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Trajectories of emotional and behavioral problems in school-age children with coordination difficulties and their relationships to ASD/ADHD traits

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ABSTRACT

Background: Although research has demonstrated associations between motor coordination difficulties and psychological problems in school-age children, including emotional and behavioral problems, longitudinal changes in these problems in children with motor coordination difficulties are not fully understood.
Aims: The current study aimed to identify patterns in the trajectory of emotional and behavioral problems in school-age children with motor coordination difficulties, and to elucidate the effect of co-existing neurodevelopmental traits on the occurrence and course of these problems.
Methods and procedures: Using the Developmental Coordination Disorder Questionnaire, 773 children were defined as cases with motor coordination difficulties and followed for 4 years, from 6 to 10 years of age. Emotional and behavioral problems were assessed using the Strengths and Difficulties Questionnaire completed by children's parents or guardians.
Outcomes and results: We identified four trajectory patterns of emotional and behavioral problems. Children with higher autism spectrum disorder and attention deficit hyperactivity disorder traits were more likely to be assigned to poor prognostic trajectory patterns.
Conclusions and implications: Our findings emphasize the importance of assessing emotional and behavioral problems and co-existing neurodevelopmental traits in children with motor coordination difficulties in early elementary school.

What this paper adds?

In the present study, using data from prospective community-based school surveys, we identified latent patterns in the trajectories

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of emotional and behavioral problems in children with motor coordination difficulties and confirmed the influence of autism spectrum disorder and attention deficit hyperactivity disorder traits on these trajectories. Latent class growth analysis identified four trajectory classes. One of these classes was represented by children with clinical levels of emotional and behavioral problems at the first datapoint whose problems showed an increasing trend over the study years. Multinomial logistic regression analyses showed that children with higher autism spectrum disorder and attention deficit hyperactivity disorder traits were more likely to be assigned to poor prognostic trajectory patterns. These findings indicate that children with elevated emotional and behavioral problems may require interventions because of the trajectory patterns of these problems, and such interventions may need to be modified based on children's neurodevelopmental traits.

1. Introduction

Motor coordination difficulties (e.g., dropping or bumping into objects, slowness and inaccuracy in using tools such as scissors, and difficulties with handwriting or riding a bike) are frequently reported in community samples of children (Blank et al., 2019), and the severe form of these difficulties is classified as cardinal symptoms of developmental coordination disorder (DCD) (American Psychiatric Association, 2013). Increasing evidence suggests that many children with DCD continue to experience motor coordination difficulties throughout adolescence (Cantellet al., 1994; Geuze, 2003; Losse et al., 1991). Additionally, DCD frequently co-occurs with other neurodevelopmental disorders, such as autism spectrum disorder (ASD) and attention deficit hyperactivity disorder (ADHD) (American Psychiatric Association, 2013; Blank et al., 2019).

Motor coordination difficulties can also lead to non-motor coordination problems, including poor scholastic achievement, poor self-efficacy, and low life satisfaction (Blank et al., 2019; Cairney, 2015). A number of studies have suggested that children with DCD are at increased risk of psychological problems that negatively impact on long-term outcomes, such as symptoms of depression and anxiety in adolescence and adulthood (Hill & Brown, 2013; Sigurdsson et al., 2002; Zwickeret al., 2013). Furthermore, one line of research suggests that motor coordination difficulties in childhood could predict psychological problems in school-age children, even in children without a clinical diagnosis of DCD (Hill et al., 2016; Katagiri et al., 2021; Lingam et al., 2012; Piek et al., 2010). However, although several patterns in the trajectories of emotional and behavioral problems in a general population sample have been reported (Mulraney et al., 2020), studies have followed psychological problems in children with DCD or those with motor difficulties over time are limited, and no studies have examined the patterns of longitudinal changes of these problems in this population. Therefore, the occurrence and course of psychological problems in this population are not fully understood. Identifying the developmental trajectories of these problems may be helpful for detecting subgroups of children with motor coordination difficulties who could potentially benefit from early psychological interventions.

Several studies have highlighted the risk of mental health problems in children with DCD, and motor coordination difficulties need to be assessed in consideration of factors that may affect this relationship (Lingam et al., 2012; Moruzzi et al., 2010; Piek et al., 2007). A theoretical framework called the "environmental stress hypothesis" has been used to explain the effects of primary and secondary stressors associated with DCD on internalizing problems in children (Cairney et al., 2013). Specifically, the hypothesis notes DCD as a primary stressor and that negative exposure to secondary personal and social/interpersonal stressors (e.g., difficulty with daily tasks and frustration caused by repeated failure at home and in the classroom, peer-victimization because of limitations in performance in team sports and games) increases the risk of symptoms of depression and anxiety in children with DCD (Cairney et al., 2013; Cairney et al., 2010). In accord with this hypothesis, it has been suggested that the presence of co-occurring disorders such as ADHD may further exacerbate the effects of DCD on secondary stressors (e.g., interpersonal conflict, negative peer relationships) (Cairney et al., 2013). Moreover, in preschool children, social skills have been reported to function as a mediating variable in the relationship between motor difficulties and internalizing symptoms (emotional symptoms such as low mood, nervousness, fearfulness, worry and somatic complaints) (Wilsonet al., 2013). Additionally, it has been reported that the risk of mental health and behavioral problems in school-age children with motor coordination difficulties is associated with developmental difficulties, including inattention and hyperactivity, short-term memory, nonverbal skills, social communication, and academic ability (Lingam et al., 2012). These results emphasize that the association between motor difficulties and emotional and behavioral problems in school-age children may be influenced by co-existing developmental difficulties, such as ASD and ADHD traits.

Therefore, the primary aim of the present study was to identify trajectory patterns of emotional and behavioral challenges in school-age children with motor coordination difficulties throughout their first four years in elementary school. The secondary aim was to elucidate the impact of co-existing ASD and ADHD traits on the occurrence and course of psychological problems in these children. Achieving these aims will provide information to support the identification of subgroups of children with motor coordination difficulties that may benefit from interventions and individualized early support, potentially leading to prevention of mental health problems and school maladaptation.

2. Methods

This study was approved by the Committee of Medical Ethics of Hirosaki University Graduate School of Medicine (IRB# 2015–055). Children and their primary caregivers provided informed assent/consent for participation in the study.

2.1. Study setting and participants

We conducted an annual community-based survey from September 2016 to July 2020 and prospectively followed children

attending national or public elementary schools in Hirosaki City, Japan. The data collection flow chart is shown in Fig. 1. Children who were in the first grade (age 6–7 years) in 2016 and 2017 were followed at four time points until the fourth grade (age 9–10 years). At each time point, we distributed questionnaires and letters containing information about this study to the children's parents or guardians through their elementary school. The classroom teacher read out an explanatory document that we had prepared and explained the purpose of the survey, that participation in the research was absolutely voluntary, that publication of results would not include identifiable personal data, and that participants would be free to discontinue participation at any time, in plain Japanese that was understandable by children. When children's parents or guardians had questions regarding certain questionnaires, they were able to call our research team, who addressed their inquiries. Of a total study population of 2503 children, 10 children (0.4 %) whose parents or guardians did not consent to their participation in this study were excluded. Parents or guardians of participating children completed the Developmental Coordination Disorder Questionnaire (DCDQ; Wilson et al., 2000) Japanese version when their child was in the first grade. We excluded 429 responses with missing values on the DCDQ. Of these, 357 children had missing values on all items of the DCDQ, possibly because of refusal by the children's parents or guardians to answer the questionnaire or because they forgot to answer the questionnaire. The other 72 children had partial missing values. The other 72 children had partial missing values. 2064 (82.4 %) children met the above participation criteria. We performed sensitivity analyses to assess whether there were differences between 429 children who were excluded from our sample and 2064 children who were included in our sample. These sensitivity analyses did not reveal any significant difference in sex ratio and traits of ASD and ADHD between the two groups (see Supplementary table 1). We included 773 children with a DCDQ total score above the cut-off point (below the cut-off score of the DCDQ, in which higher scores indicate better motor coordination skills) for suspected DCD in the final data analyses.

2.2. Measurements and procedure

The DCDQ is a 15-item parent-rating questionnaire designed to evaluate coordination difficulties in children aged 5–15 years (Wilson et al., 2000). The 15 items grouped on three distinct factors: Control During Movement (six items), Fine Motor/Handwriting (four items), and General Coordination (five items). Control During Movement items are as follows: *throwing a ball in a controlled and accurate fashion; catching a small ball thrown from a distance of 6–8 feet; hitting an approaching ball or birdie with a bat or racquet accurately; easily jumping over obstacles found in a garden or play environment; running as fast and in a similar way to other children of the same gender and age; being able to organize their body to follow a plan to a motor activity and effectively complete the task*. Fine Motor/Handwriting items are as follows: *printing or writing or drawing in class quickly enough to keep up with the rest of the children in the class; printing or writing letters, numbers and words that are legible, precise, and accurate, or, if your child is not yet printing, they are able to color and draw in a coordinated way and makes pictures that you can recognize; using appropriate effort or tension when printing or writing or drawing; cutting out pictures and shapes accurately and easily*. General Coordination items are as follows: *being interested in and enjoying participation in sports or active games requiring good motor skills; learning new motor tasks easily and not requiring more practice or time than other children to achieve the same level of skill; being quick and competent in tidying up, putting on shoes, tying shoes, dressing, etc; never being described as a "bull in a china shop"; not fatiguing easily or appearing to slouch and "fall out" of their chair if required to sit for long periods.* Each item is scored on a five-point unipolar 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)." The scores for each item are summed and the total score is calculated from 15 to 75, with higher scores indicating better motor coordination skills. The DCDQ has been standardized in Japanese, and the Japanese version of the DCDQ was found to have good psychometric properties (Nakai et al., 2011). In the present study, we used the cut-off score for the original DCDQ to identify children with suspected DCD, which was defined as $\leq$ 46 for children aged 6 years to 7 years and 11 months (Wilson et al., 2009).

We used the Strengths and Difficulties Questionnaire (SDQ) to assess emotional and behavioral problems (Goodman, 1997). The SDQ contains 25 items on four difficulty subscales (conduct problems; hyperactivity/inattention; emotional problems; peer problems) and one favorable subscale (prosocial behavior). Each subscale has five items. The conduct problem items are as follows: *often having*

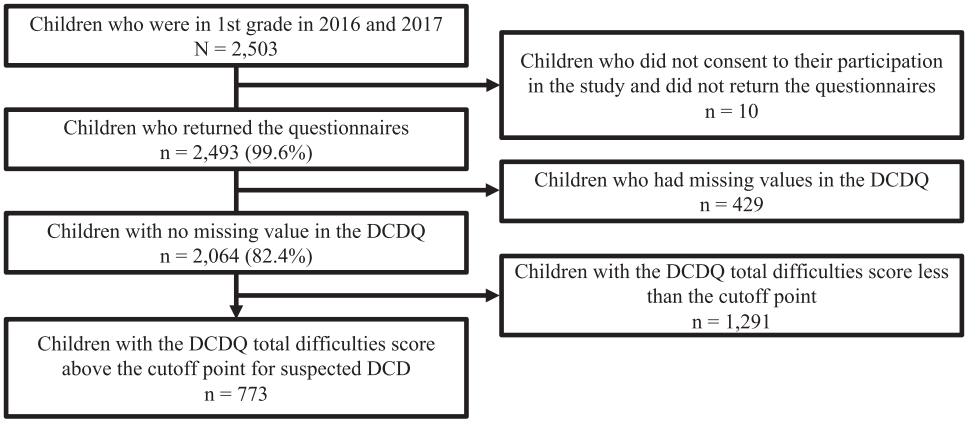

Fig. 1. Flow chart of survey data collection. DCDQ, Developmental Coordination Disorder Questionnaire.

temper tantrums or hot tempers; generally being obedient, usually doing what adults request; often fighting with or bullying other children; often lying or cheating; and stealing from home, school, or elsewhere. The hyperactivity/inattention items are as follows: *being restless, overactive, being unable to stay still for long; constantly fidgeting or squirming; being easily distracted, concentration wandering; thinking things out before acting; and seeing tasks through to their end, having good attention span*. The emotional problems items are as follows: *often complaining of headaches, stomach-aches, or sickness; having many worries, often being seems worried; often being unhappy, down-hearted, or tearful; being nervous or clingy in new situations, losing easily confidence; and having many fears, being easily scared*. The peer problems items are as follows: *being rather solitary and tending to play alone; having at least one good friend; being picked on or bullied by other children; and getting on better with adults than other children*. The prosocial behavior items are as follows: *being considerate of others' feelings; sharing readily with other children; being helpful if someone is hurt, upset, or feeling ill; being kind to younger children; and often volunteering to help others*. Each item is scored on a three-point unipolar scale as follows: "not true (0)," "somewhat true (1)," and "certainly true (2)." Higher scores indicate more serious problems, except for the prosocial behavior subscale, in which higher scores indicate more positive behavior. Scores for the difficulty subscales (conduct problems, hyperactivity/inattention, emotional problems, and peer problems) are summed to generate a total difficulty score ranging from 0 to 40. We used the Japanese version of the SDQ, which has been reported to have good reliability and validity (Matsuishi et al., 2008). We used cut-off scores for the Japanese versions of the SDQ that were consistent with the original version of the SDQ (Goodman, 1997, 2001). Total difficulties scores of $\leq$ 12 are considered to be within the normal band, scores of 13–15 place children as borderline, and scores $\geq$ 16 clinical range representing the extreme 10 % of the population. The SDQ total difficulties scores in the clinical range is reported to be associated with a substantial increase in psychiatric risk (Goodman, 1997; Matsuishi et al., 2008).

Two questionnaires were used to measure co-occurring neurodevelopmental traits: the Autism Spectrum Screening Questionnaire (ASSQ; Ehlers et al., 1999) and the Attention-Deficit/Hyperactivity Disorder Rating Scale IV (ADHD-RS; DuPaul et al., 1998). The ASSQ is used to evaluate ASD traits in school-age children, such as problems with social interaction and communication, and restricted and repetitive behavior. The ASSQ comprises 27 items rated on a 3-point scale. We used the Japanese version of the ASSQ, for which the psychometric properties had been validated in a general population sample (Ito et al., 2014). The ADHD-RS was developed to measure two features of ADHD: inattention and hyperactivity-impulsivity. We used the Japanese version of the ADHD-RS, which has good reliability and validity for school-aged children (Tani et al., 2010). For both scales, higher scores indicate a higher level of neurodevelopmental traits.

In the current study, all measurements were administered by the parents or guardians of the participating children. They completed the SDQ annually when their children were in the first, second, third, and fourth grades. The DCDQ, the ASSQ, and the ADHD-RS were only administered when children were in the first grade.

2.3. Data analysis

We performed latent class growth analysis (LCGA) to identify patterns of trajectories in the SDQ total difficulties scores through the four time points. LCGA is an established method for longitudinal data that assumes that latent variable comprising several classes/groups underlie the heterogeneity in how the variables evolve over time. In LCGA, all individual growth trajectories within a class are assumed to be homogeneous, and the variance and covariance estimates for the growth factors (i.e., intercept and slope) within each class are assumed to be fixed to zero. The dependent variable was the SDQ total difficulties scores measured at each time point, which were treated as continuous measures. Because the distributions of these scores were found to be skewed, we used an MLR estimator. After fitting a one-class model, the number of trajectory classes was increased sequentially until we found the best model fit according to analyses using the Bayesian information criterion (BIC), adjusted BIC (ABIC), entropy, Lo–Mendell–Rubin likelihood ratio test (LMR-LRT), and Bootstrap likelihood ratio test (BLRT) to determine the number of latent classes (Jung & Wickrama, 2007). The BIC and ABIC values indicate the model fit, with the best fitting model having the smallest BIC and ABIC values. High entropy values (near 1.0) indicate successful convergence. Significant LMR-LRT and BLRT results suggest that the model provides a significant improvement in model fit compared with the model with one less class (Jung & Wickrama, 2007). Missing values for the SDQ total difficulties score were processed using full information maximum likelihood. Two children were automatically excluded from the analyses because they had missing values for the SDQ total difficulties score at all time points. We also performed LCGA for the SDQ subscale (Emotional symptoms and Conduct problems) scores. Additionally, we conducted another LCGA in 1291 children with DCDQ total difficulties scores below the cutoff point (above the cut-off score) as a group without motor coordination difficulties.

Although the cut-off score for the DCDQ was originally set for the total score, we calculated the mean score of the DCDQ items for the 72 children who had partial missing values of the DCDQ and found that 29 children were expected to be above the cut-off point (below the cut-off score). As a sensitivity analysis, we reanalyzed the LCGA for 802 children, including those 29 children, and confirmed that the class structure and the proportion of children that were assigned to each class were similar to those in the original sample (773 children) (see Supplementary table 2 and Supplementary fig. 1).

We then performed multinomial logistic regression analyses with the total scores for the ASSQ and ADHD-RS as independent variables to investigate the influence of ASD and ADHD traits on poor prognosis patterns of emotional and behavioral problems. To adjust for possible confounding effects, the DCDQ total score and sex were also included as independent variables. We considered sex to be a possible confounding factor because sex differences in the SDQ total difficulties score were reported in the general population sample of school-aged Japanese children (Moriwaki & Kamio, 2014). We used a three-step estimation approach (Mplus R3STEP command; Vermunt, 2010). In this approach, the latent class model was estimated in a first step using only latent class indicator variables. In the second step, participants were assigned to each class based on the most likely posterior probabilities. In the third step, a factor of the most likely class was regressed on predictor variables, with consideration of measurement error associated with the most

likely class membership. Odds ratios (OR) and 95 % confidence intervals (CI) were calculated to show the risks of increasing probabilities of assignment to each class when the class with the least SDQ total difficulties was taken as the reference class.

Mplus version 8.6 (Muthén and Muthén, Los Angeles, CA, USA) and SPSS version 27.0 (IBM Corporation, Armonk, NY, USA) were used to perform all analyses.

3. Results

As shown in Table 1, 773 children were identified as cases with suspected DCD in the first grade. Of the 773 children, 395 (50.8 %) were boys and 380 (49.1 %) were girls. The mean DCDQ total score for these 773 children in the first grade was 39.8 ± 5.1. The missing values of the SDQ total difficulties score were found in 18, 84, 91, and 86 cases in the first to fourth grades, respectively, with the response rate remaining high (88.2–97.6 %) across the four time points. High response rates were also observed for the ASSQ (97.8 %) and the ADHD-RS (97.6 %) in the first grade (Table 1).

To identify the optimal number of trajectories for emotional and behavioral problems, we estimated models with one to six classes with a linear growth curve model (see Supplementary fig. 2). The BIC and ABIC values continued to decrease, but the rates of decrease for models with four or more classes were very small (see Supplementary fig. 3). The p-values of BLRT remained below.001 for all of the estimated class models. The p-values of the LMR-LRT were less than.05 for a model with up to four classes. On the basis of these results, we selected the four-class solution as the optimal LCGA model for our data. The information used to assess the fit of each model is shown in Table 2. Class 1 (n = 44, 6.0 %) comprised children whose SDQ total difficulties scores were within the clinical range in the first grade and the SDQ total difficulties scores showed an increasing trend over time. Class 2 (n = 147, 19.3 % of children) comprised a group of children whose SDQ total difficulties scores were within the borderline range in the first grade. This subgroup continued to have the SDQ total difficulties scores within this range throughout all measurement periods. Class 3 (n = 313, 40.0 % of children) and class 4 (n = 267, 34.6 % of children) represented groups of children whose SDQ total difficulties scores were low in the first grade and continued to be within the normal range (i.e., below the borderline and clinical range) throughout all time points. Estimated mean plots for the four-class LCGA model are shown in Fig. 2. Characteristics of the members of each trajectory class are shown in Table 3. The proportions of missing values of the ASSQ total score and ADHD-RS total score were not significantly different in each class. The results of LCGA for the SDQ subscale (Emotional symptoms and Conduct problems) scores indicated three class models (see Supplementary table 3 and Supplementary fig. 4).

In the group without motor coordination difficulties, a four-class LCGA model similar to that in the suspected DCD group was identified (see Supplementary table 4 and Supplementary fig. 5). However, the SDQ total difficulties scores of each class were lower in the former group than those than those in the suspected DCD group. Additionally, children belonging to three classes out of the four classes (96.4 %) in the former group remained within the normal range at almost all time points. In addition, the proportion of children belonging to the class that remained within the clinical range was 3.5 % in the former group, which was lower than that in the suspected DCD group (see Supplementary fig. 5).

For the multinomial logistic regression analyses to investigate the influence of ASD and ADHD traits on poor prognosis patterns of emotional and behavioral problems, we chose class 4 as the reference class (Table 4) mainly because class 4 consistently had the lowest level of problems and was the only class that did not exceed the mean level of emotional and behavioral problems measured by the SDQ in the general population sample of Japanese school-aged children (Moriwaki & Kamio, 2014). The ASSQ total score (class 1: OR = 1.35, 95 % CI: 1.20–1.52; class 2: OR = 1.31, 95 % CI: 1.17–1.46; class 3: OR = 1.22, 95 % CI: 1.09–1.35) and ADHD-RS total score (class 1: OR = 1.55, 95 % CI: 1.42–1.70; class 2: OR = 1.46, 95 % CI: 1.35–1.59; class 3: OR = 1.28, 95 % CI: 1.20–1.37) were associated with all classes, indicating that higher levels of ASD and ADHD traits were associated with a higher probability of being assigned to classes 1, 2, or 3 compared with class 4. The DCDQ total score was only associated with class 1 (OR = 0.91, 95 % CI: 0.83–0.99), indicating that a greater severity of motor problems was associated with a higher probability of being assigned to class 1 compared with class 4 (lower DCDQ scores indicate higher severity of motor problems). Sex was not significantly associated with any class.

4. Discussion

To the best of the authors' knowledge, this is the first study to identify patterns of longitudinal changes in psychological problems

Table 1
Characteristics of participating students (N = 773).

	n (%)	Mean (SD)	Range
SDQ total difficulties score at 1st grade	755 (97.6)	10.4 (5.1)	0–30
SDQ total difficulties score at 2nd grade	689 (89.1)	10.6 (5.5)	0–35
SDQ total difficulties score at 3rd grade	682 (88.2)	10.1 (5.4)	0–28
SDQ total difficulties score at 4th grade	687 (88.8)	9.7 (5.7)	0–31
DCDQ total score at 1st grade	773 (100.0)	39.8 (5.1)	19–46
ASSQ total score at 1st grade	756 (97.8)	6.0 (6.1)	0–37
ADHD-RS total score at 1st grade	755 (97.6)	10.1 (8.4)	0–48

773 children were identified as cases with suspected DCD. The response rate for the SDQ remained high throughout the four time points. ADHD-RS, Attention-Deficit/Hyperactivity Disorder Rating Scale; ASSQ, Autism Spectrum Screening Questionnaire; DCDQ, Developmental Coordination Disorder Questionnaire; SD, standard deviation; SDQ, Strengths and Difficulties Questionnaire.

Table 2
Class determination values for the Strengths and Difficulties Questionnaire total difficulties score.

N of classes	BIC	ABIC	Entropy	LMR LRT (p-value)	BLRT (p-value)	Sample size per class
1	17,536.211	17,513.983	–	–	–	771
2	16,525.278	16,490.348	0.817	<.001	<.001	517/254
3	16,186.406	16,138.774	0.791	<.001	<.001	331/309/131
4	16,089.871	16,029.537	0.788	.010	<.001	313/267/147/44
5	16,075.301	16,002.266	0.803	.152	<.001	308/259/143/56/5
6	16,062.682	15,976.945	0.807	.480	<.001	312/251/126/59/19/4

Smaller BIC and ABIC values = better model fit, high entropy values (near 1.0) = successful convergence, significant LMR-LRT and BLRT results = the model provides a significant improvement in model fit compared with the model with one less class. BIC, Bayesian information criterion; ABIC, adjusted Bayesian information criterion; LMR LRT, Lo–Mendell–Rubin likelihood ratio test; BLRT, bootstrap likelihood ratio test.

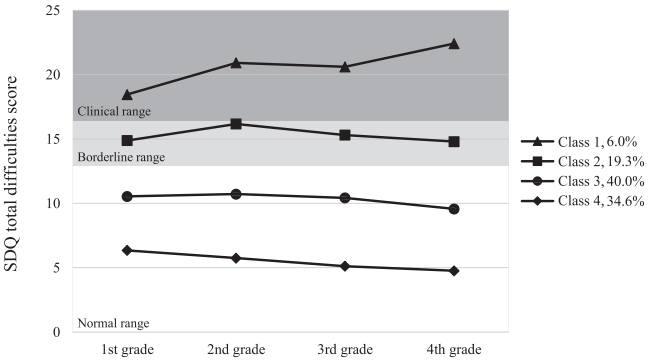

Fig. 2. Estimated mean plots for the four-class latent class growth analysis model. 6.0 % of children showed the SDQ total difficulties scores within the clinical range in the first grade and an increasing trend over time. N = 771. Number of students in each class: Class 1, n = 44; Class 2, n = 147; Class 3, n = 313; Class 4, n = 267. SDQ, Strengths and Difficulties Questionnaire.

Table 3
Characteristics of the members of each trajectory class.

	Class 1 n = 44		Class 2 n = 147		Class 3 n = 313		Class 4 n = 267	
	N (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	N (%)	Mean (SD)
Boys	29 (65.9)	–	85 (57.8)	–	164 (52.4)	–	113 (42.3)	–
Girls	15 (34.1)	–	62 (42.2)	–	149 (47.6)	–	154 (57.7)	–
DCDQ total score at 1st grade	44 (100.0)	35.1 (6.5)	147 (100.0)	38.6 (5.3)	313 (100.0)	39.6 (4.8)	267 (100.0)	41.5 (3.8)
ASSQ total score at 1st grade	44 (100.0)	15.1 (8.4)	144 (98.0)	10.1 (6.1)	304 (97.1)	6.1 (5.7)	264 (98.9)	2.4 (2.6)
ADHD-RS total score at 1st grade	44 (100.0)	22.5 (11.2)	142 (96.6)	17.0 (8.4)	303 (96.8)	9.8 (6.4)	264 (98.9)	4.4 (4.0)

The proportion of the missing values of the ASSQ total score and ADHD-RS total score were not significantly different in each class. ADHD-RS, Attention-Deficit/Hyperactivity Disorder Rating Scale; ASSQ, Autism Spectrum Screening Questionnaire; DCDQ, Developmental Coordination Disorder Questionnaire; SD, standard deviation.

among children with motor coordination difficulties extracted from a general population sample. Using longitudinal data from a community-based survey, we examined the trajectory patterns of emotional and behavioral problems over the four study years in school-age children with suspected DCD. Additionally, we investigated the association of co-existing ASD and ADHD traits with identified trajectory patterns.

We identified four distinct trajectories in the SDQ total difficulties scores in children with suspected DCD; two classes in the normal range, one class in the borderline range, and the other class in the clinical range, and each class maintained respective ranges. Importantly, 6 % of children who already had clinical levels of emotional and behavioral problems in the first grade showed a trend for problems to increase gradually over the years, whereas most children (94 %) showed stable patterns of these trajectories throughout the study period. This trend was also observed in the group without motor coordination difficulties. Furthermore, this trend in same age group matched the trends observed in a previous longitudinal study conducted in a large general population sample in Australia

Table 4
Predictors of the persisting pattern of Strengths and Difficulties Questionnaire total difficulties scores.

	OR	95 % CI	p-value
Class 1			
ASSQ	1.35	1.20–1.52	<.001
ADHD-RS	1.55	1.42–1.70	<.001
DCDQ	0.91	0.83–0.99	.032
Sex	0.74	0.27–1.99	.546
Class 2			
ASSQ	1.31	1.17–1.46	<.001
ADHD-RS	1.46	1.35–1.59	<.001
DCDQ	0.96	0.90–1.03	.288
Sex	0.91	0.46–1.80	.774
Class 3			
ASSQ	1.22	1.09–1.35	<.001
ADHD-RS	1.28	1.20–1.37	<.001
DCDQ	0.96	0.91–1.02	.210
Sex	0.81	0.46–1.43	.477

For ASSQ and ADHD-RS, bigger ORs indicate stronger associations of ASD and ADHD traits with being assigned to each class. For DCDQ, smaller ORs indicate stronger associations between motor problems and being assigned to each class. For sex, bigger ORs indicate stronger associations between being boys and being assigned to each class. The ASSQ total score and ADHD-RS total score were associated with all classes, indicating that the higher the levels of ASD and ADHD traits, the higher the probability of being assigned to classes 1, 2, or 3 compared with class 4. ADHD-RS, Attention-Deficit/Hyperactivity Disorder Rating Scale; ASSQ, Autism Spectrum Screening Questionnaire; CI, confidence interval; DCDQ, Developmental Coordination Disorder Questionnaire; OR, odds ratio.

(Mulraney et al., 2020), suggesting no spontaneous remission of emotional and behavioral problems in children who do not receive sufficient intervention. However, in our sample with motor coordination difficulties, the proportion of children that were assigned to the class characterized by persistently elevated SDQ total difficulties scores was higher than that in our sample without motor coordination difficulties and that reported in the Australian study mentioned above (3.9 %; Mulraney et al., 2020). Thus, the high proportion of children with a poor prognostic trajectory in SDQ total difficulties scores was considered specific to children with motor coordination difficulties, which is a novel finding in the present study. These findings underscore the importance of assessing psychological conditions in children with motor coordination challenges in early school age to identify those who exhibit emotional and behavioral problems. Although we were unable to determine whether children received any care with the available data, given the poor prognostic trajectory of these children, it is imperative to develop and provide effective interventions promptly.

The results of our multinomial logistic regression analyses showed that children with higher ASD and ADHD traits were more likely to be assigned to trajectory classes representing higher SDQ total difficulties scores in this study. A previous large-scale cohort study reported that the presence of motor coordination difficulties at 7 years of age was a significant risk factor for emotional and behavioral problems at 9 years of age; however, the OR decreased after controlling for developmental difficulties, including ASD and ADHD traits (Lingam et al., 2012). The current findings support the results of this previous study, indicating that co-existing ASD and ADHD traits have a significant impact on the association between motor coordination difficulties and emotional and behavioral problems in school-age children. Previous studies have reported that ASD and ADHD are frequently comorbid in DCD (American Psychiatric Association, 2013; Blank et al., 2019), and that ASD and ADHD traits are strongly associated with emotional and behavioral problems in school-age children (Berenguer et al., 2018; Salazar et al., 2015; Yorke et al., 2018). Taken together, these findings underscore the importance of assessing co-existing developmental difficulties, including ASD and ADHD traits, in children with motor coordination difficulties, even in non-clinical community samples. Furthermore, interventions focusing on ASD and ADHD traits may be effective for improving psychological problems in this population.

Our results also revealed that 19.3 % of children with suspected DCD continued to exhibit a borderline range of emotional and behavioral problems, and this trend was not observed in the group without motor coordination difficulties. Additionally, the proportion of children in the trajectory class with a borderline range of emotional and behavioral problems in our sample with suspected DCD was found to be much higher compared with that observed in a general population sample (6.1 %; Mulraney et al., 2020). The cut-off score for the borderline SDQ total difficulties score is set at the 20th percentile for children in the community (Goodman, 1997). Moreover, in the previous study conducted in a general population sample described above, the trajectory of the class with borderline range problems descended between 6 and 10 years of age, then continued to decline into adolescence (Mulraney et al., 2020). However, in the present study, the trajectory for the borderline class did not exhibit a clear decreasing tendency. It is possible that the trajectory of children in the borderline group will turn upward as the observation period is extended. Therefore, in addition to children with clinical level problems, children who have borderline range problems in the first grade of elementary school also need to be followed carefully to monitor their prognosis. Furthermore, the majority of the sample in this study exhibited a normal range of emotional and behavioral problems throughout the study period, despite having movement coordination difficulties in the first grade. A previous study that focused on children with DCD that examined psychological outcomes in adolescence reported that greater mental well-being was associated with better self-esteem (Harrowell et al., 2017). It is necessary to investigate factors that negatively influence the association between motor difficulties and psychological problems as well as factors that contribute to resilience among school-age children with motor coordination difficulties.

The present study involved several limitations. First, we selected our sample of school-age children with motor coordination difficulties on the basis of the cut-off score for the original version of the DCDQ. Therefore, the applicability of the present results to a clinical sample with an established DCD diagnosis is uncertain. Additionally, some among the 439 cases (17.5 % of the population) who were excluded from our sample because of missing values or a lack of consent for participation may have had high DCDQ scores, and we cannot rule out the possibility that this impacted the current findings. Second, we did not use the semi-structured interview to ascertain cases of emotional and behavioral disorders, and instead relied only on parent-reported rating scales, possibly impacting the diagnostic accuracy. Further research should examine whether our results can be generalized to a smaller sample with a direct observation from a neutral third party. Third, the stability of trajectories of emotional and behavioral problems in the majority of children in the present study might have been influenced by participants' age. Because the present study tracked psychological challenges of school-age children only up to 10 years of age, further research should examine adolescent participants, given that adolescence is a critical period for the emergence of emotional and behavioral diagnoses (Bongers et al., 2004; Costello et al., 2005). Fourth, because of the limited information about variables other than those used as outcomes in this study, we were not able to examine other variables that could have affected the association between motor difficulties and mental health problems (e.g., self-esteem, academic ability, formal diagnosis of neurodevelopmental disorder, medication status, and access to psychological or therapeutic support). Fifth, measurement issues involved in the SDQ might have impacted the role of ASD and ADHD in the relationship between motor coordination difficulties and emotional and behavioral problems in the present study. The SDQ includes items related to attention challenges and emotional and behavioral problems that could be transdiagnostic symptoms across ASD and ADHD, in accord with reports of the predictive validity of the SDQ for ASD and ADHD (Russell et al., 2013). A further limitation is that recall bias affected the results, even in our prospectively-designed school survey, because we relied on the parent-reported SDQ requiring parental recollections of their child's behaviors. Finally, because this study was conducted in a single area in Japan, the results may not be generalized to populations with diverse languages, races, and cultures.

Despite these limitations, our study has several strengths. We analyzed emotional and behavioral problems longitudinally, with a focus on school-age children with motor coordination difficulties in a community-based sample. Because almost all children in the city attend national or public elementary schools, the present sampling method is similar to total population sampling. The low attrition rate was a further strength of this study. In addition, we used LCGA for the analysis, which is a person-centered approach. This approach allowed us to identify subgroups in terms of the stability and changes in problems, and suggested the need for early and comprehensive screening and support based on children's characteristics. The use of internationally-validated scales for the measurement of neurodevelopmental traits was a further strength of this study.

5. Conclusions

Using data from a prospective community-based school survey, we identified latent patterns for the trajectories of psychological challenges in children with motor coordination problems and confirmed the influence of ASD and ADHD traits on these trajectories. Our findings indicate the need for early intervention for emotional and behavioral problems in a subgroup of these children with elevated psychological problems in early elementary school, given the worsening trajectory pattern in this subgroup. Our findings also highlight the importance of assessing co-existing ASD and ADHD traits. Further investigations across a broader age range while considering the influence of other factors will be required to confirm the present results.

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CRediT authorship contribution statement

All authors participated in the study's conception and design, data analysis and interpretation, preparation and writing of the manuscript and in the final critical review after the conclusion of the study, with different contributions. **Misaki Mikami:** Conceptualization, Formal analysis, Funding acquisition, Writing – original draft. **Tomoya Hirota:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing. **Masaki Adachi:** Conceptualization, Data curation, Investigation, Formal analysis, Methodology, Writing – review & editing. **Michio Takahashi:** Conceptualization, Data curation, Investigation, Funding acquisition, Writing – review & editing. **Tomoko Nishimura:** Methodology, Formal analysis, Writing – review & editing. **Manabu Saito:** Project administration, Writing – review & editing. **Kazuhiko Nakamura:** Project administration, Funding acquisition, Writing – review & editing. **Junko Yamada:** Conceptualization, Supervision, Writing – review & editing.

Declarations of interest

None.

Data availability

Our datasets are not publicly available because analyses using the datasets are in progress but are available from the corresponding author on reasonable request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ridd.2022.104394.

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