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Examining the relationships between attention deficit/hyperactivity disorder and developmental coordination disorder symptoms, and writing performance in Japanese second grade students

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ABSTRACT

The purpose of this study was to explore the relationships between attention deficit/hyperactivity disorder and developmental coordination disorder symptoms and writing performance in Japanese second grade students from regular classrooms. The second grade students ($N = 873$) in Japanese public elementary schools participated in this study. We examined a variety of writing tasks, such as tracing, copying, handwriting (Hiragana and Katakana), and spelling (Hiragana, Katakana, and Kanji). We employed the Japanese version of the home form ADHD-rating scale (ADHD-RS) and the Japanese version of the Developmental Coordination Disorder Questionnaire (DCDQ-J) to assess the developmental characteristics of the participating children. Seven writing performance scores were submitted to a principal component analysis with a promax rotation, which yielded three composite scores (Spelling Accuracy, Tracing and Copying Accuracy, and Handwriting Fluency). A multiple regression analysis found that inattention predicted Spelling Accuracy and Handwriting Fluency and that hyperactive-impulsive predicted Handwriting Fluency. In addition, fine motor ability predicted Tracing and Copying Accuracy. The current study offered empirical evidence suggesting that developmental characteristics such as inattention and fine motor skill are related to writing difficulties in Japanese typical developing children.

1. Introduction

Writing is one of the basic academic skills that students should master during elementary school education. Because students need to integrate visual, motor, and conceptual abilities in the process of writing (Mercer & Mercer, 2005), some elementary school students struggle to master writing. Students with developmental disabilities such as attention

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deficit/hyperactivity disorder (ADHD) and developmental coordination disorder (DCD) have particular difficulties in writing (Graham, Harris, & Fink, 2000). The present study examined the relationships of ADHD and DCD symptoms with writing performance in Japanese public elementary school students from regular classrooms.

The core symptoms of ADHD in the DSM-IV-TR (American Psychiatric Association, 2000) are inattention, impulsivity, and hyperactivity. ADHD children tend to show continuing poor academic performance when they enter elementary school (McConaughy, Achenbach, & Gent, 1988). Previous studies have shown that ADHD children have handwriting (Barkley, 1998; Racine, Majnemer, Shevell, & Snider, 2008) and spelling difficulties (Kroese, Hynd, Knight, Heimenz, & Hall, 2000; Mayes, Calhoun, & Crowell, 2000). Although little is known about the mechanisms of ADHD-related writing difficulties, some studies have suggested that the attention component of ADHD is involved. Amundson and Weil (2001) identified sustained attention as a precursor of legible handwriting in typically developing children. In addition, Tsai, Meng, Hung, Chen, and Lu (2011) showed that attention impairments play an important role in the specific types of writing errors observed in Taiwanese children. By contrast, Resta and Eliot (1994) compared the writing performance of ADHD children with and without hyperactive behavior and found poorer visual-motor skills in ADHD children with hyperactive behavior than in those without it, but they found no differences in their handwriting abilities. There is little available evidence on the relationship between hyperactivity/impulsivity symptoms and writing.

The other developmental disability related to writing difficulties is DCD. The DSM-IV (American Psychiatric Association, 1994) defines DCD as "a marked impairment in the development of motor coordination, which interferes with daily living and studying." Missiuna, Rivard, and Pollock (2004) described that students with DCD struggle with written classroom work and daily activities requiring motor coordination. Flapper, Houwen, and Schoemaker (2006) reported that children with ADHD and DCD, who displayed poor fine motor skills on a motor impairment screening tool (Movement Assessment Battery for Children; Henderson & Sugden, 1992), had poor handwriting. They also found that children with ADHD and DCD drew more fluently but with less accuracy in a graphomotor task than did control children. Chang and Yu (2009) found that children with DCD acquired automated handwriting more slowly than those without handwriting deficits. They suggested that children with DCD have difficulties performing the open-loop and closed-loop movements required for fluent handwriting.

Considering these previous findings, we hypothesized that ADHD and DCD symptoms were related to writing difficulties in Japanese elementary school students from regular classrooms. However, little research has addressed the relationships between ADHD and DCD symptoms and writing in Japanese students. The Japanese language uses two syllabaries (Hiragana and Katakana) and an ideograph system (Kanji). Hiragana symbols represent high-frequency words of Japanese origin, while Katakana symbols represent foreign words and foreign names (Kobayashi, Haynes, Macaruso, Hook, & Kato, 2005). These Japanese syllabary characters use a syllable-based orthography, in contrast to the English alphabetic system, which uses grapheme–phoneme relationships (for a discussion of Japanese syllabic structures, see Tamaoka & Terao, 2004). In addition to the Hiragana and Katakana characters, Japanese orthography includes Kanji characters, which are introduced to elementary school students in the middle of first grade. Kanji characters are ideographic and often have several pronunciations and multiple meanings (Kobayashi et al., 2005). Most Japanese texts include Hiragana, Katakana, and Kanji systems.

As discussed above, these Japanese characters differ from English in many aspects. Therefore, we may not be able to apply previous findings about the relationship between developmental characteristics and writing in English-speaking children to Japanese-speaking students. The present study aimed to examine whether ADHD and DCD symptoms relate to the writing performance in Japanese second grade students. We used a variety of writing tasks (tracing, copying, handwriting, and spelling) to examine the relationships between the specific writing problem areas and ADHD and DCD symptoms.

2. Method

2.1. Participants

Second grade students ($N = 873$) in regular classrooms (age 7–8) and their parents/guardians from all eight public elementary school in one suburban city participated in this study. The participants included 405 boys and 468 girls. We used a passive consent procedure consisting of a letter describing the study that was mailed to the parents; they were asked to sign the letter and return it if they did not want their child to participate. The parents/guardians received the questionnaire via the teachers. Implied assent was also obtained from the children; the survey materials clearly stated that a waiver or alteration would not adversely affect the rights or welfare of children, and they have agreed to participate in the research by participating in the writing tasks. The institutional review board of the Hamamatsu University School of Medicine approved this procedure.

2.2. Instruments

2.2.1. Writing tasks

2.2.1.1. Tracing and copying tasks. Using a standardized screening test for measuring reading and writing achievement, the Screening Test of Reading and Writing for Japanese Primary School Children (STRAW; Uno, Haruhara, Kaneko, & Wydell, 2006), Fujita and Tsujii (2011) developed tracing, copying, and spelling tasks (for Hiragana, Katakana, and Kanji) that can be used in group classroom instruction. Fig. 1 shows the worksheet used in the tracing and copying task. We used these tasks to assess visual-motor integration, component that is relevant for writing. These tasks were identical to that described in Fujita

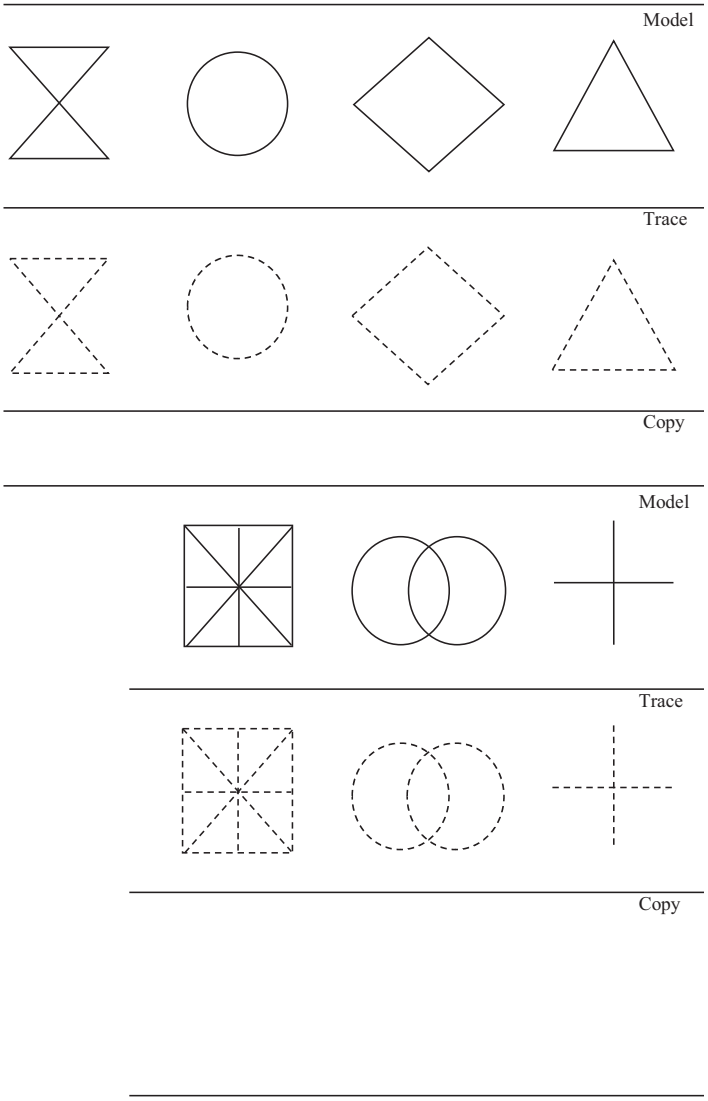

Fig. 1. Worksheet used in the tracing and copying tasks.

and Tsujii (2011) except for the number of shapes. We selected seven simple shapes from the nine shapes in the original task because schoolteachers requested for shortening the administration time. These shapes were outlined with dotted lines, and the students traced these shapes. In the copying task, the students looked at models of the shapes (which were identical to those used in the tracing task) and copied them. The α factors were .71 and .65 in tracing and copying tasks, respectively, which indicated that these tasks had acceptable levels of internal consistencies. In addition, tracing and copying tasks were positively correlated with the Japanese standardized achievement test (Tatsuno et al., 2009), which meant that these tasks had the convergent validity (r = .27 and .28 in tracing and copying tasks, respectively).

2.2.1.2. Handwriting fluency tasks. Berninger, Mizokawa, and Bragg (1991) developed a simple task for measuring handwriting fluency that involves writing as many letters of the alphabet as possible in order within one minute. Berninger et al. (1997) found a high inter-rater reliability for this task (r = .97). In addition, this task has been used and cited in many handwriting studies (see Berninger, 1999, for a review), and the psychometric information from this task is available as a developed test that is linked to other writing skills. We applied this task to the Japanese language and developed a handwriting fluency task for Hiragana and Katakana. In this task, the children wrote as many Hiragana or Katakana characters as possible in their Japanese syllabary order within one minute. These tasks were positively correlated with the Japanese standardized achievement test (Tatsuno et al., 2009), which indicated the convergent validity (r = .13 and .32 in Hiragana handwriting and Katakana handwriting, respectively).

2.2.1.3. Spelling tasks. We revised the spelling tasks in Fujita and Tsujii (2011) to develop shorter version that were more convenient for the teachers. We selected 24 Hiragana characters and created nine concrete words composed of these characters (Table 1). Illustrations of the nine selected words were presented to the students in an A4-size worksheet. The Hiragana spelling task required the students to look at an illustration and write its name in Hiragana. The Katakana spelling

Table 1
Materials used in each spelling task.

Hiragana	Katakana	Kanji	
りゅう (dragon)	リュウ (dragon)	赤 (red)	足 (foot)
たぬき (racoon dog)	タヌキ (racoon dog)	町 (town)	耳 (ear)
ろけっと (rocket)	ロケット (rocket)	青 (blue)	音 (sound)
くぎ (nail)	クギ (nail)	雨 (rain)	草 (grass)
ふで (writing brush)	フデ (writing brush)	天気 (weather)	右 (right)
だちょう (ostrich)	ダチョウ (ostrich)	左 (left)	
おやゆび (thumb)	オヤユビ (thumb)	糸 (string)	
へそ (navel)	ヘソ (navel)	夕立 (shower)	
ほん (book)	ホン (book)	空 (sky)	

Note. Words in parentheses indicate the English words corresponding to each Japanese word.

task was identical to the Hiragana spelling task, except that students were required to write the name of the illustration in Katakana (Table 1). The Kanji spelling task included 14 words composed from 16 Kanji characters. The students were required to look a Hiragana word and then write the Kanji characters corresponding to that word.

The α factors of Hiragana, Katakana, and Kanji spelling were .88, .94, and .78, respectively, which indicated that these tasks had sufficient levels of internal consistencies. In addition, these three spelling tasks were positively correlated with the Japanese standardized achievement test (Tatsuno et al., 2009), which meant that these tasks had the convergent validity (r = .40, .45, and .53 in Hiragana, Katakana, and Kanji spelling tasks, respectively).

2.2.2. Questionnaire

2.2.2.1. Japanese version of home form of the ADHD-RS. The ADHD-Rating Scale-IV (ADHD-RS: DuPaul, Power, Anastopoulos, & Reid, 1998) was developed to measure the two major characteristics of ADHD: Inattentive (9 items) and Hyperactive-impulsive (9 items). Previous research has confirmed sufficient reliability and validity for the home form of the ADHD-RS (DuPaul, Power, McGoey, Ikeda, & Anastopoulos, 1998; DuPaul et al., 1998). Tani, Okada, Ohnishi, Nakajima, and Tsujii (2010) developed the Japanese version of the ADHD-RS home form and showed that it had good reliability and validity. The parents/guardians of the children rated each item on a 4-point Likert scale ranging from "Not at all or rarely (0)" to "Sometimes (1)," "Often (2)," or "Very often (3)." Therefore, the higher a child's score on the ADHD-RS, the more ADHD symptoms the child displayed.

2.2.2.2. Japanese version of the DCDQ. The developmental coordination disorder questionnaire (DCDQ) is a parent questionnaire designed to screen for pediatric DCD (Wilson et al., 2009; Wilson, Kaplan, Crawford, Campbell, & Dewey, 2000). Nakai, Yoshizawa, Kawatani, and Wilson (2009) recently developed a Japanese version of the DCDQ (DCDQ-J), and Nakai et al. (2011) have reported on a relatively large-scale school-based study describing the applicability of the DCDQ-J to a community-based population of Japanese children. The DCDQ-J is a 15-item parent rating scale that includes three factors: Control during movement (6 items), Fine motor (4 items), and General coordination (5 items). Each item is scored on a 5-point scale as follows: "Not at all like your child (1)", "A bit like your child (2)", "Moderately like your child (3)", "Quite a bit like your child (4)", and "Extremely like your child (5)", with higher scores indicating better motor coordination.

2.3. Procedures

2.3.1. Writing task

Classroom teachers handed the worksheets to their students in the classroom. Teachers explained the procedures to students and timed the administration time. All procedures were conducted in a group instruction format.

Experienced speech therapists and a psychologist scored the students' performances on all the tasks. We trained each scorer using the coding sheet prior to this study. Scorers coded each character in writing tasks as correct, incorrect, and blank. We counted the blank as incorrect. The coding sheet illustrated the definition of each code and concrete examples. We calculated the percent of correct characters in tracing, copying, and spelling tasks. We counted the number of correct characters in handwriting fluency task.

2.3.2. Questionnaire

We sent each questionnaire to the parents/guardians of students via the classroom teachers. The parents/guardians who agreed to participate in this study answered the questionnaire and sent it back. The responses from the 816 respondents were analyzed.

2.4. Statistical analysis

We used the PASW Statistics 18.0 software package (SPSS Inc.) for the statistical analysis. We first calculated the descriptive statistics (mean and standard deviations) for the tracing, copying, handwriting, and spelling tasks. In addition,

Table 2
Descriptive statistics of writing performances and each score in ADHD-RS and DCDQ-J.

	Boys			Girls			*t*
	n	*M*	*SD*	*n*	*M*	*SD*	
Writing task							
Tracing	405	78.84	22.89	468	88.03	16.11	6.77***
Copying	405	72.84	22.48	468	83.52	20.13	7.35***
Hiragana handwriting fluency	395	18.50	7.17	459	17.84	7.25	−1.33
Katakana hand writing fluency	385	19.34	7.37	448	20.77	7.72	2.74**
Hiragana spelling	405	88.95	15.64	468	91.81	12.42	2.96**
Katakana spelling	405	77.09	25.89	468	84.11	21.76	4.30***
Kanji spelling	405	84.41	16.35	468	86.27	14.22	1.78
ADHD-RS							
Inattentive	375	6.07	4.92	452	4.51	3.85	−4.97***
Hyperactive-impulsive	382	3.79	4.06	450	2.29	2.86	−5.97***
Total score	372	9.83	8.36	444	6.79	6.17	−5.76***
DCDQ-J							
Control during movement	379	21.28	5.09	448	20.25	4.70	−2.96**
Fine motor	387	13.89	3.46	455	15.61	3.23	7.40***
General coordination	384	16.17	4.00	453	17.12	3.96	3.39***
Total score	377	51.26	10.95	442	53.00	10.15	2.35*

* $p < .05$.
** $p < .01$.
*** $p < .001$.

we computed the descriptive statistics (mean and standard deviations) for each ADHD-RS and DCDQ-J subscale score. Because some previous studies in Japan demonstrated the gender difference in writing performance (e.g., Kono, Hirabayashi, & Nakamura, 2008; Uno et al., 2006), we used *t*-test to examine the difference between boys and girls in each writing performances and each score of ADHD-RS and DCDQ-J. A principal component analysis with a promax rotation was then performed using the seven writing performance scores. Three writing composites scores (Spelling Accuracy, Tracing and Copying Accuracy, and Handwriting Fluency) were derived from the results of the principal component analysis. Third, we calculated the Pearson Product Moment Correlations between the ADHD-RS and DCDQ-J subscale scores and the three writing composites scores. Finally, a multiple regression analysis with backward elimination was performed to predict each composite writing score using the children's sex and their ADHD-RS and DCDQ-J subscale scores. The number of data inputs in the analysis varied because missing data were excluded.

3. Results

3.1. Descriptive statistics

Table 2 shows the descriptive statistics for writing performances and for each ADHD-RS and DCDQ-J subscale scores by sex. The girls demonstrated significantly higher writing performance scores than the boys in all the tasks except for the Kanji spelling and Hiragana handwriting fluency. By contrast, two ADHD-RS subscale and total scores were significantly higher in the boys than in the girls. Although the boys had significantly higher DCDQ-J Control during movement score than the girls, the girls had significantly higher Fine motor, General coordination, and total scores than the boys.

3.2. Principal component analysis

Seven writing performance scores were submitted to a principal component analysis with a promax rotation. Using Kaiser's criterion and the scree plot (2.54, 1.52, 1.01, .56, .051, etc.), we derived three interpretable components from the component structure. Table 3 shows the component loadings for principal component analysis with promax rotation of writing performances and the inter-component correlations. Based on the magnitude of each component loading, we named Component 1 "Spelling Accuracy", component 2 "Tracing and Copying Accuracy", and component 3 "Handwriting Fluency". Spelling Accuracy was moderately correlated with the other two components. The correlations between Tracing and Copying Accuracy and Handwriting Fluency were not significant. Using the results of the principal component analysis, we created three composite scores. We calculated the *z*-score of each writing performance score and then summed them by component.

3.3. Correlation analysis

Table 4 shows the correlations between the composite writing performance scores and the ADHD-RS and DCDQ-J scores. Tracing and Copying Accuracy was moderately correlated with Fine motor on the DCDQ-J and weakly correlated with the other ADHD-RS and DCDQ-J scores. No significant correlations were found between Handwriting Fluency and the other scores. Spelling Accuracy was moderately correlated with Inattentive on the ADHD-RS and Fine motor on the DCDQ-J; it was weakly correlated with other subscale scores and with the ADHD-RS and DCDQ-J total scores.

Table 3
Component loadings for principal component analysis with promax rotation of writing performances and inter-component correlations.

Writing performance	Component loadings		
	C1	C2	C3
Hiragana spelling	**.93**	−.12	−.13
Katakana spelling	**.83**	−.06	.07
Kanji spelling	**.58**	.28	.12
Tracing	.01	**.86**	−.17
Copying	−.08	**.88**	.10
Hiragana handwriting fluency	−.11	−.14	**.91**
Katakana handwriting fluency	.12	.11	**.81**

	Inter-component loadings		
	C1	C2	C3
C2	.35***	–	
C3	.29***	.07*	–

Note. Component loadings > .50 are in bold face.
* $p < .05$.
*** $p < .001$.

Table 4
Correlations between writing performances and each score in ADHD-RS and DCDQ-J.

	ADHD-RS			DCDQ-J			
	Inattentive	Hyperactive-impulsive	Total score	Control during movement	Fine motor	General coordination	Total score
Spelling accuarcy	−.289*** ($n = 768$)	−.185*** ($n = 773$)	−.255*** ($n = 758$)	.078* ($n = 768$)	.253*** ($n = 782$)	.125*** ($n = 777$)	.165*** ($n = 760$)
Tracing and copying accuracy	−.178*** ($n = 768$)	−.130*** ($n = 773$)	−.158*** ($n = 758$)	.095** ($n = 768$)	.319*** ($n = 782$)	.191*** ($n = 777$)	.221*** ($n = 760$)
Handwriting fluency	−.065 ($n = 768$)	.018 ($n = 773$)	−.031 ($n = 758$)	.053 ($n = 768$)	.058 ($n = 782$)	.010 ($n = 777$)	.056 ($n = 760$)

Note.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Table 5
Multiple regression analysis with backward elimination predicting composite writing performance scores from sex, and ADHD and DCD symptoms.

テキスト	Spelling Accuracy		Tracing and Copying Accuracy		Handwriting Fluency	
	$R^2 = .102$		$R^2 = .131$		$R^2 = .015$	
	β	p	β	p	β	p
Sex (Girls)			.188	<.001		
ADHD-RS						
Inattentive	−.220	<.001			−.182	.001
Hyperactive-impulsive					.153	.005
DCDQ-J						
Control during movement						
Fine motor	.157	<.001	.267	<.001		
General coordination						

3.4. Multiple regression analysis

Table 5 shows the results of the multiple regression analysis with backward elimination for predicting the composite writing performance scores using ADHD and DCD symptoms and sex. In the correlation analysis, we found that the subscale scores of both the ADHD-RS and DCDQ-J correlated more strongly with writing performance than did the total scores. Therefore, we used each subscale score as an independent variable for predicting writing performances in the multiple regression analysis.

Inattentive was negatively associated with Spelling Accuracy and Handwriting Fluency. Hyperactive-impulsive was also significantly associated with Handwriting Fluency. By contrast, Fine motor on the DCDQ-J was positively associated with Spelling Accuracy and with Tracing and Copying Accuracy. Sex (female) was positively associated with Tracing and Copying Accuracy.

4. Discussion

The purpose of the present study was to examine the relationships between ADHD and DCD symptoms and writing performance in Japanese second grade students from regular classrooms. We hypothesized that ADHD and DCD symptoms were related to writing performance in Japanese children. The Japanese language has three character systems and it differs from English in many aspects. Therefore, this study uniquely contributed to understanding the relationships between developmental characteristics and writing performance for this specific type of language (Japanese).

The descriptive statistics showed that the girls demonstrated higher writing performance scores than the boys in all of the tasks except for the Kanji spelling and Hiragana handwriting fluency. In addition, gender differences were also found in each ADHD-RS and DCDQ-J subscale scores and total scores. Previous studies about writing performance (e.g., Graham, Berninger, Weintraub, & Schafer, 1998; Kono et al., 2008; Uno et al., 2006) reported the same results. The result of this study is consistent with these previous findings. The gender differences in ADHD-Rs and DCDQ-J are also consistent with previous Japanese studies (Nakai et al., 2011; Tani et al., 2010).

Using principal component analysis, we derived three interpretable components from the seven writing performance scores and created composites scores for each component: Spelling Accuracy, Tracing and Copying Accuracy, and Handwriting Fluency. Three composite writing scores significantly correlated each other. However, the Pearson correlation coefficient between Tracing and Copying Accuracy and Handwriting Fluency was very low. Although these two components involve graphmotor aspects of writing, these components represent somewhat different aspects: accuracy and fluency. Students who trace or copy accurately are not necessarily able to write words fluently. This difference may lead to the low correlation between these two components.

We assessed the developmental characteristics of the children using the ADHD-RS and DCDQ-J, and we examined the correlations between three composite writing scores and each developmental characteristic. Spelling Accuracy and Tracing and Copying Accuracy were significantly correlated with all scores in ADHD-RS and DCDQ-J. Especially, we found relatively high correlation between Spelling Accuracy and Inattentive, and Fine motor, and between Tracing and Copying Accuracy and Fine motor. On the other hand, Handwriting fluency did not correlate with any scores in ADHD-RS and DCDQ-J. Because these correlation analyses did not control for each variable, we then conducted the multiple regression analysis. The multiple regression analysis revealed that the developmental characteristics had differing correlation patterns with the composite writing performance scores. Sex significantly predicted only Tracing and Copying Accuracy. A high Inattentive score predicted poor Spelling Accuracy and Handwriting Fluency. This result is consistent with previous findings that have addressed the relationship between the attention component and writing (e.g., Amundson & Weil, 2001; Tsai et al., 2011). The relationship between the inattention component and spelling suggests that children with attention problems have difficulty associating phonemes with graphemes. Moreover, the children with attention problems could not maintain their attention on the handwriting fluency task, which required them to continue to respond over one minute. Hyperactive-impulsive predicted Handwriting Fluency. The children with more Hyperactive-impulsive symptoms had more fluent handwriting skills. This result differs from those of Resta and Eliot (1994), who found no writing differences between ADHD children with and without hyperactive behavior. This discrepancy may be due to the different methods for measuring writing. We used performance in the handwriting fluency task as our measure, and Resta and Eliot (1994) measured writing performance by the parent's subjective rating of their child's handwriting. In addition, the differing study populations (typically developing children / children with ADHD) may have affected this inconsistency.

Of the DCDQ-J subscale scores, only Fine motor predicted Spelling Accuracy and Tracing and Copying Accuracy. The other two subscale scores did not predict any writing performance scores. Previous studies (Berninger & Rutberg, 1992; Flapper et al., 2006) have reported similar relationships between fine motor skills and writing performance. Because children are required to integrate visual, motor, and conceptual abilities in the process of writing (Mercer & Mercer, 2005), children with fine motor dysfunction tend to have difficulties in writing.

5. Limitation and perspectives

In this study, we examined only handwriting and spelling skills. Writing has many other components such as content and spatial arrangement. Further researches are needed to examine the relationship between developmental characteristics and other writing components. We used a cross-sectional survey consisting only of second grade children. Therefore, we need to assess the relationships between writing performance and ADHD and DCD symptoms in a large longitudinal study to investigate causal relationships. In this study, we used only parent-rating questionnaires to assess the children's ADHD and DCD characteristics. Further research with more sensitive neuropsychological tests is needed to clarify the mechanisms by which these developmental characteristics lead to writing difficulties.

6. Conclusion

The results of this study of Japanese-speaking students are consistent with previous findings for English-speaking children. Although this study had some limitations, it provides empirical evidence that developmental characteristics such as inattention and fine motor skill are related to writing difficulties. Identifying the precise relationships between developmental characteristics and writing difficulties is an important prerequisite for developing effective interventions.

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