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Original Article

Relationship between motor coordination, cognitive abilities, and academic achievement in Japanese children with neurodevelopmental disorders

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Neurodevelopmental disorders;
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Abstract *Background/Objective:* Motor coordination impairment is common in children with neurodevelopmental disorders such as autism spectrum disorder (ASD) and attention deficit/hyperactivity disorder (AD/HD). The purpose of this study was to investigate the relationship between motor coordination, cognitive ability, and academic achievement in Japanese children with neurodevelopmental disorders.
Methods: Thirty-four school-age (6–12 years old) children with neurodevelopmental disorders and 34 age-matched typically developing (TD) children were recruited in this study. Correlations between the scores of the Movement Assessment Battery for Children-2 (M-ABC2) and the Kaufman Assessment Battery for Children – Second Edition (K-ABCII) that assesses cognitive abilities, and academic achievement were analyzed.
Results: The children with neurodevelopmental disorders obtained a lower total score and all component scores on M-ABC2 compared to the TD children. In children with neurodevelopmental disorders, M-ABC2 Manual Dexterity score was significantly correlated with K-ABCII Simultaneous Processing ($r = .345$, $p = .046$), Knowledge ($r = .422$, $p = .013$), Reading ($r = .342$, $p = .048$), Writing ($r = .414$, $p = .017$), and Arithmetic ($r = .443$, $p = .009$) scores. In addition, M-ABC2 Balance score was significantly correlated with K-ABCII Learning ($r = .341$,

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p = .048), Writing (r = .493, p = .004), and Arithmetic (r = .386, p = .024) scores.
Conclusion: These findings stress that it is essential to accurately identify motor coordination impairments and the interventions that would consider motor coordination problems related to cognitive abilities and academic achievement in Japanese children with neurodevelopmental disorders.

Introduction

Neurodevelopmental disorders such as autism spectrum disorder (ASD), attention deficit/hyperactivity disorder (AD/HD), and specific learning disorder (SLD) frequently co-occur with developmental coordination disorder (DCD) (American Psychiatric Association, 2013). Previous studies have also shown that motor coordination impairments are common in children with ASD (Green et al., 2009; Whyatt & Craig, 2012), AD/HD (Kadesjö & Gillberg, 1998; Piek & Dyck, 2004; Pitcher, Piek, & Hay, 2003; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007), and SLD (Jongmans, Smits-Engelsman, & Schoemaker, 2003; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011). Therefore, it is essential to accurately identify motor coordination problems among children with neurodevelopmental disorders.

DCD impedes the acquisition and execution of coordinated motor skills (American Psychiatric Association, 2013). DCD is more prevalent among boys and occurs in 5–6% of children of 5–11 years of age. DCD is a serious impairment in the development of motor coordination that significantly interferes with academic achievement and daily living skills. Previous studies have shown that motor coordination problems are associated with secondary psychological, emotional, and sociability problems such as depression (Lingam et al., 2012), poor self-image and self-esteem (Cocks, Barton, & Donelly, 2009; Piek, Baynam, & Barrett, 2006), and psychosocial issues (Dewey, Kaplan, Crawford, & Wilson, 2002).

Motor coordination involves a series of cerebral processes including sensory input, perceptual and cognitive processing, and action production (Vickerman, 2008). Diamond (2000) suggested that motor development may be related to cognitive development, and that the cerebellum and the prefrontal cortex may play a role in motor function and cognition. A recent study revealed a relationship between motor and cognitive skills in typically developing children (Luz, Rodrigues, & Cordovil, 2014; Roebers & Kauer, 2009; van der Fels et al., 2015). Besides, Luz et al. (2014) detected associations between motor coordination and executive functioning in healthy 9–11-year-old children. Furthermore, previous studies revealed that children with DCD show decreased cognitive abilities (Asonitou, Koutsouki, & Charitou, 2010; Leonard, Bernardi, Hill, & Henry, 2015; Wilson & McKenzie, 1998). Asonitou et al. (2010) found that children with DCD differed from children without DCD and performed at a lower level in motor and cognitive tasks.

Recently, the relationship between motor coordination and academic achievement/cognitive abilities has been evaluated. Several studies revealed that children with motor coordination problems show poor academic achievement (Lopes, Santos, Pereira, & Lopes, 2013; Roussounis, Gaussen, & Stratton, 1987). Studies using regression analysis and focusing on school-aged children found that motor coordination was a predictor of positive academic performance (Fernandes et al., 2016). Moreover, Rigoli, Piek, Kane, and Oosterlaan (2012) found that motor coordination has an indirect effect on academic achievement through working memory in a normative adolescent sample. Thus, it appears that motor coordination is directly related to academic achievement. Indeed, previous research revealed that children with DCD tend to have poor academic achievement. Children with DCD displayed significantly poorer performance in reading, writing, and spelling (Dewey et al., 2002), literacy and numeracy (Alloway, 2007), and mathematics (Pieters, Desoete, Van Waelvelde, Vanderswalmen, & Roeyers et al., 2012), and children with learning disabilities scored lower in gross motor coordination tests (Westendorp et al., 2011). It can thus be concluded that motor coordination problems are directly related to academic achievement.

However, the relationship between specific motor coordination abilities, cognitive abilities, and academic achievement in children with neurodevelopmental disorders has been rarely investigated. Furthermore, no study has examined such relationships in Japanese children with neurodevelopmental disorders. The acquisition of literacy skills varies according to writing systems (Koyama, Hansen, & Stein, 2008). While alphabetic or syllabic scripts such as the English alphabet employ phonographic systems in which a symbol is mapped onto a sound unit (Shaywitz, Shaywitz, Fletcher, & Escobar, 2015), the Japanese writing system uses not only phonographic but also logographic systems in which a symbol is mapped onto either a word or a meaningful unit, such as in Chinese (Higuchi et al., 2015; Koyama et al., 2008; Uno Wydell, Haruhara, Kaneko, & Shinya et al., 2009). In addition, logographic Japanese characters have visual forms that are different from alphabetic letters. Therefore, understanding the relationship between the motor coordination abilities and academic achievement in Japan is essential to promote academic success among Japanese children with neurodevelopmental disorders.

Thus, we conducted a study examining motor coordination problems among Japanese children with neurodevelopmental disorders and the relationship of such impairments with cognitive abilities and academic achievement in Japan. The purpose of this study was to investigate the relationship between motor coordination and both cognitive abilities and academic achievement in Japanese children with neurodevelopmental disorders.

Methods

Participants

The participants in this study consisted of 68 school-age (6–12 years old) children. Thirty-four children (30 boys and four girls) with neurodevelopmental disorders (8.97 ± 1.82 years old) were recruited through primary schools and parents' association for children with neurodevelopmental disorders based in Nagasaki Prefecture. The children were provided with special support services in resource rooms in each school. All children were diagnosed with neurodevelopmental disorders based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria (ASD: $n = 17$, AD/HD: $n = 17$). Furthermore, all children's intellectual ability was evaluated by the first author using the Wechsler Intelligence Scale for Children-IV (WISC-IV). The children's average Full Scale IQ was 90.7 ± 15.7 (range = 70–126). None of the children were diagnosed with any physical or intellectual disability other than the neurodevelopmental disorder.

To collect the reference values for motor coordination ability in children with neurodevelopmental disorders, 34 typically developing (TD) children (15 boys and 19 girls; 8.29 ± 1.4 years old) were also recruited from the primary schools in the same region. As the TD children were attending mainstream schools, they were assumed to be of normal intelligence. The teachers of these children reported no physical, psychological, or intellectual problems.

The two groups (children with neurodevelopmental disorder and TD children) did not statistically differ in age ($t = 1.718$, $p = .091$).

Instrument

Movement Assessment Battery for Children-2 (M-ABC2)
The M-ABC2 was administered to assess motor coordination impairments. This standardized test consists of eight subtests, the results of which provide a total score and three component scores: Manual Dexterity (MD), Aiming and Catching (AC), and Balance. The raw score for each subtest is converted to a standard score by using the test manual, and each component standard score can be calculated. The sum of eight subtest scores can be recorded as a total standard score. Standard scores have a mean of 10 and a standard deviation (SD) of 3. Higher standard scores indicate greater motor coordination ability. This test has three age bands, covering 3–6, 7–10, and 11–16 years. The total duration of the test was 20–40 minutes. The validity and reliability of the test were confirmed using the test manual (Kaufman & Kaufman, 2013).

The Japanese version of the Kaufman Assessment battery for children-second edition (K-ABCII)
The Japanese version (Kaufman & Kaufman, 2013) of the K-ABCII was applied to assess cognitive abilities and academic achievement. The standardized K-ABCII test is a revised edition of the original K-ABC test developed in 1983 by Kaufman et al. The American version (Kaufman & Kaufman, 2013) of the K-ABCII was developed in 2004, and the Japanese standardized version was developed in 2013. The K-ABCII provides separate measures of children's cognitive abilities and basic scholastic aptitude. The Japanese version of the K-ABCII includes cognitive and academic achievement tests. The Japanese version is based on the Kaufman model based on Luria's theory. The Kaufman model allows us to measure eight abilities, with four subscales measuring cognitive abilities (Sequential Processing, Simultaneous Processing, Planning, and Learning) and four subscales measuring academic achievement (Knowledge, Reading, Writing, and Arithmetic). The test is suitable for a wide range of ages (2 years 6 months–18 years 11 months). The basic test for all ages includes 20 subtests (11 cognitive and nine academic). The results yield standard scores based on the total scores, converted into percentiles, for each test item. The standard score is a mean score of 100 with a SD of 15. Higher values indicate higher cognitive ability and academic achievement.

Procedures

Parental informed consent was obtained for each child. All children were tested individually in separate rooms by researchers according to the instructions given in the M-ABC2 manual. In addition, children with neurodevelopmental disorders were subjected to the K-ABCII.

This study was approved by the ethics board of the Nagasaki University Graduate School of Biomedical Sciences (No. 15010864).

Data analysis

SPSS Statistics (version 22.0) was used for data analysis, and the significance level was set to .05. We used Levene's test to examine whether the M-ABC2 scores had equal variance in the two groups, and found that only the Balance component scores had unequal variance. We therefore used Welch's *t*-test to analyze the differences in motor coordination abilities between the two groups (children with neurodevelopmental disorder and TD children).

For the children with neurodevelopmental disorders, Pearson's correlation analysis was conducted to examine the relationship between the standard scores of the M-ABC2 and the K-ABCII.

Results

Motor coordination abilities

Table 1 shows the results of Welch's *t*-test for standard scores of the M-ABC2, the total score, and all component scores.

The children with neurodevelopmental disorders had significantly lower total scores and component scores than did TD children ($p < .001$).

Cognitive abilities and academic achievement

Table 2 shows mean standard scores and SDs of the K-ABCII cognitive ability and academic achievement subscales in children with neurodevelopmental disorders.

Table 1 Comparison of Scores for M-ABC2 Total Score and all Component Scores between the Children with Neurodevelopmental Disorders and the Children with Typically Developing.

	Children with neurodevelopmental disorders (n = 34)	Children with typically developing (n = 34)	t	p
	Mean ± SD	Mean ± SD		
Manual dexterity	9.56 ± 3.17	12.38 ± 2.73	−3.93	<.001
Aiming & catching	8.50 ± 3.17	10.94 ± 2.34	−3.62	<.001
Balance	10.21 ± 3.04	13.53 ± 1.94	−5.37	<.001
Total	9.35 ± 2.95	12.85 ± 2.08	−5.65	<.001

Note. SD = standard deviation.

Relationships between motor coordination and cognitive ability/academic achievement

There were no significant correlations between the M-ABC2 component scores and intelligence measured with the WISC-IV in children with neurodevelopmental disorders.

Tables 3 and 4 list the correlations between the standard scores of the M-ABC2 and the K-ABCII. A significant positive correlation was obtained between the M-ABC2 total score and the K-ABCII total academic achievement score ($r = .357$, $p = .038$). Moreover, M-ABC2 MD was significantly correlated with K-ABCII Simultaneous Processing ($r = .345$, $p = .046$), Language ($r = .422$, $p = .013$), Reading ($r = .342$, $p = .048$), Writing ($r = .414$, $p = .017$), and Arithmetic ($r = .443$, $p = .009$). In addition, M-ABC2 Balance was significantly correlated with KABC-II Learning ($r = .341$, $p = .048$), Writing ($r = .493$, $p = .004$), and Arithmetic ($r = .386$, $p = .024$).

Discussion

This study compared the motor coordination abilities of Japanese children with neurodevelopmental disorders to those of age-matched TD children to identify motor coordination impairments specific to children with neurodevelopmental disorders. Our results show significantly poorer motor coordination abilities in Japanese children with neurodevelopment disorders than in TD children, as assessed with the M-ABC2. This result is consistent with previous studies showing significant motor impairments in children with neurodevelopmental disorders such as ASD and AD/HD (Green et al., 2009; Kadesjö & Gillberg, 1998; Piek & Dyck, 2004; Pitcher et al., 2003; Watemberg et al., 2007; Whyatt & Craig, 2012). However, to our knowledge, no study has compared the motor coordination abilities of Japanese children with neurodevelopmental disorders to those of TD children before. Thus, the results of this study stress that it is essential to accurately identify and then provide support for motor coordination problems among Japanese children with neurodevelopmental disorders.

Table 2 The K-ABCII Subscale Scores in Children with Neurodevelopmental Disorders (n = 34).

	Mean ± SD
Cognitive ability	
Sequential processing	88.59 ± 16.96
Simultaneous proccessing	98.76 ± 14.91
Planning	96.29 ± 15.55
Learning	102.76 ± 15.90
Total	93.97 ± 15.30
Academic achivement	
Knowledge	95.74 ± 14.98
Reading	94.44 ± 18.77
Writing	89.94 ± 18.43
Arithmetic	92.56 ± 16.06
Total	91.97 ± 17.78

Note. SD = standard deviation.

The results of the analyses examining the relationship between the motor coordination abilities and cognitive abilities/academic achievement in Japanese children with neurodevelopmental disorders showed a significant positive correlation between M-ABC2 total scores and K-ABCII total academic achievement scores. This result is consistent with previous studies showing that children with motor coordination problems tend to show poor academic achievement (Alloway, 2007; Dewey et al., 2002; Lopes, Santos, Pereira, & Lopes et al., 2013; Pieters et al., 2012; Roussounis et al., 1987). Interestingly, although the Japanese writing system and its visual form differ from other languages, this study found that motor coordination problems were significantly related to academic achievement in Japanese children with neurodevelopmental disorders. Thus, this study extends the current knowledge on motor coordination problems in relation to academic achievement, and suggests that children with motor coordination problems are at risk for academic failure. Conversely, it is also possible that children with academic skill problems might be at risk for motor performances problems. This study could not identify the causal relationship between motor performance problems and academic skill problems and thus further studies should be conducted to elucidate this.

Interestingly, although no significant correlation between M-ABC2 total scores and K-ABCII total cognitive ability scores was found in this study, the examination of the specific relationships between the individual components showed that MD and Balance were significantly correlated with both cognitive ability subscale scores and academic achievement subscale scores of the K-ABCII.

Regarding M-ABC2 MD, the total score of MD was significantly correlated with K-ABCII Simultaneous Processing, Language, Reading, Writing, and Arithmetic. According to the M-ABC2 manual, MD subtests consist of manual tasks that require precision. Moreover, an MD component is designed to reveal how the child copes with spatial and

Table 3 Correlation Analysis of the Total Score and Three Component Scores of M-ABC2 and Four Subscales of Cognitive Ability of the K-ABCII in Children with Neurodevelopmental Disorders (n = 34).

M-ABC2	Sequential processing	Simultaneous processing	Planning	Learning	Total cognitive ability
Manual dexterity	.112	.345*	.306	.269	.337
Aiming & catching	−.143	.013	−.184	−.125	−.134
Balance	.057	.280	.111	.341*	.276
Total M-ABC2	.037	.266	.116	.224	.225

*p < .05, **p < .01.

Table 4 Correlation Analysis of the Total Score and Three Component Scores of M-ABC2 and Four Subscales of Academic Achievement of the K-ABCII in Children with Neurodevelopmental Disorders (n = 34).

M-ABC2	Knowledge	Reading	Writing	Arithmetic	Total academic achievement
Manual dexterity	.422*	.342*	.414*	.443**	.447**
Aiming & catching	−.087	−.108	.153	.001	−.039
Balance	.185	.270	.493**	.386*	.359*
Total M-ABC2	.251	.244	.472**	.376*	.357*

*p < .05, **p < .01.

temporal demands imposed by manual tasks. A previous study (Asonitou, Koutsouki, Kourtessis, & Charitou, 2012) showed that the MABC MD score was significantly correlated with Simultaneous Processing, similarly to the results of this study. Simultaneous Processing involves integrating multiple units of information into groups. Furthermore, previous studies (Bonifacci, 2004; Sigmundsson, Hansen, & Talcott, 2003) reported that children with motor coordination problems had low visual sensitivity and poor visual-motor integration abilities, suggesting that the impairment of fine motor skills was related to visual processing abilities such as simultaneous processing in particular. On the contrary, fine motor skills involve coordinating small muscle movements needed for tasks such as drawing, writing, speaking, and playing an instrument. Grissmer, Grimm, Aiyer, Murrah, and Steele (2010) revealed that children in the United States who showed well-developed fine motor skills at the age of 5 performed more optimally in mathematics and reading than did their peers with poorly developed motor skills when they were 6, 8, and 10 years old. In this study, M-ABC2 MD was significantly correlated with all academic achievement subscale scores (Language, Reading, Writing, and Arithmetic) of the K-ABCII. Therefore, these results suggest that fine motor skills are associated with a wide range of academic achievements.

Regarding M-ABC2 Balance, the total Balance score was significantly correlated with KABC-II Learning, Writing, and Arithmetic scores. Several factors may account for this result. It is possible that the balance and academic skills share a common neural basis. Balance, as a motor function, is associated with the cerebellum. Since balance M-ABC2 subtests consist of static and dynamic balance tasks, the cerebellum is essential for good performance. Although the cerebellum has been considered as primarily involved in motor control, neuroimaging studies revealed that this structure also plays an important role in non-motor functions such as language, learning, and memory (De Smet, Baillieux, De Deyn, Mariën, & Paquier, 2007; Desmond & Fiez, 1998; Frings et al., 2006). Furthermore, previous studies revealed that cerebellar lesions play an important role in dyslexia and dyscalculia (Braga, Souza, Najjar, & Dellatolas, 2007; Dinkel, Willmes, Krinzinger, Konrad, & Koten, 2013). Therefore, the results of this study suggest a common neural basis for balance, cognitive functions, and academic skills. Thus, interventions targeting motor abilities, in particular balance, and therefore the areas controlling cognitive and academic skills, may be essential to improve academic outcomes.

In this study, no significant correlations between M-ABC2 AC scores and K-ABCII cognitive and academic achievement subscale scores were observed. Likewise, Asonitou, Koutsouki, Kourtessis, and Charitou (2012) reported that the MABC AC domain was significantly correlated with all Das-Naglieri Cognitive Assessment System (CAS) scales for the entire sample, but not for DCD and non-DCD samples individually. Thus, this suggests that the AC component might differ from MD and Balance. Further research should examine the factors that affect aiming and catching in children with neurodevelopmental disorders to develop effective interventions for improving these skills.

This study has several limitations. One of the limitations is that we did not consider several factors that may influence motor coordination and academic performance in children with neurodevelopmental disorders, such as, in particular in ASD and AD/HD, core deficits in executive function, praxis, sensory processing, and others. Therefore, future studies should consider ruling out these factors via inclusion/exclusion criteria. Furthermore, we did not have access to information about socio-economic status and other family characteristics, IQ score for children without neurodevelopmental disorders, and academic achievement data for either group. This information should be collected and reported in future studies. Additionally, these factors should be controlled in future studies to further understand the relationship between motor coordination abilities and academic achievement.

Conclusion

This study supports previous findings that children with neurodevelopmental disorders show worse motor coordination ability than typically developing children. Interestingly, this study revealed the relationship between motor coordination ability, cognitive ability, and academic achievement in Japanese children with neurodevelopmental disorders. In particular, the M-ABC2 components MD and Balance were significantly correlated with both cognitive abilities and academic achievement reflected by the K-ABCII. The findings of this study stress that it is essential to accurately identify motor coordination impairments and take into consideration their relation to academic problems among Japanese children with neurodevelopmental disorders.

References

Alloway, T. P. (2007). Working memory, reading, and mathematical skills in children with developmental coordination disorder. *Journal of Experimental Child Psychology, 96*(1), 20–36. https://doi.org/10.1016/j.jecp.2006.07.002.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. Washington DC: American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596.744053.

Asonitou, K., Koutsouki, D., & Charitou, S. (2010). Motor skills and cognitive abilities as a precursor of academic performance in children with and without DCD. *Procedia – Social and Behavioral Sciences, 5*, 1702–1707. https://doi.org/10.1016/j.sbspro.2010.07.350.

Asonitou, K., Koutsouki, D., Kourtessis, T., & Charitou, S. (2012). Motor and cognitive performance differences between children with and without developmental coordination disorder (DCD). *Research in Developmental Disabilities, 33*(4), 996–1005. https://doi.org/10.1016/j.ridd.2012.01.008.

Bonifacci, P. (2004). Children with low motor ability have lower visual-motor integration ability but unaffected perceptual skills. *Human Movement Science, 23*(2), 157–168. https://doi.org/10.1016/j.humov.2004.08.002.

Braga, L. W., Souza, L. N., Najjar, Y. J., & Dellatolas, G. (2007). Magnetic resonance imaging (MRI) findings and neuropsychological sequelae in children after severe traumatic brain injury: The role of cerebellar lesion. *Journal of Child Neurology, 22*(9), 1084–1089. https://doi.org/10.1177/0883073807306246.

Cocks, N., Barton, B., & Donelly, M. (2009). Self-Concept of boys with developmental coordination disorder. *Physical & Occupational Therapy in Pediatrics, 29*(1), 6–22. https://doi.org/10.1080/01942630802574932.

De Smet, H. J., Baillieux, H., De Deyn, P. P., Mariën, P., & Paquier, P. (2007). The cerebellum and language: The story so far. *Folia Phoniatrica et Logopaedica, 59*, 165–170. https://doi.org/10.1159/000102927.

Desmond, J. E., & Fiez, J. A. (1998). Neuroimaging studies of the cerebellum: Language, learning and memory. *Trends in Cognitive Sciences, 2*(9), 355–362. https://doi.org/10.1016/S1364-6613(98)01211-X.

Dewey, D., Kaplan, B. J., Crawford, S. G., & Wilson, B. N. (2002). Developmental coordination disorder: Associated problems in attention, learning, and psychosocial adjustment. *Human Movement Science, 21*(5–6), 905–918. https://doi.org/10.1016/S0167-9457(02)00163-X.

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development, 71*(1), 44–56. https://doi.org/10.1111/1467-8624.00117.

Dinkel, P. J., Willmes, K., Krinzinger, H., Konrad, K., & Koten, J. W. (2013). Diagnosing developmental dyscalculia on the basis of reliable single case FMRI methods: Promises and limitations. *PLoS One, 8*(12), 1–15. https://doi.org/10.1371/journal.pone.0083722.

Fernandes, V. R., Ribeiro, M. L. S., Melo, T., Maciel-Pinheiro, P. de T., Guimaraes, T. T., Araujo, N. B., et al. (2016). Motor coordination correlates with academic achievement and cognitive function in children. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.00318.

Frings, M., Dimitrova, A., Schorn, C. F., Elles, H. G., Hein-Kropp, C., Gizewski, E. R., et al. (2006). Cerebellar involvement in verb generation: An fMRI study. *Neuroscience Letters, 409*(1), 19–23. https://doi.org/10.1016/j.neulet.2006.08.058.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology, 51*(4), 311–316. https://doi.org/10.1111/j.1469-8749.2008.03242.x.

Grissmer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology, 46*(5), 1008–1017. Retrieved from: http://www.scopus.com/inward/record.url?eid=2-s2.0-77956778697&partnerID=40&md5=d9865e329448116ae9687c2c0eddf023.

Higuchi, H., Moriguchi, Y., Murakami, H., Katsunuma, R., Mishima, K., & Uno, A. (2015). Neural basis of hierarchical visual form processing of Japanese Kanji characters. *Brain and Behavior, 5*(12), 1–14. https://doi.org/10.1002/brb3.413.

Jongmans, M. J., Smits-Engelsman, B. C. M., & Schoemaker, M. M. (2003). Consequences of comorbidity of developmental coordination disorders and learning disabilities for severity and pattern of perceptual-motor dysfunction. *Journal of Learning Disabilities, 36*(6), 528–537. https://doi.org/10.1177/00222194030360060401.

Kadesjö, B., & Gillberg, C. (1998). Attention deficits and clumsiness in Swedish 7-year-old children. *Developmental Medicine and Child Neurology, 40*(12), 796–804. https://doi.org/10.1111/j.1469-8749.1998.tb12356.x.

Kaufman, A. S., & Kaufman, N. L. (2013). *Japanese version of the Kaufman Assessment Battery for Children, second edition (K-ABC II)*. NCS Pearson, Inc.

Koyama, M. S., Hansen, P. C., & Stein, J. F. (2008). Logographic Kanji versus phonographic Kana in literacy acquisition: How important are visual and phonological skills? *Annals of the New York Academy of Sciences, 1145*, 41–55. https://doi.org/10.1196/annals.1416.005.

Leonard, H. C., Bernardi, M., Hill, E. L., & Henry, L. A. (2015). Executive functioning, motor difficulties, and developmental coordination disorder. *Developmental Neuropsychology, 40*(4), 201–215. https://doi.org/10.1080/87565641.2014.997933.

Lingam, R., Jongmans, M. J., Ellis, M., Hunt, L. P., Golding, J., & Emond, A. (2012). Mental health difficulties in children with developmental coordination disorder. *Pediatrics, 129*(M), e882–e891. https://doi.org/10.1542/peds.2011-1556.

Lopes, L., Santos, R., Pereira, B., & Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. *Human Movement Science, 32*(1), 9–20. https://doi.org/10.1016/j.humov.2012.05.005.

Luz, C., Rodrigues, L. P., & Cordovil, R. (2014). The relationship between motor coordination and executive functions in 4th grade children. *European Journal of Developmental Psychology, 12*(2), 1–13. https://doi.org/10.1080/17405629.2014.966073.

Piek, J. P., Baynam, G. B., & Barrett, N. C. (2006). The relationship between fine and gross motor ability, self-perceptions and selfworth in children and adolescents. *Human Movement Science, 25*(1), 65–75. https://doi.org/10.1016/j.humov.2005.10.011.

Piek, J. P., & Dyck, M. J. (2004). Sensory-motor deficits in children with developmental coordination disorder, attention deficit hyperactivity disorder and autistic disorder. *Human Movement Science, 23*(3–4 SPE. ISS.), 475–488. https://doi.org/10.1016/j.humov.2004.08.019.

Pieters, S., Desoete, A., Van Waelvelde, H., Vanderswalmen, R., & Roeyers, H. (2012). Mathematical problems in children with developmental coordination disorder. *Research in Developmental Disabilities, 33*(4), 1128–1135. https://doi.org/10.1016/j.ridd.2012.02.007.

Pitcher, T. M., Piek, J. P., & Hay, D. A (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine and Child Neurology*. https://doi.org/10.1111/j.1469-8749.2003.tb00952.x.

Rigoli, D., Piek, J. P., Kane, R., & Oosterlaan, J. (2012). Motor coordination, working memory, and academic achievement in a normative adolescent sample. *Archives of Clinical Neuropsychology, 27*(7), 766–780. https://doi.org/10.1093/arclin/acs061. T4-Testing a mediation model M4-Citavi.

Roebers, C. M., & Kauer, M. (2009). Motor and cognitive control in a normative sample of 7-year-olds. *Developmental Science, 12*(1), 175–181. https://doi.org/10.1111/j.1467-7687.2008.00755.x.

Roussounis, S. H., Gaussen, T. H., & Stratton, P. (1987). A 2-year follow-up study of children with motor coordination problems identified at school entry age. *Child: Care, Health and Development, 13*(6), 377–391. https://doi.org/10.1111/j.1365-2214.1987.tb00554.x.

Shaywitz, S. E., Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (2015). Prevalence of reading disability in boys and girls. Results of the connecticut longitudinal study. *JAMA: The Journal of the American Medical Association, 264*(8), 998–1002. https://doi.org/10.1001/jama.264.8.998.

Sigmundsson, H., Hansen, P. C., & Talcott, J. B. (2003). Do "clumsy" children have visual deficits. *Behavioural Brain Research, 139*(1–2), 123–129. https://doi.org/10.1016/S0166-4328(02)00110-9.

Uno, A., Wydell, T. N., Haruhara, N., Kaneko, M., & Shinya, N. (2009). Relationship between reading/writing skills and cognitive abilities among Japanese primary-school children: Normal readers versus poor readers (dyslexics). *Reading and Writing, 22*(7), 755–789. https://doi.org/10.1007/s11145-008-9128-8.

van der Fels, I. M. J., Te Wierike, S. C. M., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science and Medicine in Sport, 18*(6), 697–703. https://doi.org/10.1016/j.jsams.2014.09.007.

Vickerman, P. (2008). Ecological intervention for children with movement difficulties (Manual) — By David Sugden and Sheila Henderson. *British Journal of Special Education, 35*(4), 252–253.

Watemberg, N., Waiserberg, N., Zuk, L., & Lerman-Sagie, T. (2007). Developmental coordination disorder in children with attention-deficit-hyperactivity disorder and physical therapy intervention. *Developmental Medicine & Child Neurology, 49*(12), 920–925. https://doi.org/10.1111/j.1469-8749.2007.00920.x.

Westendorp, M., Hartman, E., Houwen, S., Smith, J., & Visscher, C. (2011). The relationship between gross motor skills and academic achievement in children with learning disabilities. *Research in Developmental Disabilities, 32*(6), 2773–2779. https://doi.org/10.1016/j.ridd.2011.05.032.

Whyatt, C. P., & Craig, C. M. (2012). Motor skills in children aged 7–10 years, diagnosed with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 42*(9), 1799–1809. https://doi.org/10.1007/s10803-011-1421-8.

Wilson, P., & McKenzie, B. (1998). Information processing deficits associated with developmental coordination disorder: A meta-analysis of research findings. *Journal of Child Psychology and Psychiatry, 39*(6), 829–840. http://onlinelibrary.wiley.com/doi/10.1111/1469-7610.00384/full.