only included children who had an intelligence quotient (IQ) score of > 80 in the Full-scale IQ (FSIQ) and/or Verbal Comprehension Index (VCI) and/or Perceptual Reasoning Index (PRI) in the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV). Some subjects were also diagnosed with other neurodevelopmental disorders such as ASD and ADHD according to the DSM-5 criteria.

This study was approved by the Ethics Committee of Okayama University.

2.2 Methods

We investigated the subject characteristics and the rate of DCD in children with DD.

2.2.1 Assessment of DCD

(1) Japanese version of the Developmental Coordination Disorder Questionnaire (DCDQ-J)

The DCDQ is a parent rating scale for screening pediatric DCD. The DCDQ 2007 is a 15-item parent questionnaire designed to screen for DCD in children aged 5 to 15 years (Wilson et al., 2009). The descriptions of each item are scored with a 5-point scale, with higher scores indicating better coordination based on a comparison between the child and other children.

The DCDQ-J was developed and adapted to the Japanese culture and reports gender-segregated, grade-specific normative scores of the DCDQ-J, total score, and three subscales, namely, Control during movement (six subitems), Fine motor (four subitems), and General coordination (five subitems). The raw scores of the DCDQ-J total score were transformed into z-scores using the means and standard deviations (SDs) of the data in the previous study (Nakai et al., 2011).

We defined children with z-scores of DCDQ-J total scores ≤ -1.5 as having poor motor coordination. Children with poor motor coordination were subsequently diagnosed with DCD by one of the authors [M.O] based on the DSM-5 criteria. The diagnostic assessment included evaluation of clumsiness and soft neurological signs such as diadochokinesis, repetitive finger tapping, and tandem gait, and standing on one leg with eyes closed. We classified subjects into those with DD and DCD (DCD group) and those with DD without DCD (Non-DCD group).

(2) Wide-range Assessment of Vision-related Essential Skills (WAVES)

The WAVES is designed to assess visual perception abilities and eye-hand coordination skills of Japanese elementary school children, which consists of nine subtests such as line tracing, form tracing, number comparisons I and II, discrimination speed, figure-ground speed, visual closure speed, discrimination accuracy, visual memory, and copying (Okumura et al., 2020). We examined four index scores derived from these subtests, which are Eye-hand Coordination General Index (ECGI), Eye-hand Coordination Accuracy Index (ECAI), Visual Perception Index (VPI), and Visual Perception and Eye-hand Coordination Index (VPECI). All index scores were standardized as age-specific and gender-segregated. A higher index score on this test indicates better visual perception and eye-hand coordination.

2.2.2 learning and cognitive tasks

(1) Japanese version of the Kaufman Assessment Battery for Children, Second Edition (KABC-II)

The KABC-II provides separate measures of children's cognitive abilities and basic scholastic aptitude (Kaufman & Kaufman, 2004). Since the Japanese version of the KABC-II (Kumagami & Kumagami, 2014) was used to evaluate learning ability in this study, we examined only four of the eight subscales measuring academic achievement (i.e., Vocabulary, Reading, Writing, and Mathematics). The scores of these subscales were standardized in an age-specific and gender-segregated manner. Higher scores on this assessment battery are associated with better basic scholastic aptitude.

(2) Reading task

The Reading task consists of four kana reading tests, namely, the Monomoraic syllable task, Word task, Non-word task, and Short sentence task. The Reading task was already established for the diagnosis of reading disorders in Japan, in accordance with the method previously reported by the 2010 Japanese Practical Guidelines for the Diagnosis and Treatment of Specific Developmental Disorders (Inagaki et al., 2010; Ogino et al., 2011). Measuring reading time allows an evaluation of reading fluency, which reflects reading ability well. Based on gender-segregated, grade-specific normative times required for comparable reading tasks (Inagaki et al., 2010), the reading times of the four tasks were transformed into z-scores using the means and SDs of the reading times in each task.

Monomoraic syllable task: 50 monomoraic syllables (5 rows, 10 columns), including 20 contracted sounds (CjV), were used. A mora usually consists of a consonant and a vowel, and the term 'monomoraic syllables' denotes syllables containing one mora.

Word and non-word tasks: 30 words, each composed of three or four morae, were printed in hiragana on a card (10 rows, three columns). The subjects were also instructed to read 30 nonwords, each composed of three or four morae, printed on another card.

Short sentence task: Subjects were shown three cards in succession, on each of which a short sentence composed of 23 to 27 morae was printed. Each card displayed one sentence written in a mixture of hiragana and kanji; some words in the sentence were written in hiragana while others were written in kanji. Above the kanji letters, however, there were hiragana indicating the correct pronunciation of the kanji letters.

(3) Das-Naglieri Cognitive Assessment System (DN-CAS), Japanese version

The DN-CAS is an assessment battery of the cognitive processing of individuals between the ages of 5 and 17 years that has been standardized in different languages, including Japanese (Naglieri, 1999; Maekawa et al., 2007). The DN-CAS consists of four independent cognitive factors: Planning, Attention, Simultaneous Processing, and Successive Processing, known collectively as the PASS model (Naglieri, 1999). All PASS scale scores were standardized as age-specific and gender-segregated. Higher scores on this assessment battery are associated with better cognitive processing skills.

The WISC-IV, KABC-II, Reading task, and DN-CAS are approved for health care services in the Japanese health insurance system and are commonly used for children with neurodevelopmental disorders, including DD in Japan. The WAVES has been used in Japan, particularly for children with poor motor coordination and/or learning difficulty. These tests were performed for the assessment of DD within one year before or after the evaluation of motor coordination of subjects by the DCDQ-J.

2.3 Data analysis

The Mann-Whitney U test was performed to compare the four index scores of the WAVES between the DCD and Non-DCD groups. Subject characteristics and the results of learning and cognitive tasks that predicted DCD in DD were investigated through logistic regression analysis with backward stepwise elimination. All statistical analyses were performed with SPSS version 28 (IBM Corporation, Armonk, NY, USA).

3. Results

3.1 Subject characteristics

Forty-four children were elementary school students and two were in the first year of junior high school. The children were classified into lower graders (1st-3rd graders at elementary school) and upper graders (4th-6th graders at elementary school and 1st-year students at junior high schools). Twenty-three children (16 males and 7 females) were in the lower grade and 23 children (16 males and 7 females) were in the upper grade. Ten children with DD had ASD (ASD alone in 4), and 28 had ADHD (ADHD alone in 22). Six children had comorbid ASD and ADHD.

3.2 Rate of DCD in DD, and the characteristics of DD with DCD

Eleven children out of 46 with DD were judged to have poor motor coordination based on the results of the DCDQ-J. These 11 children were clinically diagnosed with DCD, and the prevalence of DCD among children with DD was 24%. Figure 1 illustrates the overlap and distribution of children with ASD, ADHD, and DCD. The details and characteristics of the DCD and Non-DCD groups are shown in Table 1.

Figure 2 shows a comparison of the four index scores of the WAVES between the DCD and Non-DCD groups. There was a significant difference between the two groups in ECGI ($p = 0.041$),

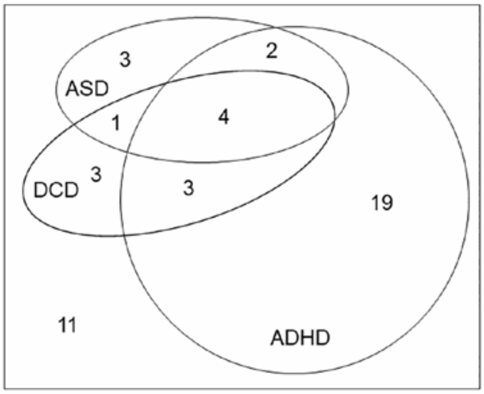

Figure. 1. Distribution of 46 children with developmental dyslexia (DD) in terms of comorbidities.
ADHD: attention-deficit/hyperactivity disorder; ASD: autism spectrum disorder; DCD: developmental coordination disorder

Table 1 Demographic and clinical characteristics of children with DD according to DCD status

	Total	DCD group	Non-DCD group
N	46	11 (24%)	35 (76%)
Gender			
Male	32	5	27
Female	14	6	8
Age			
Median (range)	9.6 (6.9-12.7)	8.9 (7.7-11.5)	9.8 (6.9-12.7)
School grade			
Lower	23	6	17
Upper	23	5	18
Comorbidity			
ASD	10	5	5
ADHD	28	7	21
DCDQ-J total score (z-score)			
Median (range)	-0.7 (-2.4-0.6)	-1.8 (-2.4 - -1.6)	-0.4 (-1.2-0.62)

In the DCDQ-J, the descriptions of each item are scored as follows based on the comparison between the child and other (children): "Not at all like your child (1 point)," "A bit like your child (2 points)," "Moderately like your child (3 points)," "Quite a bit like your child (4 points)," and "Extremely like your child (5 points)," with higher scores indicating better coordination.

but no significant differences were observed in other index scores.

Table 2 shows the results of the learning and cognitive tasks in the DCD and Non-DCD groups.

3.3 Predictors of DCD in children with DD

We investigated whether each of the subject characteristics (gender, age, and comorbidity) and the results of each test (WISC-IV, KABC-II, reading tasks, and DN-CAS) were related to DCD in children with DD through the univariate logistic regression analysis (Table 3). Comorbid ASD had a significant relationship with DCD in DD (p=0.038).

The multivariate logistic regression analysis indicated two significant relationships between comorbid ASD and DCD (p=0.013; odds ratio: 14.522; 95% confidence interval [CI]: 1.75-120.87), and between PSI of WISC-IV and DCD (p=0.025; odds ratio: 0.914; 95% CI: 0.85-0.99) (Table 3).

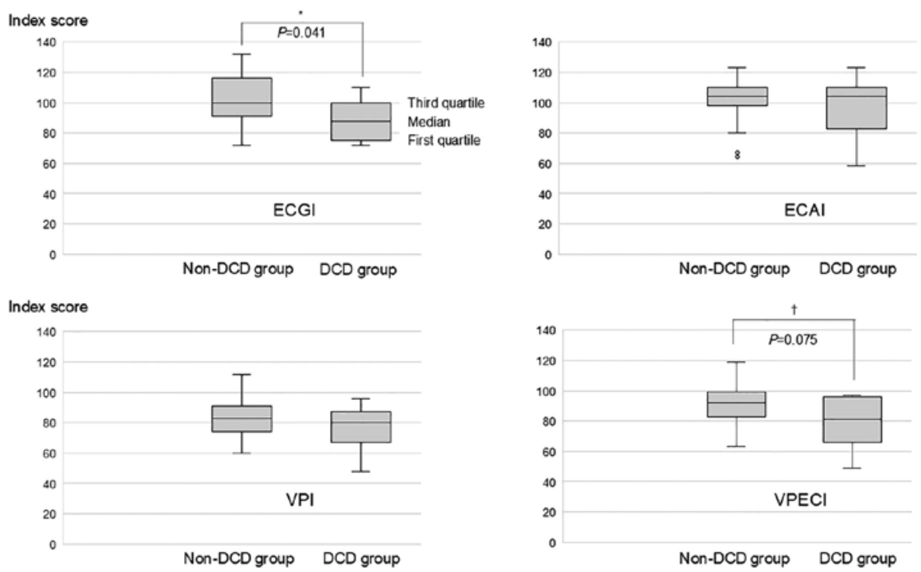

Figure. 2. Box plots comparing four index scores of the Wide-range Assessment of Vision-related Essential Skills (WAVES) between the DCD and Non-DCD groups.
Outliers are plotted beyond the end of the lower whisker.
*p < 0.05, † p< 0.1 (Mann-Whitney U test)

4. Discussion

The present study investigated the rate of DCD in Japanese children with DD based on the results of the DCDQ-J and clinical findings. We further investigated the relationship between DCD in DD and subject characteristics and results of several learning and cognitive tasks associated with reading and writing.

We used the DCDQ-J in this study because it allows accurate evaluation of poor motor coordination and has been reported to have a significant correlation with the Movement Assessment Battery for Children, Second Edition (MABC-2) (Pannekoek et al., 2012; Hirata et al., 2015). The MABC-2 is widely used to evaluate motor coordination, and was developed based on a normative sample in the UK (Henderson et al., 2007). The MABC-2 consists of three components: Manual Dexterity, Aiming and Catching, and Balance. Unfortunately, the Japanese version of the MABC-2 had not yet been officially released at the time of writing and the normative data for Japan has not been established. As illustrated in Fig.2, there was a significant difference between the DCD and Non-DCD groups in ECGI of the WAVES. ECGI is measured by subtests such as line tracing and form tracing, which are designed as a general indicator of eye-hand coordination speed (including some aspects of accuracy) (Okumura et al., 2020).

Eleven out of 46 children with DD were diagnosed with DCD, and the rate of DCD in DD was 24% in the present study. To the best of our knowledge, no similar research has been carried out in Japanese children. In the United Kingdom (UK), 52% or 59% of children with DD were reported to show impairments on tests that evaluate motor coordination. (Ramus et al., 2003; Haslum & Miles, 2007). Other studies reported in Norway that 60% of children with DD had DCD (Iversen et al., 2005). The 24% rate reported in this study is substantially lower than those reported in previous studies. Our study did not use the same evaluative tasks as the UK studies, so it is not possible to

Table 2 Results of assessments in the DCD and Non-DCD groups

	N	Total 46	DCD group 11	Non-DCD group 35
		Median (range)		
WISC-IV				
FSIQ		88 (72-109)	85 (77-100)	88 (72-109)
VCI		90.5 (72-111)	91 (82-99)	90 (72-111)
PRI		89.0 (71-120)	89 (76-109)	89 (71-120)
WMI		85 (65-123)	85 (76-94)	85 (65-123)
PSI		94 (70-132)	86 (73-115)	96 (70-132)
KABC-II				
Vocabulary		86 (67-103)	86 (73-94)	86 (67-103)
Reading		77 (60-101)	79 (71-89)	75 (60-101)
Writing		74 (61-96)	79 (71-84)	71 (61-96)
Mathematics		84 (70-115)	90 (77-115)	84 (70-113)
Reading task (z-scores)				
Monomoraic syllable task		2.3 (-0.4-7.9)	1.7 (-0.1-6.0)	2.5 (-0.4-7.9)
Word task		3.2 (0.1-13.1)	2.5 (0.1-11.7)	3.4 (0.3-13.1)
Non-word task		1.8 (-0.2-8.1)	1.5 (0.2-4.7)	1.9 (-0.2-8.1)
Short sentence task		2.6 (-1.4-31.4)	2.8 (-1.4-7.5)	2.5 (-1.0-31.4)
DN-CAS				
Planning		89 (68-128)	83 (70-111)	89 (68-128)
Simultaneous		87 (67-122)	85 (72-122)	89 (67-116)
Attention		91 (63-130)	76 (66-110)	93 (63-130)
Successive		82 (58-115)	81 (58-108)	83 (66-115)
WAVES				
ECGI		97 (72-132)	72 (86-110)	100 (72-132)
ECAI		104 (58-123)	104 (58-123)	104 (64-123)
VPI		83 (48-112)	80 (48-96)	83 (60-112)
VPECI		90 (49-119)	81 (49-97)	92 (63-119)

FSIQ: Full-scale IQ; VCI: Verbal Comprehension Index; PRI: Perceptual Reasoning Index; WMI: Working Memory Index; PSI: Processing Speed Index

ECGI: Eye-hand Coordination General Index; ECAI; Eye-hand Coordination Accuracy Index; VPI: Visual Perception Index; VPECI; Visual Perception and Eye-hand Coordination Index

make a direct comparison. However, this 24% rate is close to our impression of the frequency of DCD in children with DD that we have observed in our clinical experience here in Japan.

Many children with ASD are thought to have poor motor coordination (Ming et al., 2007), and it has been reported that DCD coexists with ASD at a frequency of almost 80% (Green et al., 2009). In the present study, 10 out of 46 children with DD had ASD (22%), and five out of 10 children with ASD had DCD (50%). These rates were much lower than those reported by Green et al. (2009). In Japan, Miyachi et al. (2014) reported that the rate of poor motor coordination in boys with high-function pervasive developmental disorder was almost 40%, which is lower than the rate mentioned above for other countries.

We investigated whether various subject characteristics and test results were related to DCD in children with DD. A logistic regression analysis revealed that only ASD and PSI of the WISC-IV had a significant relationship with DCD in DD. Nicolson et al. (2001) reported a close relationship

Table 3 Logistic regression analysis of factors associated with DCD in children with developmental dyslexia (DD)

	N	Odds ratio	95% CI	*p*-Value		N	Odds ratio	95% CI	*p*-Value
Univariate analysis									
Gender (Male)	32	0.247	0.06–1.03	0.054	Reading task (z-scores)				
Age		0.819	0.51–1.30	0.399	Monomoraic syllable task		0.773	0.50–1.20	0.255
Comorbidity					Word task		0.877	0.70–1.10	0.254
ASD	10	5.000	1.10–22.82	0.038*	Non-word task		0.902	0.63–1.30	0.575
ADHD	28	1,167	0.29–4.74	0.829	Short sentence task		0.923	0.75–1.13	0.442
					DN-CAS				
WISC-IV					Planning		0.971	0.92–1.03	0.299
FSIQ		0.976	0.90–1.06	0.570	Simultaneous		0.990	0.93–1.06	0.777
VCI		1.024	0.94–1.12	0.606	Attention		0.967	0.92–1.02	0.208
PRI		0.994	0.94–1.05	0.840	Successive		0.991	0.94–1.05	0.769
WMI		1.002	0.94–1.07	0.959					
PSI		0.942	0.88–1.01	0.071	*Multivariate analysis*				
KABC-II					Gender (Male)	32	0.135	0.02–1.00	0.050
Vocabulary		0.967	0.90–1.05	0.403	Comorbidity				
Reading		1.045	0.96–1.14	0.303	ASD	10	14.522	1.75–120.87	0.013*
Writing		1.067	0.98–1.16	0.135	WISC-IV				
Mathematics		1.028	0.98–1.08	0.294	PSI		0.914	0.85–0.99	0.025*
					KABC-II				
					Writing		1.112	0.98–1.26	0.105

FSIQ: Full-scale IQ, VCI: Verbal Comprehension Index, PRI: Perceptual Reasoning Index, WMI: Working Memory Index, PSI: Processing Speed Index CI: confidence interval *$p<0.05$

between poor motor coordination and reading difficulty in DD, but several studies have argued that poor motor coordination in DD is not due to DD itself but to coexisting ADHD and/or DCD (Ramus et al., 2003; Wimmer et al., 1999). Although, the relationship between poor motor coordination and ADHD in children with DD is recognized, there have been no reports regarding the relationship between ASD and poor motor coordination in children with DD. It appears that our study is the first to report this relationship.

Motor impairments and clumsiness are often observed in children with ASD, and it has been reported that there is a close relationship between social impairments and poor motor coordination in children with ASD (Green et al., 2008; Holloway et al., 2018). In investigating poor motor coordination in DD, the coexistence of ASD must have a strong influence. In Western countries, children with ASD are well known to have poor reading comprehension, but there have been few detailed reports on the coexistence of DD and ASD (Nation et al., 2006). We previously reported that the rate of reading disability in children with pervasive developmental disorder was 26% (Oka et al., 2012), and it is not uncommon for children with DD to have ASD. Regarding poor motor coordination in children with DD, not only ADHD but also ASD should be considered as possible comorbidities.

PSI of the WISC-IV is measured by the subtests such as the coding and symbol search, which require appropriate eye-hand coordination skills, visual attention and motor speed. Because motor coordination and visual perception including eye-hand coordination are considered to be directly and strongly related to each other (Wilson & McKenzie, 1998), it is to be expected that the results of PSI were significantly related to DCD in DD in the present study. In contrast, there were no significant relationships found between DCD and results of reading and writing tasks. The results of this study do not support the previously reported the theory proposed by Nicolson et al. (2001) that motor coordination is directly related to reading ability in children with DD.

Evaluating handwriting skills requires examining its product (i.e., legibility and accuracy of the written trace), its process (i.e., movements that generate the trace), or both. There was no significant relationship between the product of the writing task and comorbid DCD in children with DD, but this may be because the Writing subtest of the KABC-II is evaluated by its product and not the handwriting process or speed. The DCD group can have poorer handwriting speed and accuracy and therefore requires more reasonable accommodation tailored to their characteristics (i.e., additional time, reduced handwriting tasks, exemption from copying what is written on the blackboard, etc.).

Our study has some possible limitations. First, the sample size was small, which could have hampered the statistical power of our results. Future studies with larger sample sizes could identify even more differences between the DCD and Non-DCD groups. Second, another important issue related to poor motor coordination is the possibility of skill improvement through learning or training (Sigmundsson et al., 2017). Development of skill may be possible in children with DD with or without DCD, but this issue is beyond the scope of the present study and requires well-designed future studies.

5. Conclusion

Various factors are considered to play a role in the occurrence of DD. This study focused on poor motor coordination in children with DD, but the results did not support the theory that motor coordination is directly related to reading abilities (Nicolson et al., 2001). Motor coordination is not considered to be a core factor in reading and writing ability, but poor motor coordination may be a symptom associated with comorbid ASD and/or DCD. The consideration in this study was similar to the theory on Ramus et al. (2003), which focused on the comorbidities of DD. However, unlike previous reports, comorbid ADHD was not significantly related to DD in children with DD. Taking into account the difference in the rate of DCD in DD, the results of this study may be due to the difference in the characteristics of DD and/or DCD between people using Japanese and those using alphabetic languages. This issue requires further study in the future.

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Conflicts of interest

None to report.

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