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Original article

# Fine and gross motor skills predict later psychosocial maladaptation and academic achievement

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**Abstract**

*Background:* Difficulties in fine and gross motor skills are often overlooked as developmental problems, although approximately 6–13% of all school-age children have poor motor coordination. Understanding motor coordination is important from the perspective of school adaptation. This longitudinal cohort study aimed to determine whether fine and gross motor skills in preschool children predict later academic achievement and psychosocial maladaptation.

*Methods & Procedures:* Participants were 2,501 children from nursery and elementary schools (5–13 years old). The motor skills of preschool children were assessed by their nursery teacher immediately before entering elementary school. The Strengths and Difficulties Questionnaire and a standardized Japanese test were administered annually throughout elementary school.

*Results:* Early motor difficulties in preschool children had significant effects on their academic achievement and psychosocial maladaptation up until the sixth grade. Gross motor difficulties in preschool were associated with the later peer problems and worsened emotional symptoms.

*Conclusions:* Motor skills in preschool children are useful as a predictor of later psychosocial maladaptation and academic achievement.


*Keywords:* Coordination; Motor skills; Academic achievement; Psychosocial maladaptation

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## 1. Introduction

Fine and gross motor difficulties, such as manual and physical clumsiness, can be detected relatively easily in childhood. However, they are often overlooked as developmental problems despite an estimated prevalence of developmental coordination disorder (DCD) of 6–13% among all school-age children [1]. Children with poor motor coordination may exhibit psychosocial maladaptation in school life, and those with DCD often have negative self-perceptions and lower global self-worth [2]. It is likely that there are children who fulfill the diagnostic criteria of DCD in regular elementary school classes. However, poor motor skills in children are usually not considered to be relevant to psychosocial maladaptation. Understanding the development of motor coordination in elementary school children is nevertheless important from the perspective of school adaptation.

Many researchers have reported an overlap between DCD and problems associated with other conditions [3]. Motor problems are found not only in children with DCD but also among those with attention deficit hyperactivity disorder (ADHD), autism spectrum disorder, and specific language impairment [4–6]. ADHD, in particular, is strongly associated with motor difficulties [7]. Because many neurodevelopmental disorders are considered to appear on a continuous spectrum between presence and absence of the disorder, those who do not fulfill the diagnostic criteria but do have some characteristics of DCD may still exhibit considerable psychosocial maladaptation behaviors and poorer academic achievement in elementary school.

In such children without DCD, the overlap between motor difficulties and traits of other common neurodevelopmental disorders could significantly interfere not only with their school adaptation but also with their academic achievement. Grissmer et al. indicated that early fine motor skills predicted later reading skill and mathematic achievement in elementary school [8]. Moreover, gross motor skills were found to be associated with social skills and predict later school-age mental health problem scores in typically developing preschool-age children [9]. Piek et al. reported a strong relationship between early gross motor skills and later school-age cognitive development [10].

Children with DCD are also known to have higher levels of internalizing problems [11]. There is evidence that children with motor difficulties have more mental health problems, such as higher levels of anxiety and depression, than children without motor difficulties [9] despite not having received a diagnosis of DCD. A recent study reported a relationship between children's manual coordination abilities and the total Strengths and Difficulties Questionnaire (SDQ) score, suggesting a link between children's fine motor skills and mental health problems [12]. In several longitudinal studies, early motor difficulties were found to predict later mental health problems, especially internalizing problems in school-age children [9,13–15].

In addition to their influence on academic achievement and mental health, motor skill difficulties affect the everyday life of children in various other ways (e.g., everyday self-care, sports, peer relationships, and leisure activities). Motor skills require higher-order cognitive skills, and a strong relationship between these skills has been reported in typically developing children [16]. Social skills mediate the relationship between motor ability and internalizing symptoms in preschool children [17]. Furthermore, children at risk of DCD reported more symptoms of depression and more frequent verbal and relational victimization than did their peers [18]. Because peer problems in school-age children can be considered a mediating variable in the relationship between DCD and internalizing and externalizing problems [19] children with motor difficulties may be more likely to experience peer problems. Thus, motor difficulties increase the risk of problems in terms of mental health, social skills, and academic skills (e.g., attention, reading, and spelling) [20].

The above-mentioned studies indicate that fine and gross motor skills in preschool-age children are strongly associated with their later academic achievement and school adaptation. However, the results of previous research are not always congruent because some studies did not examine the relationship between motor and cognitive skills [16]. Furthermore, there is scarce research on whether both fine and gross motor difficulties are associated with later school adaptation and academic achievement using a longitudinal study design. Investigating whether problems with motor skills in childhood predict later psychosocial maladaptation and academic achievement can offer very important suggestions for child education.

The purpose of the present study was to determine whether fine and gross motor skills assessed by preschool nursery teachers predicted later psychosocial maladaptation and academic achievement in elementary school children. We used the Developmental Scale for Nursery Records (DSNR) [21] which has confirmed reliability and validity in Japan, and examined nine subscales—including those for fine and gross motor skills—using principal component analysis. We hypothesized that early motor difficulties would significantly affect academic achievement and psychosocial maladaptation.

## 2. Methods

### 2.1. Participants

This was a prospective longitudinal cohort study of children living in a suburban city in Japan who were

born between 2002 and 2007. This 7-year investigation was conducted with 2,243 children (females = 1,148, males = 1,095) from all nursery and elementary schools in the city; school children who did not attend nursery school were not included. Our survey at the elementary school involved all school children, regardless of whether or not they had attended nursery school. Data of children who did not attend nursery school were used only for the statistical analysis of the sample's representativeness, and data of 39.9% of the children who participated in the survey from nursery to elementary school were statistically analyzed. Of these children, 95.4% participated in all of our investigations over 4 years. Data from dropout participants were excluded from the analysis. Table 1 shows the number of participants after exclusion.

We refrained from collecting children's medical data and their socio-economic status (SES). As medical information is a very sensitive issue, we aimed to prevent parents' refusal to participate in the study by omitting medical information in the survey. However, developmental disabilities are a considerable confounding factor. Accordingly, our study did not include nursery and elementary school children who attended special education classes. Therefore, the sample likely includes few, if any, children with a confirmed diagnosis of intellectual and developmental disabilities.

The surveyed city in this study has a population of about 90,000 and exists within commuting distance of the megalopolis. The city has a large industrial and agricultural population, as well as citizens who work in the larger cities; therefore, the SES of families is diverse. Since our study included all nursery school children and their parents in the city, participants from all various social classes were included. However, no household in Japan is extremely poor because of the existence of a social welfare system. Additionally, the psychological load is high for individuals who disclose their personal household situation in Japan. Therefore, we aimed to reduce the dropout rates and prevent parents' refusal to participate by omitting the collection of SES data.

Using the data collected from elementary school children, we statistically verified whether those who had attended nursery school were significantly different from those who had not in terms of the mean of school adaptation (outcome) variables investigated in elementary school. A paired $t$-test indicated that problem behaviors were significantly higher in children who had attended nursery school than in those who had not ($t(5191) = 3.24$, $d = 0.09$). By contrast, academic achievement was significantly higher in children who had not attended nursery school than in those who had ($t(4487) = 9.09$, $d = -0.27$). However, the effect size was very small for both [22]. Therefore, we believe that the representativeness of the sample in this study was not problematic.

Table 1
Number of participants in the cohorts of each age group born between 2002 and 2007.

| Birth year | Age (grade) | Boys | Girls | Total |
|---|---|---|---|---|
| 2002 | 6–7 (1st) | 624 | 578 | 1202 |
| 2003 | 7–8 (2st) | 770 | 747 | 1517 |
| 2004 | 8–9 (3st) | 761 | 716 | 1477 |
| 2005 | 9–10 (4st) | 727 | 688 | 1415 |
| 2006 | 10–11 (5st) | 524 | 517 | 1041 |
| 2007 | 11–12 (6st) | 378 | 348 | 726 |
| Total | | 3784 | 3594 | 7378 |

### 2.2. Questionnaires

We assessed fine and gross movement using the DSNR [20] an evaluation scale of childhood development that was administered by the nursery teacher. It comprises seven subscales (35 items in total). On this children's behavior scale, all items were assessed by the nursery teacher on a scale of 0–2: 0 (cannot do by oneself), 1 (can do with help from another person), and 2 (can do by oneself). The reliability and validity of gross and fine motor skills scores on this scale have already been established in terms of internal consistency, factorial structure, and externality of criterion with the Developmental Coordination Disorder Questionnaire [23].

Participants' academic achievement was measured using a standardized Japanese test (Kyoukensiki Norm Referenced Test) [24]. We used the deviation scores in the subjects of Japanese language and mathematics, calculated from each score distribution in standardized samples of the Kyoukensiki Norm Referenced Test.

Emotional and behavioral problems were assessed using the Japanese parent-report version of the SDQ [25] with scores ranging from 0 to 2 for each question item: 0 (not true), 1 (somewhat true), and 2 (certainly true). The peer problems, emotional symptoms, and conduct problems subscales of the SDQ were used in this study.

### 2.3. Procedure

We used a sequential cohort design and collected the data from six cohorts of children born between 2002 and 2007 (Fig. 1). We assessed the fine and gross motor skills of preschool children in all nursery schools in the city from 2007 to 2012. The preschool children were assessed using the DSNR by their nursery teacher immediately before entering elementary school. Thus, almost all of these children were 6 years old at the time of assessment (mean age = 6.4 years). Movement skills were assessed in February each year.

Written and oral informed consent was obtained from all participating nursery schools and teachers prior

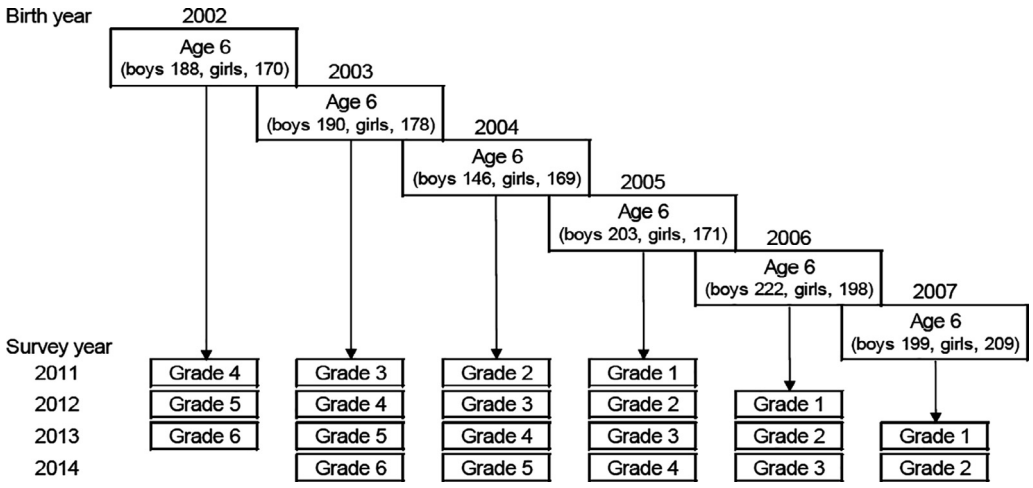


Fig. 1. Flowchart of the survey data.

to the study. They were informed that they could refuse or withdraw their consent to participate at any time during or after the study. In addition, written informed consent was obtained from all parents about using data of their children's motor skills.

After this, we continued following-up the children (first to sixth grade), who regularly attended classes between 2011 and 2014. Academic achievement and emotional/behavioral problems were assessed prospectively through the administration of annual questionnaires completed by teachers and parents in September, from 2011 to 2014. The SDQ was completed by the parents. Academic achievement was evaluated using a standardized test that children took from second to sixth grade.

In this study, oral informed consent was obtained from all children through the teacher. Additionally, parents were given the SDQ questionnaire and a survey form with an explanation of the survey through the teacher. The survey materials clearly stated that refusal to participate or withdrawal will not adversely affect the rights or welfare of the children who had agreed to complete the questionnaire. Completing the questionnaire was regarded as consent to participate. All data were anonymized to avoid personal identification. The anonymized data could later be re-identified with the participant using coded information.

### 2.4. Statistical analysis

We used Mplus version 7 [26] for the statistical analysis. We first calculated the descriptive statistics (mean and standard deviations) for the scores of fine and gross motor skills, academic achievement, peer problems, emotional symptoms, and conduct problems. To construct adequate predictive models, we conducted a linear latent growth curve modeling (LGCM) analysis of the collected data within the framework of structural equation modeling (Fig. 1). This analysis enables a researcher to test for differences in developmental trajectories across time using longitudinal data. More noteworthy, it can describe individual differences in changes over time in explanatory variables (i.e., fine and gross motor skills). In this model, the independent variables were fine and gross motor skills as measured by the DSNR subscales. The intercept factor indicates the default value of school adaptation in the first grade of elementary school. The slope depicts the linear trajectories of school adaptation from the first to the sixth grade.

This research adopted a sequential cohort design. This design can be applied as a profile across the full grade range, using responses from different grade cohorts to determine the existence of a common developmental trend or growth curve [27]. We integrated 4 years of data from six cohorts (including first to sixth grade). Then, the integrated cohort data for 4 years was used to estimate the linear trajectories of school adaptation from first to sixth grade. Thus, this trajectory analysis spanned a 6-year age-range, from age 6 to 12, using only 4 years of longitudinal data (Fig. 1). The dependent variables were later academic achievement (a deviation score of an academic achievement test) and peer problems, emotional symptoms, and conduct problems (subscale scores of the SDQ), which were analyzed separately.

## 3. Results

### 3.1. Descriptive statistics

Table 2 shows the descriptive statistics (mean and standard deviations) for the scores of fine and gross motor skills, academic achievement, peer problems, emotional symptoms, and conduct problems. Tables 3–6 show the correlations between motor skills in nursery school and school adaptation (academic achieve-

Table 2
Descriptive statistics (mean and standard deviations) for scores of fine motor skills, gross motor skills, academic achievement, peer problems, emotional symptoms, and conduct problems.

| | Fine Motor | | Gross Motor | | Academic Achievement | | Peer Problems | | Emotional Symptoms | | Conduct Problems | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Boys | | | | | | | | | | | | |
| Nursery School | 6.85 | 1.35 | 5.69 | 0.68 | – | – | – | – | – | – | – | – |
| Grade 1 | – | – | – | – | – | – | 6.04 | 1.68 | 5.98 | 1.71 | 6.49 | 2.09 |
| Grade 2 | – | – | – | – | 50.05 | 10.53 | 6.22 | 1.69 | 5.97 | 1.63 | 6.58 | 2.03 |
| Grade 3 | – | – | – | – | 50.30 | 10.04 | 6.05 | 1.49 | 5.81 | 1.47 | 6.48 | 1.90 |
| Grade 4 | – | – | – | – | 48.76 | 11.09 | 6.08 | 1.65 | 5.95 | 1.60 | 6.59 | 1.98 |
| Grade 5 | – | – | – | – | 48.54 | 10.45 | 6.09 | 1.55 | 5.88 | 1.52 | 6.47 | 1.82 |
| Grade 6 | – | – | – | – | 49.18 | 9.19 | 6.01 | 1.60 | 5.59 | 1.10 | 6.20 | 1.65 |
| Girls | | | | | | | | | | | | |
| Nursery School | 7.70 | 0.70 | 5.87 | 0.45 | – | – | – | – | – | – | – | – |
| Grade 1 | – | – | – | – | – | – | 5.70 | 1.05 | 5.89 | 1.53 | 5.69 | 1.33 |
| Grade 2 | – | – | – | – | 52.32 | 9.74 | 6.08 | 1.48 | 5.96 | 1.60 | 5.76 | 1.37 |
| Grade 3 | – | – | – | – | 51.89 | 8.58 | 6.05 | 1.46 | 5.77 | 1.41 | 5.79 | 1.37 |
| Grade 4 | – | – | – | – | 50.43 | 9.94 | 6.06 | 1.53 | 5.93 | 1.61 | 5.84 | 1.42 |
| Grade 5 | – | – | – | – | 50.19 | 9.71 | 6.05 | 1.55 | 5.79 | 1.31 | 5.75 | 1.22 |
| Grade 6 | – | – | – | – | 50.84 | 8.07 | 5.86 | 1.35 | 5.64 | 1.16 | 5.64 | 1.05 |
| Total | | | | | | | | | | | | |
| Nursery School | 7.26 | 1.16 | 5.78 | 0.58 | – | – | – | – | – | – | – | – |
| Grade 1 | – | – | – | – | – | – | 5.86 | 1.42 | 5.94 | 1.63 | 6.09 | 1.80 |
| Grade 2 | – | – | – | – | 51.14 | 10.23 | 6.15 | 1.59 | 5.97 | 1.62 | 6.17 | 1.78 |
| Grade 3 | – | – | – | – | 51.09 | 9.38 | 6.05 | 1.47 | 5.79 | 1.44 | 6.14 | 1.69 |
| Grade 4 | – | – | – | – | 49.59 | 10.57 | 6.07 | 1.59 | 5.94 | 1.61 | 6.23 | 1.77 |
| Grade 5 | – | – | – | – | 49.36 | 10.11 | 6.06 | 1.54 | 5.84 | 1.42 | 6.13 | 1.60 |
| Grade 6 | – | – | – | – | 49.98 | 8.71 | 5.94 | 1.49 | 5.61 | 1.13 | 5.94 | 1.42 |

Table 3
Correlations between motor skills and academic achievement.

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 3. | Academic Achievement, Grade 2 | 0.31*** | 0.17*** | – | | | |
| 4. | Academic Achievement, Grade 3 | 0.34*** | 0.19*** | 0.85*** | – | | |
| 5. | Academic Achievement, Grade 4 | 0.28*** | 0.19*** | 0.81*** | 0.85*** | – | |
| 6. | Academic Achievement, Grade 5 | 0.28*** | 0.18*** | 0.82*** | 0.83*** | 0.87*** | – |
| 7. | Academic Achievement, Grade 6 | 0.26*** | 0.19*** | 0.81*** | 0.83*** | 0.85*** | 0.88*** |

*Note:* Fine and gross moter measured at nursery school.
"1" indicates fine motor and "2" Indicates gross motor. ***$p<.001$

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Table 4
Correlations between motor skills and peer problems.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 3. | Peer Problems, Grade 1 | −0.20*** | −0.27*** | – | | | | |
| 4. | Peer Problems, Grade 2 | −0.10*** | −0.19*** | 0.36*** | – | | | |
| 5. | Peer Problems, Grade 3 | −0.18*** | −0.30*** | 0.42*** | 0.37*** | – | | |
| 6. | Peer Problems, Grade 4 | −0.20*** | −0.15*** | 0.34*** | 0.38*** | 0.33*** | – | |
| 7. | Peer Problems, Grade 5 | −0.15*** | −0.14*** | 0.25*** | 0.35*** | 0.48*** | 0.44*** | – |
| 8. | Peer Problems, Grade 6 | −0.13*** | −0.12** | 0.17*** | 0.21*** | 0.26*** | 0.41*** | 0.52*** |

Note: Fine and gross moter measured at nursery school.
"1" indicates fine motor and "2" Indicates gross motor. **$p<.01$, ***$p<.001$

ment, peer problems, emotional symptoms, and conduct problems) in each elementary school grade. The positive correlations between fine and gross motor skills were in the moderate range ($r = 0.30$, $p < .001$). Regarding the long-term stability of the dependent variables, there were strong positive correlations between academic achievements in each grade ($r = 0.81$ to $0.88$, all $ps < 0.001$). However, peer problems, emotional symp-

Table 5
Correlations between motor skills and emotional symptoms.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 3. | Emotional Symptoms, Grade 1 | −0.16*** | −0.14*** | – | | | | |
| 4. | Emotional Symptoms, Grade 2 | −0.14*** | −0.20*** | 0.30*** | – | | | |
| 5. | Emotional Symptoms, Grade 3 | −0.20*** | −0.25*** | 0.30*** | 0.30*** | – | | |
| 6. | Emotional Symptoms, Grade 4 | −0.20*** | −0.12*** | 0.29*** | 0.19*** | 0.38*** | – | |
| 7. | Emotional Symptoms, Grade 5 | −0.10** | −0.18*** | 0.13*** | 0.21*** | 0.30*** | 0.28*** | – |
| 8. | Emotional Symptoms, Grade 6 | 0.01 | −0.12** | 0.11** | 0.12** | 0.33*** | 0.26*** | 0.31*** |

Note: Fine and gross moter measured at nursery school.
"1" indicates fine motor and "2" Indicates gross motor. **$p$<.01, ***$p$<.001

Table 6
Correlations between motor skills and conduct problems.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 3. | Conduct Problems, Grade 1 | −0.07* | −0.06* | – | | | | |
| 4. | Conduct Problems, Grade 2 | −0.08** | −0.06* | 0.51*** | – | | | |
| 5. | Conduct Problems, Grade 3 | −0.03 | −0.05 | 0.48*** | 0.51*** | – | | |
| 6. | Conduct Problems, Grade 4 | −0.06* | 0.03 | 0.44*** | 0.38*** | 0.49*** | – | |
| 7. | Conduct Problems, Grade 5 | −0.05 | −0.02 | 0.28*** | 0.37*** | 0.43*** | 0.43*** | – |
| 8. | Conduct Problems, Grade 6 | −0.07 | −0.02 | 0.27*** | 0.29*** | 0.51*** | 0.39*** | 0.43*** |

Note: Fine and gross moter measured at nursery school.
"1" indicates fine motor and "2" Indicates gross motor. *$p$<.05, **$p$<.01, ***$p$<.001

toms, and conduct problems showed weak-to-moderate positive correlation coefficients. Thus, although the long-term stability of academic achievement was high, that of the other variables of school adaptation was low.

Regarding the relationship between motor skills and school adaptation, fine and gross motor skills were both significantly correlated with academic achievement and peer problems. Positive correlations between fine motor skills and academic achievement were in the moderate range ($r$ = 0.26 to 0.31). Peer problems had weak-to-moderate negative correlations with gross motor skills ($r$ = −0.12 to −0.30). The correlations between motor skills and emotional symptoms in each grade were weak, while motor skills and conduct problems were almost uncorrelated.

### 3.2. LGCM analysis

The LGCM analysis was performed to investigate the potential relationship between motor skills and school adaptation variables. The model fit was evaluated using a combination of fit indices (comparative fit index [CFI], root mean squared error of approximation [RMSEA], and standardized root mean residual [SRMR]). As for empirical criteria, the model fit was considered good if CFI ≥ 0.90, RMSEA ≤ 0.05, and SRMR ≤ 0.08 [28,29]. With the exception of academic achievement, the model revealed an adequate fit to the data for all the variables (academic achievement: CFI = 0.963, RMSEA = 0.073, SRMR = 0.116; peer problems: CFI = 0.954, RMSEA = 0.027, SRMR = 0.055; emotional symptoms: CFI = 0.918, RMSEA = 0.025, SRMR = 0.055; conduct problems: CFI = 0.984, RMSEA = 0.019, SRMR = 0.046). Regarding academic achievement, the RMSEA and SRMR data were slightly worse than the empirical criteria, which suggests that the changes in academic achievement in each child between second and sixth grade did not necessarily fit the linear changes assumed by the model. This problem can be solved by including the second-order slope model. However, the complexity of the model increases the difficulty of interpretation. Thus, we gave priority to ease of interpretation and did not include the second-order slope model.

Table 7 shows the standardized estimates of the correlations between the effects of fine and gross motor skills on the four factors of school adaptation. The trajectories of the coefficients displayed in Figs. 2 and 3 show the observed and estimated values of fine and gross motor skills on academic achievement, peer problems, emotional symptoms, and conduct problems from first to sixth grade, respectively (academic achievement was only assessed from second to sixth grade).

First, regarding academic achievement (Table 7), the coefficients for the intercepts were statistically significant for fine and gross motor skills. The coefficient for the slope was statistically significant for fine motor skills but not significant for gross motor skills. The trajectory of "mean" in the slope was significantly lower than zero ($M$ = −0.447, $p$ < .001, Fig. 3a). Second, regarding peer

Table 7
Results of linear latent growth curve modeling analysis (standardized estimates).

| | Academic Achievement | | | Peer Problems | | | Emotional Symptoms | | | Conduct Problems | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *B* | β | *p* | *B* | β | *p* | *B* | β | *p* | *B* | β | *p* |
| Mean | | | | | | | | | | | | |
| Intercept | **51.190** | | **<0.001** | **5.997** | | **<0.001** | **5.972** | | **<0.001** | **6.186** | | **<0.001** |
| Slope | **−0.438** | | **<0.001** | 0.013 | | 0.339 | **−0.055** | | **<0.001** | −0.026 | | 0.055 |
| Path Coefficient | | | | | | | | | | | | |
| Fine Motor→Intercept | **2.350** | **0.295** | **<0.001** | **−0.104** | **−0.147** | **0.001** | **−0.137** | **−0.191** | **<0.001** | **−0.173** | **−0.151** | **<0.001** |
| Fine Motor→Slope | **−0.148** | **−0.176** | **0.010** | −0.004 | −0.031 | 0.734 | 0.019 | 0.186 | 0.271 | 0.005 | 0.037 | 0.686 |
| Gross Motor→Intercept | **1.423** | **0.090** | **0.002** | **−0.482** | **−0.361** | **<0.001** | **−0.349** | **−0.256** | **<0.001** | −0.110 | −0.050 | 0.137 |
| Gross Motor→Slope | −0.091 | −0.055 | 0.406 | 0.043 | 0.158 | 0.149 | 0.030 | 0.160 | 0.287 | 0.007 | 0.024 | 0.779 |
| Intercept⇔Slope | **−2.379** | **−0.284** | **<0.001** | 0.001 | 0.006 | 0.988 | **−0.047** | **−0.547** | **0.001** | **−0.152** | **−0.674** | **<0.001** |

Note. Boldface text indicates statistically significant coefficients at the 0.05 level.

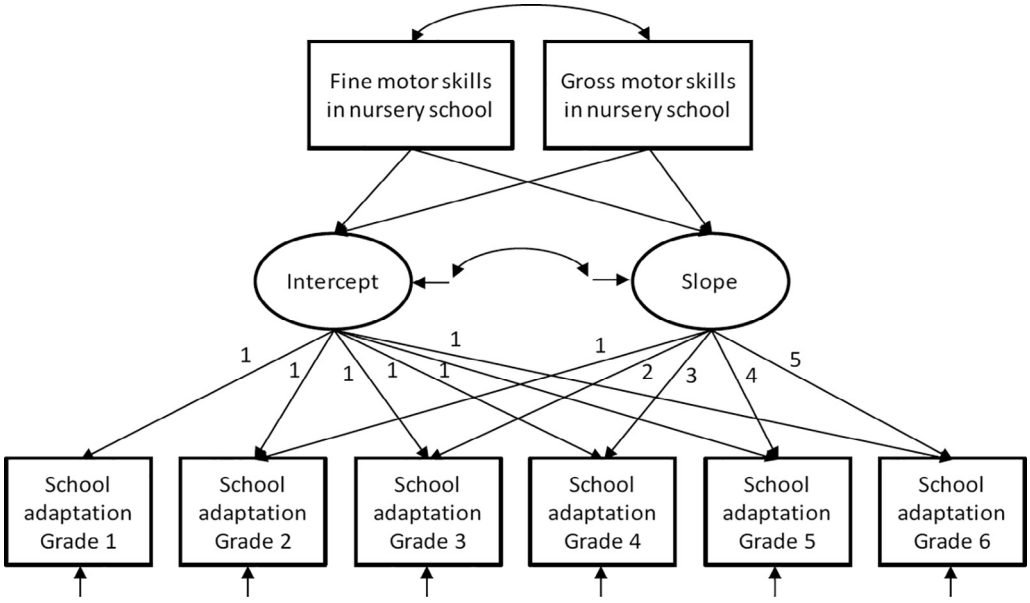


Fig. 2. Hypothetical model of the potential relations between motor skills and school adaptation.

problems, only the coefficient for the intercept was statistically significant for fine and gross motor skills (Table 7). The trajectory of "mean" in the slope was not statistically significant ($M = 0.077$, $p = .356$, Fig. 3b). Third, regarding emotional symptoms, only the coefficient for the intercept was statistically significant for fine and gross motor skills (Table 7). The trajectory of "mean" in the slope was not statistically significant ($M = -0.477$, $p = .130$, Fig. 3c). Finally, regarding conduct problems, the coefficient for the intercept was statistically significant only for fine motor skills (Table 7). The trajectory of "mean" in the slope was not statistically significant (M = −0.153, $p = .083$, Fig. 3d).

## 4. Discussion

The present study was conducted to determine whether the fine and gross motor skills of preschool children predicted their later academic achievement and psychosocial maladaptation (peer problems, emotional symptoms, and conduct problems) in elementary school. The LGCM analysis in our longitudinal investigation demonstrated that early motor difficulties in preschool children have considerable effects on the outcomes of academic achievement and psychosocial maladaptation up until the sixth grade. These results are in agreement with previous studies that revealed that motor skills predicted academic achievement and adaptation behaviors [8–10]. Thus, since psychosocial maladaptation and academic achievement in preschool children are more difficult to assess than in school children, the assessment of motor skills in early childhood is important in terms of predicting later psychosocial maladaptation and poor academic performance.

In this study, children who had fine motor difficulties upon entering elementary school had a consistently low

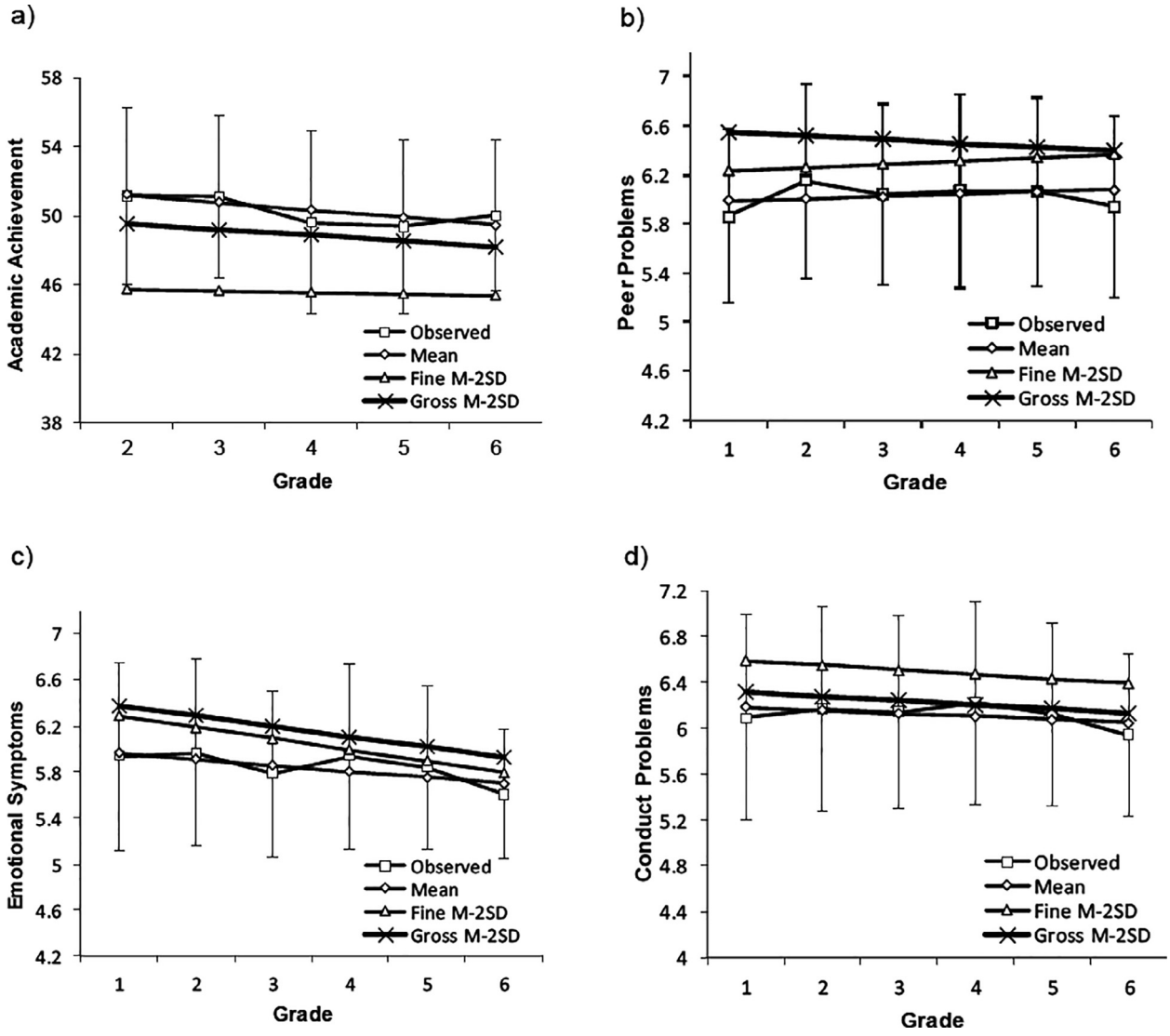


Fig. 3. Observed and estimated values of the trajectories of a) academic achievement, b) peer problems, c) emotional symptoms, and d) conduct problems on motor skills. Bars indicate 0.5 standard deviations (SD). "Observed" indicates the observation value; "mean" indicates that the values for both fine and gross motor skills were average; "fine M −2 SD" indicates that fine motor skills were 2 SD lower than the mean and that gross motor skills were at the mean; and "gross M –2 SD" indicates that gross motor skills were 2 SD lower than the mean and that fine motor skills were at the mean.

deviation score for academic achievement until the sixth grade. The effect of academic achievement on the intercept was much larger than the effect on the slope for academic achievement. As the LGCM model fit for academic achievement was slightly worse than the other measures, this finding should be carefully interpreted; however, even if this is taken into consideration, the impact of this large effect cannot be ignored. Thus, it is possible that, even though the effect on the slope was negative and the difference in academic achievement reduced, the difference remained until sixth grade. The results suggest that fine motor skills are an important predictor of academic achievement throughout elementary school.

The correlation coefficients between academic achievement scores from second to sixth grade were consistently strong and well established compared to the psychosocial maladaptation variables. Hence, there is a possibility that the variable of academic achievement is relatively insulated from the influence of the environment. Fine motor skills are associated with writing skills in elementary school children [30] which are likely to influence academic achievement continuously, although writing skills generally improve as the grade increases. Carlson et al. emphasized the effectiveness of interventions that focus on enhancing children's visual-spatial integration skills, given the impact of fine motor skills on academic achievement [31]. Note that motor abilities

are also affected by psychosocial problems, such as parents' attitudes toward raising children and poverty [32]. These psychosocial issues are one of the key complicating factors of academic achievement. Therefore, the interpretation of our data must also consider psychosocial development problems in early childhood.

Peer problems were more strongly influenced by gross than by fine motor skills. Children with gross motor difficulties at preschool faced consistent peer problems throughout elementary school. These results are consistent with a previous study that highlighted the importance of physical exercise for positive physical and psychological health outcomes [6,18]. It should be noted that the effect of gross motor skills on emotional symptoms showed similar trends, consistent with the findings of Piek et al. [9]. This suggests the following possibilities: 1) motor skills may worsen emotional symptoms directly and 2) movement skills may lead to peer problems and worsen emotional symptoms indirectly [11]. Piek and Dyck pointed out that children with movement difficulties tend to withdraw from physical play with their peers [6]. They also indicated that these children's problems with visual-spatial organization may influence their ability to accurately perceive emotional cues, such as facial expressions and body language [6]. The findings from this study suggest that physical movement plays an important role not only in enhancing emotional adjustment but also in maintaining peer relationships during school life.

Conduct problems exhibited a weak link only with fine motor skills, similar to the trend of academic achievement in this study. A previous study indicated that conduct problems predicted worse academic outcomes [33] while another reported that the relationship between motor difficulties and externalizing problems in school-age children was mediated in part by peer problems [19]. Motor difficulties have also been found to be a risk factor for peer victimization and depression [18]. Thus, it is possible that motor difficulties exacerbate not only peer problems and academic achievement, but also both internalizing and externalizing behavioral problems. Therefore, it is important for teachers to consider that poor motor skills in pre- and school children may lead to maladaptation issues.

We note the following limitations to this study and suggest some future research directions. First, although our data indicated that fine and gross motor difficulties at preschool predict later psychosocial maladaptation and academic achievement, we could not explain all intermediary factors affecting these two outcomes in this study. In addition, we only used parent-rated questionnaires to assess psychosocial maladaptation. Indeed, in a study on the psychosocial functioning of children with motor difficulties, Miyahara and Cratty highlighted the importance of using quantitative and qualitative methods, including case studies and naturalistic observations, as the questionnaire survey method is vulnerable to respondent bias [34].

Second, we need to consider the possibility that our results may have been influenced by children's psychosocial problems and characteristics of developmental disabilities. The problem of motor ability in early childhood may be part of other psychosocial development problems that coexist or are latent. In addition, although the present study excluded pre- and school children who attended special education classes, the characteristics of developmental disabilities are broadly spread across the spectrum in typically developing children. Thus, various characteristics of developmental disabilities may have influenced the results of this study [6]. Further research into more psychosocial development problems, not only in early childhood but also in school age, is needed using multiple longitudinal case and intervention studies that target potential mediating variables. Furthermore, even though this study included various social classes, families with young children attending kindergarten or not in daycare did not participate. Whether our results reflect the general characteristics of Japanese children needs to be examined in comparison with other similar studies.

Lastly, since aerobic physical activity in daily life was found to improve children's peer behavior, moodiness, and even academic achievement [35] future research is expected to examine effective motor skill interventions for pre- and school children. Combining therapy for motor coordination difficulties with interventions that help promote social interactions, self-esteem, and positive peer relationships may prove to be very effective [13].

## 5. Conclusion

In conclusion, we found that fine motor difficulties in preschool children carry the risk of later manifesting not only as peer problems, emotional symptoms, and conduct problems throughout elementary school, but also as low academic achievement beyond elementary school. We also found that gross motor difficulties at preschool were associated with later peer problems and emotional symptoms. That is, motor skills in preschool children are useful as a predictor of later psychosocial maladaptation and academic achievement. The LGCM model could adequately identify whether the trend of the problem was maintained, not only improved or worsened. Thus, the results have important implications for children showing maladaptation and academic achievement below the mean, when no interventions are implemented to improve fine and gross motor skills over 6 years. The assessment of motor skills in preschool children may enable the early detection of special educational needs, psychosocial maladaptation, or a combination of both, and ensure that appropriate treatment is provided to support these children.

## 6. Declarations

### 6.1. Ethics approval and consent to participate

Approval for this study was granted by the ethics committee of the Hamamatsu University School of Medicine (Approval No. 18-166). Participation in this survey was voluntary, and completing the questionnaire was regarded as consent to participate. Participants were not compensated for their participation.

## 7. Consent for publication

Not applicable.

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## Authors contributions

MK: designed the research, collected the data, and wrote and edited the manuscript; HI: analyzed and interpreted the data; YM, MH, SN, NT, AU, and MM: collected the data; AN: reviewed and edited the manuscript; MT: collected the data and supervised the research. All authors read and approved the final manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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