(i) Title page;

Association between small for gestational age and motor coordination difficulties in children aged 5-6 years: Insights from the Hokkaido Study on Environment and Children's Health

Maki TOJO[a], Hiroyoshi IWATA[a], Naomi TAMURA[a], Takeshi YAMAGUCHI[a], Kenji J TSUCHIYA[b,c], Satoshi SUYAMA[d], Taku OBARA[e,f], Akio NAKAI[g], Toshio YOSHIKAWA[a], Toyoki YAMAGATA[a], Mariko ITOH[a], Keiko YAMAZAKI[a], Sumitaka KOBAYASHI[a,h], Reiko KISHI[a]*

a Hokkaido University Center for Environmental and Health Sciences, Sapporo, Hokkaido, Japan.

b Research Center for Child Mental Development, Hamamatsu University School of Medicine, Hamamatsu, Japan.

c Osaka University United Graduate School of Child Development, Suita, Japan.

d Hokkaido University Hospital Center for Child Mental Health and Development, Sapporo, Hokkaido, Japan.

e Department of Preventive Medicine and Epidemiology, Tohoku University Tohoku Medical Megabank Organization, Sendai, Japan.

f Division of Molecular Epidemiology, Tohoku University Graduate School of Medicine, Sendai, Japan.

g Graduate School of Clinical Education & The Center for the Study of Child Development, Institute for Education, Mukogawa Women's University, Hyogo, Japan.

h Division of Epidemiological Research for Chemical Disorders, Research Center for Chemical Information and Management, National Institute of Occupational Safety and Health, Kawasaki, Japan.

[*]**Corresponding author**

Reiko Kishi, MD, PhD, MPH

Hokkaido University Center for Environmental and Health Sciences

North-12, West-7, Kita-ku Sapporo 060-0812, Japan

E-mail: rkishi@med.hokudai.ac.jp

Tel: +81-(0)11-706-4746

Fax: +81-(0)11-706-4725

(ii) Structured abstract (up to approximately 250 words) and 3-9 keywords;

Abstract

Background: Developmental coordination disorder (DCD) presents motor skill delays in early childhood and has been associated with later maladaptation, necessitating early intervention. However, research on the potential risk factors, particularly in preschool-aged children, remains scarce.

Aims: We aimed to explore the association between small for gestational age (SGA) and other factors and motor coordination problems in 5–6-year-olds from the Hokkaido Study on Environment and Children's Health Cohort.

Study Design: Prospective

Subjects: We analyzed data from >3,500 participants from the Hokkaido study, a prospective birth cohort, and assessed children aged 5–6 years.

Outcome measures: Participants underwent assessment with the Developmental Coordination Disorder Questionnaire Japanese version (DCDQ-J). We conducted linear regression analyses adjusted for variables such as the child's sex, maternal age, and maternal smoking history during pregnancy, while also examining the independent associations of each risk factor.

Results: Among the 3,883 children analyzed for SGA, children with SGA exhibited significantly lower DCDQ-J total scores than non-SGA children (mean difference: -2.25, 95% confidence interval [-4.19, -0.30], p=0.02). On the subscales, children with SGA demonstrated significantly lower “Control During Movement” scores than non-SGA children (mean difference: -0.96, 95% confidence interval [-1.78, -0.13], p=0.02). Furthermore, the child’s sex, maternal smoking, maternal age, and preterm birth were independently associated with DCD.

Conclusions: SGA was shown to be one of the risk factors for the manifestation of motor coordination difficulties in 5–6-years old children. In combination with other factors, screening for motor coordination difficulties in SGA children will be an important means of initiating appropriate interventions.

Keywords:

Small for gestational age, Developmental coordination disorder, Motor coordination difficulties, Preschool age, Cohort study, Japan

(iii) Text and acknowledgments;

Introduction

Developmental coordination disorder (DCD) requires early detection and intervention; therefore, the establishment of the potential risk factors associated with DCD is crucial[1-3]. DCD is classified within the realm of neurodevelopmental disorders and is diagnosed based on the manifestation of difficulties such as delays in acquiring motor skills and clumsiness [4, 5]. The lack of motor skills hinders age-appropriate daily activities, has long-term effects on productivity in academic performance and employment, and influences play and social activities [5, 6]. Moreover, DCD has been shown to be associated with both externalizing and internalizing problem behaviors [7, 8], and it has been suggested that these associations may be secondary impairments mediated by difficulties in participating in school activities and peer relationships [9]. Despite such a significant need for understanding and support, there is a lack of awareness of DCD within educational institutions [10]. Many parents of children with DCD have serious concerns about their children's current situations and future prospects [11].

According to the Diagnostic and Statistical Manual of Mental Disorders Text Revision published by the American Psychiatric Association (DSM-5TR), the reported prevalence of DCD in children aged 5–11 years is 5–8%. Additionally, prevalence rates of 7–8% have been reported in Canada, Sweden, and Taiwan. However, a 2022 survey in Japan [12], which randomly selected

2000 childcare facilities nationwide, revealed that only 0.2% of children were diagnosed with DCD, while 4.8% showed signs of motor coordination difficulties without diagnosis. However, it has also been reported that there is no significant difference between the worldwide prevalence of attention-deficit hyperactivity disorder, known for its high comorbidity with DCD [13], and its prevalence in Japan [14]. These findings indicate the potential under-recognition of DCD in Japan.

In children with DCD, 50–70% continue to experience coordination difficulties into adolescence[4]. Due to significant individual differences in early childhood motor skill acquisition, diagnosing DCD before the age of 5 years is atypical [4, 15]. However, considering the potential benefits of early intervention for improving developmental trajectories and preventing secondary consequences in at-risk children, diagnosing DCD or at least identifying motor coordination difficulties before a child enters elementary school is encouraged [2, 3].

Extensive research has been conducted on the risk factors associated with the development of DCD in children. Low birth weight and preterm birth have been identified as significant early risk factors for the development of DCD[1, 4, 16, 17]. Recently, small for gestational age (SGA), which has some overlap with low birth weight and preterm birth, has attracted attention. SGA infants can be identified at birth, and this early detection can have a positive impact on later neurodevelopment[18-22]. Faebo Larsen et al. investigated early risk factors for DCD in a study involving 33,354 mothers and their children from the Danish National Birth Cohort. In this study, SGA was defined as birth weight below -2 standard deviations (SD) relative to gestational age[23, 24]. The results indicated that male sex, preterm birth, and SGA were strong predictors of DCD at the age of 7 years[23]. In a cohort study conducted in three regions of Italy, risk factors for DCD were investigated in 803 children aged 8–11 years, revealing that SGA is a risk factor for DCD[25]. In this study, SGA was defined as a birth weight below the 10th percentile for gestational age. Both studies suggested that SGA is an independent risk factor for later DCD, distinct from low birth weight and preterm birth. However, neither study reported findings concerning the risk of DCD in preschool-aged children born as SGA. In Japan, Suyama et al. conducted a study on birth-related risk factors for DCD and reported that a child's sex and maternal smoking during pregnancy are associated with a higher likelihood of DCD in preschool-aged children [26]. However, the association between SGA and DCD has not been reported in Japan to date.

Head circumference (HC) serves as a metric for assessing central nervous system development and identifying neonates vulnerable to neurodevelopmental issues [27]. Due to the link between DCD and neurological development, a small HC at birth is deemed a potential risk factor. Prior research has indicated that infants with a small HC may experience negative impacts on later neurodevelopment, affecting motor skills and cognitive abilities [28] up to age 4.5 years and intellectual capacities [29] up to age 8. However, evidence regarding coordination difficulties in preschool-aged SGA children or those with a small HC is lacking.

Therefore, this study aimed to investigate the relationship between SGA and small HC and motor coordination difficulties in preschool-aged children (aged 5–6 years) in a Japanese birth cohort. One of the significant aspects of this study is that it was conducted using large-scale cohort data from Japan.

Materials and methods

Study participants

The Hokkaido Study on Environment and Children's Health is an ongoing prospective cohort study that was initiated in 2002. The details of this study have been described previously [30] [31]. The study population comprised women in their first trimester of pregnancy who visited one of the 37 affiliated hospitals or clinics in the study area (Hokkaido, Japan) and were enrolled between February 2003 and March 2012. Demographic characteristics, medical history, and obstetric history were obtained from the mothers at enrollment (first trimester of pregnancy) using a baseline questionnaire. Information on smoking during pregnancy was obtained using an additional questionnaire after childbirth. The initial cohort comprised 20,926 pregnant women, and the total number of eligible children was 20,945. We sent follow-up questionnaires, including the Japanese version of the Developmental Coordination Disorder Questionnaire (DCDQ-J), to children born between April 2008 and November 2011 during the academic year when they turned 5 years old, and obtained responses from 4,851 participants.

Figure 1 depicts the participant selection process from the Hokkaido Study on Environment and Children's Health, initially involving 20,945 participants. Those lacking essential information to determine SGA and small HC (birth weight, height, HC, gestational age, and sex of the infant) were excluded. Additionally, participants who were born as multiples or had Down's syndrome were excluded. Individuals without parity information were considered primiparous and were included. Furthermore, considering that the target age for DCDQ-J is ≥5 years, along with the purpose of focusing on preschool-aged children, individuals who were aged less than 60–85 months during the DCDQ-J assessment were excluded. Following these criteria, 3,883 and 3,848 children were included in the SGA and small HC analyses, respectively.

Definition of SGA and small HC

In this study, SGA was defined as having a birth weight and height below the 10th percentile relative to parity, infant sex, and gestational age[32]. The definition of SGA varies, and no single consensus exists[33]. Criteria such as birth weight less than the 10th percentile [25], below the 5th percentile[18], or below -2SD of weight [18, 23] are utilized. Some criteria consider both birth weight and height less than the 10th percentile [34] or less than -2SDs for both weight and height [35]. In this study, we refined the definition of SGA from a previous study in this cohort [36], which was based solely on gestational age, sex, and weight. By integrating birth height into our criteria [37], we aimed to identify factors of growth restriction with greater precision and capture more severe cases through a more stringent definition [33]. The Hokkaido Study was equipped to incorporate and validate definitions of SGA that included birth height, owing to its access to professionally measured birth height data from medical institutions. This was facilitated using a database furnished by the Japanese Paediatric Society[38]. Small HC was defined as a birth HC less than the 10th percentile of the reference according to gestational age and infant sex, following previous research guidelines [28].

Measurement tool: the Japanese version of the DCDQ-J

To assess motor coordination in preschool-aged children, we used the DCDQ-J[39]. The Japanese version was adapted for the Japanese population using the DCDQ 2007 and the recommended international guidelines[40] for measuring children's motor coordination impairments. The questionnaire comprises 15 items, and parents evaluate their child using the following 5-point scale: (1) "Not at all like your child;" (2) "A bit like your child;" (3) "Moderately like your child;" (4) "Quite a bit like your child;" and (5) "Extremely like your child." The total score ranges from 15 to 75 points, with lower scores indicating potential issues with motor coordination. While standardized cut-off scores for the total score are established in the DCDQ 2007[41], they have not been set for the DCDQ-J. Therefore, we conducted analyses using continuous variables. Additionally, as the interpretive guideline, we used the cut-off in the DCDQ 2007, which is for children aged 5–7 years; a total score of 46 or lower suggests or raises suspicion of DCD[41]. The DCDQ-J comprises three subscales. The first, "Control During Movement," includes six items pertaining to motor control, for example, "Your child throws a ball with control and accuracy." The "Fine Motor/Handwriting" subscale encompasses four items that gauge fine motor skills, illustrated by "Your child's writing or drawing keeps pace with peers." The "General Coordination" subscale comprises five items assessing overall movement coordination, such as "Your child enjoys and engages in sports or active games that demand proficient motor skills." To comprehensively assess the link between SGA and DCD, we analyzed each subscale in conjunction with the aggregate DCDQ-J score.

Covariates

Covariates in our statistical analysis included, based on prior research, the child's sex [4, 42], maternal smoking during pregnancy [26, 36], and maternal age at childbirth [25, 43]. Previous research from the ongoing Hokkaido Study identified male sex and maternal smoking during pregnancy as significant risk factors in 2020 [26]. Additionally, a 2021 study demonstrated that smoking during pregnancy mediated socioeconomic determinants, contributing to increased SGA incidence[36]. Smoking during pregnancy status is based on postpartum questionnaire responses, categorizing participants as "Smoked during pregnancy" or "Did not smoke during pregnancy".

In this study, the information of gestational age was used to identify SGA and small HC; therefore, gestational age itself was not included as a covariate to avoid multicollinearity. However, as previous research has indicated that preterm birth is a risk factor for DCD, we conducted a univariate analysis on the association between gestational age (≧37 weeks or below) and DCD, providing this as supplementary information in Supplemental Table 1. [1, 4, 16, 17].

Statistical analysis

The baseline research participants' characteristics were evaluated using descriptive analysis. As of 2024, given that a standard cut-off value for the Japanese version of the DCDQ[41] remains unestablished and focuses on observing differences in motor coordination characteristics rather than diagnosis in preschool-aged children, we have recorded the results as continuous variables. Consequently, we performed a linear regression analysis on the individual scores for "Control During Movement," "Fine motor/handwriting," and "General Coordination" in the DCDQ-J, in addition to the total score. We set the presence of SGA or small HC as the exposure variable. After conducting the univariate regression analysis, we implemented multivariate regressions adjusted for the child's sex, maternal smoking during pregnancy, and maternal age at childbirth. Referring to previous research and considering multicollinearity, the associations between SGA and DCDQ-J scores, as well as small HC and DCDQ-J scores, were analyzed separately. Statistical analyses were performed using R version 4.3.2 (R Development Core Team, Vienna, Austria;

https://www.R-project.org), and a *p*-value less than 0.05 indicated statistical significance.

Results

The present study encompassed data on 3,883 participants for SGA in relation to motor coordination issues and on 3,848 participants concerning small HC and its association with motor coordination challenges. Figure 1 illustrates a flowchart of the participants included in this study's analyses. Table 1 shows the characteristics of SGA and non-SGA children, as well as those with small HC and non-small HC. The proportion of SGA children according to weight and height was 2.9% of the total sample (N=3,883). The proportion of children with a small HC was 9.1% of the total sample (N=3,848). Infants born SGA and those born with weight and height in the appropriate range for gestational age, as well as those with a small HC and those with an HC in the appropriate range for gestational age, shared a median gestational age of 39 weeks. The median birth weight of SGA infants was 2,400 g, whereas that of non-SGA infants was 3,050 g. Regarding small HC, the median birth weight for infants with small HC was 2,760 g, whereas in infants who were non-small HC, the median birth weight was 3,060 g. Among SGA children, 9.7% (N=11) were born at or before 36 weeks of gestation, compared to 3.3% (N=125) of children not born SGA. Similarly, 3.4% (N=12) of children with small HC were born at or before 36 weeks of gestation, compared to 3.5% (N=122) of those without small HC.

The association between child's sex and the occurrence of SGA was examined using the Chi-square test. The results indicated that the association between child's sex and SGA was not statistically significant (p = 0.37). Similarly, the association between child's sex and the occurrence of small HC was also examined using the Chi-square test. The results showed that the association between child's sex and small HC was statistically significant ($p < 0.01$). These findings suggest that there may be no association between child's sex and SGA, but there may be an association between child's sex and small HC.

Table 2 presents the results of the univariate linear regression analysis of changes in DCDQ-J scores based on the presence or absence of SGA or small HC. Univariate linear regression analysis demonstrated that the total DCDQ-J score was 2.25 points lower in SGA children than in non-SGA children (p=0.02). Regarding the subscales, "Control During Movement" was 0.96 points lower in SGA children than in non-SGA children (p=0.02). However, no consistent trend was observed for "Fine Motor/Handwriting" and "General Coordination" scores based on the presence or absence of SGA. Regarding the presence or absence of small HC, no consistent trend was observed in either the total score or in each subscale of the DCDQ-J. For the effect sizes, the R^2 values for SGA and small HC in relation to the total DCDQ-J score and all subscales were below 0.01, indicating that the impact of these variables on DCDQ-J scores is relatively minimal. While SGA and small HC have a statistically significant effect on motor coordination issues, the magnitude of this effect is considered to be limited.

The results of the multivariate linear regression analysis are shown in Table 3. Factors considered, apart from SGA and small HC, included the child's sex, maternal smoking during pregnancy, and the mother's age at childbirth. Figure 2A and Figure 2B present the associations between SGA and small HC with DCDQ-J scores, adjusted for the covariates, based on the results of the multivariate linear regression analysis shown in Table 3. Estimated differences are displayed along with their 95% confidence intervals. The results revealed that even when accounting for the aforementioned factors, the total scores on the DCDQ-J were 2.27 points lower in SGA children than in non-SGA children (p=0.02). Regarding the subscales of DCDQ-J, the "Control During Movement" scores were 0.9 points lower in SGA children than in non-SGA children (p=0.03). Additionally, in SGA children, the score for "Fine Motor" was reduced by 0.67 points (p=0.049, listed as p=0.05 in Table 3) compared to those without SGA. In terms of small HC, children with small HC had total DCDQ-J scores 1.05 points lower than those in children without small HC. However, the 95% confidence interval ranged from -2.19 to 0.09, indicating no statistically significant difference. Additionally, consistent with the findings of the univariate linear regression analysis, the multivariate linear regression analysis revealed no consistent trends in DCDQ-J subscales based on the presence or absence of small HC. The results of the multivariate regression analysis, considering the child's sex, maternal smoking during pregnancy, and maternal age at childbirth, showed that even after adjusting for SGA and other variables, boys had DCDQ-J total scores that were 3.03 points lower (p<0.01). Additionally, children whose mothers did not smoke during pregnancy had DCDQ-J total scores that were 1.37 points higher (p<0.01), and for each additional year of mother's age at childbirth, DCDQ-J total scores decreased by 0.11 points (p<0.01). Similarly, after adjusting for small HC and other variables, boys had DCDQ-J total scores that were 3.09 points lower (p<0.01), children whose mothers did not smoke during pregnancy had DCDQ-J total scores that were 1.46 points higher (p<0.01), and each additional year of mother's age at childbirth was associated with a 0.11-point decrease in DCDQ-J total scores (p<0.01). These results suggest that, in addition to SGA, factors such as sex, maternal smoking during pregnancy, and maternal age significantly influence children's motor coordination.

However, considering the effect sizes, the R^2 values for SGA and small HC in relation to the total DCDQ-J score and all subscales were below 0.1, indicating that even for variables showing statistically significant differences, the magnitude of their impact should be considered limited.

The t-test results for the DCDQ-J scores based on the presence or absence of SGA and small HC are presented in Supplemental Table 2. Significant differences were observed for total DCDQ-J scores based on the presence or absence of SGA (p=0.02). Specifically, we found significant differences in the scores for "Control During Movement," indicating body coordination in motor activities (p=0.02). However, no significant differences were observed in the scores for "Fine Motor/Handwriting" and "General Coordination." Additionally, no significant differences were observed in the DCDQ-J total score or any subscale score based on the presence of a small HC.

In this study, based on previous research, we used the child's sex, maternal smoking during pregnancy, and maternal age at childbirth as covariates in the multivariate analysis. The results of the univariate regression analysis examining the independent associations between each variable and DCDQ-J scores are presented in Supplemental Table 1. Additionally, we assessed the independent association between preterm birth, which was excluded from the multivariate analysis due to concerns about multicollinearity with SGA, and DCDQ-J scores. The results are shown in Supplemental Table 1.

First, boys had DCDQ-J total scores that were 2.99 points lower than those of girls (p<0.01), fine motor scores that were 2.18 points lower (p<0.01), and general coordination scores that were 0.92 points lower (p<0.01). Next, children whose mothers smoked during pregnancy had DCDQ-J total scores that were 1.37 points lower than those of children whose mothers did not smoke (p<0.01), fine motor scores that were 0.62 points lower (p<0.01), and general coordination scores that were 0.44 points lower (p=0.02). Regarding the mother's age, for each 1-year increase in maternal age, the DCDQ-J total score decreased by 0.09 points (p=0.01), the fine motor score decreased by 0.04 points (p<0.01), and the general coordination score decreased by 0.02 points

(p<0.01). For preterm birth, when comparing children born at 36 weeks or earlier with those born at 37 weeks or later, the group born at 37 weeks or later had DCDQ-J total scores that were 2.71 points lower (p<0.01), control during movement scores that were 1.10 points lower (p<0.01), and fine motor scores that were 0.93 points lower (p<0.01).

Discussion

This study demonstrated the association between SGA and motor coordination difficulties in Japanese preschool-aged children from a prospective birth cohort using *t*-tests and regression analyses, suggesting that SGA is a risk factor for motor coordination difficulties during early childhood. We observed no statistically significant association between small HC and motor coordination difficulties in preschool-aged children. Therefore, our results suggest the importance of evaluating motor coordination difficulties at an earlier age in children born SGA. Additionally, other risk factors besides SGA were examined, and it was suggested that being male, maternal smoking during pregnancy, and maternal age at birth are associated with DCD in preschool-aged children.

One key finding was that SGA children had significantly lower mean DCDQ-J scores than non-SGA children, even after adjusting for variables such as the child's sex, maternal smoking during pregnancy, and maternal age at childbirth. Children born SGA particularly struggled in the "Control During Movement" subscale, indicating having difficulties in activities requiring body control, such as walking, running, jumping over obstacles, stacking objects, and throwing. This underscores the importance of early identification and intervention for motor coordination difficulties. Additionally, it was indicated that SGA children might also exhibit difficulties in "fine motor" tasks. This shows that they may struggle with tasks requiring hand movements and finger manipulation. It is considered advantageous to initiate training and support before the commencement of elementary school, where tasks such as writing and personal grooming become more frequent. Task-oriented approaches have the highest level of evidence and are recommended as methods to improve coordinated motor skills in children with DCD [15]. However, the association between SGA and fine motor skills is statistically weak, considering the large sample size of this study; thus, the necessity for intervention should be evaluated cautiously. It is advantageous to assess individual characteristics with subscale metrics such as the DCDQ and to formulate personalized support strategies crucial for mastering skills required in everyday life. Another key observation was that when compared to the cut-off value of 46 points used as a reference for the DCDQ 2007[41, 26], even SGA children scored 6.2 points higher than the cut-off value. This could be attributed to significant individual differences in the acquisition of motor skills among preschool-aged children, making it challenging to distinguish between developmental variations and actual coordination issues. Additionally, Asian individuals frequently exhibit greater dexterity than their European counterparts, who were the original focus of the questionnaire. This suggests the potential need for a higher cut-off value [44]. Independent of a diagnosis of DCD, it is advisable to conduct regular assessments and observations of motor coordination skills in SGA children to support optimal developmental outcomes.

This study aimed to investigate the association between SGA and small HC, and developmental coordination difficulties in early childhood. Our findings indicate that SGA is associated with DCD even after adjusting for covariates. However, it is important to recognize the presence of other risk factors when interpreting these results. Consistent with previous studies, this study also demonstrated independent associations between factors such as child’s sex, maternal smoking during pregnancy, and maternal age at childbirth., and preterm birth with scores indicating coordination difficulties. These results can be interpreted as follows: First, regarding sex, boys were found to have lower DCDQ-J scores than girls, indicating more significant motor coordination problems. This trend has been consistently reported in previous studies, with boys being known to be at higher risk for DCD [4, 25]. Next, regarding maternal smoking during pregnancy, children whose mothers smoked were found to have lower DCDQ-J scores. It is widely recognized that smoking during pregnancy negatively affects fetal development, which may also lead to motor coordination difficulties [26, 36]. Therefore, smoking cessation counseling during pregnancy should be emphasized as a critical intervention to support healthy child development. Furthermore, it was found that DCDQ-J scores slightly decreased as maternal age increased. The impact of advanced maternal age on a child's neurodevelopment has been the subject of various debates; however, higher maternal age may lead to relatively reduced nutrient and oxygen supply to the fetus, potentially affecting motor coordination [25]. Finally, preterm birth was also identified as a risk factor for DCD. Preterm birth is particularly associated with immature neurological development, which is known to influence motor coordination [1] [16]. In addition to SGA, continuous developmental monitoring and early intervention for preterm children are considered especially important. These factors may independently influence DCD, and it is also possible that multiple factors interact to amplify their effects. Therefore, it is essential to consider these factors comprehensively when assessing the risk of DCD.

Our findings are consistent with those of several prior studies. Research conducted by Faebo Larsen et al. on school-aged children (aged 7 years) found that being SGA is a risk factor for later DCD, aligning with our findings[23]. Similarly, studies on low birth weight, which frequently overlap with SGA, such as Deshmukh et al.'s study on school-aged children up to 10 years old, support our findings[17]. Scammon's growth curves [45] evidently show that motor neuron development, crucial for motor coordination, reaches approximately 80% and 100% by ages 5 and 12, respectively. Therefore, it is considered adequate to conduct screening for coordination difficulties around preschool age. For children born SGA, it will be desirable to conduct regular observations from preschool age (5–6 years) through the end of elementary school (approximately

12 years old).

This study boasts several strengths and expected external validity. First, the Hokkaido Study stands as Japan's inaugural prospective birth cohort study, boasting a robust sample size and comprehensive collection of children's growth and birth-related data. The cohort's profile has been previously outlined by Kishi et al. [30] [30, 31]. Second, the assessment team comprised child psychologists and experts in the DCDQ, as demonstrated in a prior study by Suyama et al. [26]. Furthermore, we utilized the validated Japanese version of the DCDQ 2007, as confirmed by Nakai et al. [39].

The delineation of SGA using both height and weight as opposed to weight alone warrants careful consideration across different studies. In one investigation, predictions of height at 18 years did not vary, whether based solely on weight or both weight and height [46]. Nonetheless, within neurodevelopmental research, it is acknowledged that such differences in SGA criteria could influence the prognosis of neurodevelopmental outcomes. In this study, we defined SGA using weight, height, gestational age, sex, and birth order (parity), focusing on DCD risk assessment. Additionally, supplementary data on the risk of DCD in children classified as below the 10th percentile for weight are presented in Supplemental Tables 3–6. Supplemental Table 3 shows the characteristics of SGA and non-SGA children defined by weight. Supplemental Table 4 presents the results of a univariate regression analysis of SGA and DCDQ-J scores in preschool children, while Supplemental Table 5 provides the results of a multivariable linear regression analysis adjusted for covariates. Supplemental Table 6 shows the results of t-tests for SGA and DCDQ-J scores. In all analyses, no significant differences were observed between SGA defined by weight and DCDQ-J scores at ages 5–6. While children classified as SGA showed a tendency toward motor coordination difficulties, motor coordination difficulties, statistical significance was not confirmed. This underscores the importance of vigilant monitoring of neurodevelopmental progress in children small for both height and weight at birth relative to their gestational age. Such insights bear crucial clinical implications for enhancing long-term neurodevelopmental outcomes in these children through early identification and intervention.

As a limitation of this study, although a statistically significant association was observed between SGA and motor coordination problems in early childhood, the effect size was small. This suggests that the impact of SGA and other variables examined in this study on motor coordination is limited. Therefore, when considering interventions and support, it is important to fully account for the possibility that other risk factors may interact and contribute to these issues. Further research is needed to comprehensively understand the risk factors for DCD.

In conclusion, our research findings are considered to have both clinical and practical implications. Particularly, the importance of early screening for motor coordination issues is emphasized for children born SGA, especially when both height and weight are below the expected levels at birth. This is mainly crucial for boys, as well as for those whose mothers smoked during pregnancy or were of advanced maternal age during childbirth. Future studies should explore whether the associations between SGA, other risk factors, and motor coordination difficulties are consistent across different large-scale populations and cohorts. Additionally, through longitudinal data collection and analysis, a deeper understanding of the link between these risk factors and motor coordination during early childhood can be achieved. This will enhance our comprehension of the neurodevelopmental patterns in children born smaller than expected for their gestational age and contribute to the development of tailored screening and intervention protocols.

Acknowledgments

We would like to express our sincere gratitude to all participants who took part in this study, as well as the hospitals and clinics that cooperated with us. We also extend our thanks to the staff who supported the Hokkaido Study on Environment and Child Health. Their dedication was indispensable to the completion of this research.

(iv) Author contributions;

Author contributions: Maki TOJO: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Software; Validation; Visualization;

Writing – original draft; Writing – review & editing. Hiroyoshi IWATA: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Supervision; Writing – original draft; Writing – review & editing. Naomi TAMURA: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Supervision; Writing– review & editing. Takeshi YAMAGUCHI: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Supervision; Writing – review & editing. Kenji J TSUCHIYA: Conceptualization; Funding acquisition; Investigation; Methodology; Resources; Supervision; Writing – original draft, Writing – review & editing. Satoshi SUYAMA: Conceptualization; Investigation; Methodology; Resources; Supervision; Writing – review & editing. Taku OBARA: Conceptualization; Funding acquisition; Methodology; Supervision; Validation; Writing – original draft, Writing – review & editing. Akio NAKAI: Conceptualization; Investigation; Methodology; Resources; Supervision; Writing – review & editing. Toshio YOSHIKAWA: Investigation; Methodology; Resources; Validation; Visualization; Writing – review & editing. Toyoki YAMAGATA: Investigation; Methodology; Resources; Writing – original draft, Writing – review & editing. Mariko ITOH: Conceptualization; Data curation; Investigation; Methodology; Resources; Writing – review & editing. Keiko Yamazaki:

Conceptualization; Funding acquisition; Data curation; Investigation; Methodology; Resources; Writing – review & editing. Sumitaka KOBAYASHI: Conceptualization; Funding acquisition; Investigation; Methodology, Resources; Supervision; Writing– review & editing. Reiko KISHI: Conceptualization; Funding acquisition; Investigation; Methodology; Project Administration; Resources; Supervision; Writing – original draft; Writing – review & editing.

Ethics

Written informed consent was obtained from all participants(the guardians of the children). The Institutional Ethics Board for Epidemiological Studies at Hokkaido University Center for Environmental and Health Sciences and Hokkaido University Graduate School of Medicine approved the study protocol (approval number: 14-27, on June 26th, 2014).

Data availability

The data used in this study are not suitable for deposition in public databases due to ethical constraints and specific legal frameworks in Japan. The Ethical Guidelines for

Epidemiology issued by the Japan Ministry of Education, Culture, Sports, Science, and Technology and the Ministry of Health, Labor, and Welfare restrict the public sharing of epidemiological data. Additionally, the Act on the Protection of Personal Information prohibits the public deposition of personal data. Therefore, any inquiries regarding access to data should be directed to rkishi@med.hokudai.ac.jp. This email address is managed by Professor Reiko Kishi, the Principal Investigator of the Hokkaido Study on Environment and Children's Health at the Center for Environmental and Health Sciences, Hokkaido University.

(v) Declaration of competing interest;

Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this study.

Funding

This work was supported by the Japan Agency for Medical Research and Development (AMED, Japan) (grant number JP19gk0110039).

(vi) Referenc

References

[1] Edwards J, Berube M, Erlandson K, Haug S, Johnstone H, Meagher M, et al. Developmental coordination disorder in school-aged children born very preterm and/or at very low birth weight: a systematic review. J Dev Behav Pediatr 2011;32:678-87.
[2] Lee EJ, Zwicker JG. Early identification of children with/at risk of developmental coordination disorder: a scoping review. Dev Med Child Neurol 2021;63:649-58.
[3] Zwicker JG, Lee EJ. Early intervention for children with/at risk of developmental coordination disorder: a scoping review. Dev Med Child Neurol 2021;63:659-67.
[4] Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR®): American Psychiatric Association; 2022.
[5] Harrowell I, Hollen L, Lingam R, Emond A. The impact of developmental coordination disorder on educational achievement in secondary school. Res Dev Disabil 2018;72:13-22.
[6] Barnett AL, Hill EL. Understanding motor behaviour in developmental coordination disorder: Routledge Taylor & Francis Group; 2019.
[7] James ME, Graham JD, Chirico D, King-Dowling S, Cairney J. Investigating the mediating role of internalizing and externalizing problems on physical fitness in children at risk for Developmental Coordination Disorder. Appl Physiol Nutr Metab. 2022;47:575-81.
[8] Tamplain P, Miller HL, Peavy D, Cermak S, Williams J, Licari M. The impact for DCD - USA study: the current state of Developmental Coordination Disorder (DCD) in the United States of America. Res Dev Disabil 2024;145:104658.
[9] Wagner MO, Bös K, Jascenoka J, Jekauc D, Petermann F. Peer problems mediate the relationship between developmental coordination disorder and behavioral problems in school-aged children. Res Dev Disabil 2012;33:2072-9.
[10] Miyahara M, Moebs I, Pocock T, Farquhar J. Experiences of activity limitations and participation restrictions in individuals with developmental coordination disorder/dyspraxia, their families, and service providers: a qualitative systematic review protocol. JBI Evid Synth 2020;18:1515-21.
[11] Reynolds JE, Alvares GA, Williams J, Froude E, Elliott C, McIntyre S, et al. Investigating the impact of developmental coordination difficulties across home, school, and community settings: findings from the Australian Impact for DCD survey. Res Dev Disabil 2024;147:104712.
[12] Ministry of Health Law, Japan. Ministry of Health, Labour and Welfare Report on the Designated Project for the Fiscal Year of Reiwa 4 on Comprehensive Welfare for People with Disabilities: Investigation for the Early Detection of Coordinated Movements and the Spread of Appropriate Support. 2022.
[13] Goulardins JB, Marques JCB, De Oliveira JA. Attention deficit hyperactivity disorder and

motor impairment: a critical review. Percept Mot Skills. 2017;124:425-40.
[14] Ikeno T, Kobayashi S, Baba T, Kishi R. Chui ketsujo・tadousei syougai(ADHD)no yubyoritsu to youiku kankyou ni kansuru bunken Review. “Review of the Prevalence of Attention Deficit Hyperactivity Disorder and Factors Related to Parenting Environments.” [Translated from Japanese by the present authors] Hokkaido journal of public health 2011;25(2):53-9. Japanese.
[15] Blank R, Barnett AL, Cairney J, Green D, Kirby A, Polatajko H, et al. International clinical practice recommendations on the definition, diagnosis, assessment, intervention, and psychosocial aspects of developmental coordination disorder. Dev Med Child Neurol 2019;61:242-85.
[16] Van Hoorn JF, Schoemaker MM, Stuive I, Dijkstra PU, Rodrigues Trigo Pereira F, van der Sluis CK, et al. Risk factors in early life for developmental coordination disorder: a scoping review. Dev Med Child Neurol 2021;63:511-9.
[17] Deshmukh AA, Sahu V, Deshpande MS. Prevalence of suspected Developmental Coordination Disorder and its association with preterm and low birth weight in 5–10-year old children. Med J Armed Forces India 2024;80:153-60.
[18] Strauss RS. Adult functional outcome of those born small for gestational age: twenty-six-year follow-up of the 1970 British Birth Cohort. JAMA 2000;283:625-32.
[19] Maciejewski E, Hamon I, Fresson J, Hascoet JM. Growth and neurodevelopment outcome in symmetric versus asymmetric small for gestational age term infants. J Perinatol 2016;36:670-5.
[20] Lundgren EM, Cnattingius S, Jonsson B, Tuvemo T. Intellectual and psychological performance in males born small for gestational age with and without catch-up growth. Pediatr Res 2001;50:91-6.
[21] Gutbrod T, Wolke D, Soehne B, Ohrt B, Riegel K. Effects of gestation and birth weight on the growth and development of very low birthweight small for gestational age infants: a matched group comparison. Arch Dis Child Fetal Neonatal Ed. 2000;82:F208-14.
[22] Arcangeli T, Thilaganathan B, Hooper R, Khan KS, Bhide A. Neurodevelopmental delay in small babies at term: a systematic review. Ultrasound Obstet Gynecol 2012;40:267-75.
[23] Faebo Larsen R, Hvas Mortensen L, Martinussen T, Nybo Andersen AM. Determinants of developmental coordination disorder in 7-year-old children: a study of children in the Danish National Birth Cohort. Dev Med Child Neurol 2013;55:1016-22.
[24] Marsal K, Persson PH, Larsen T, Lilja H, Selbing A, Sultan B. Intrauterine growth curves based on ultrasonically estimated foetal weights. Acta Paediatr 1996;85:843-8.
[25] Zoia S, Biancotto M, Caravale B, Valletti A, Montelisciani L, Croci I, et al. Early factors associated with risk of developmental coordination disorder in very preterm children: a prospective area-based cohort study in Italy. Paediatr Perinat Epidemiol 2022;36:683-95.
[26] Suyama S, Yagyu K, Araki A, Miyashita C, Itoh S, Minatoya M, et al. Risk factors for motor coordination problems in preschool-age children. Pediatr Int 2020;62:1177-83.
[27] Harris SR. Measuring head circumference: update on infant microcephaly. Can Fam Physician 2015;61:680-4.

[28] Selvanathan T, Guo T, Kwan E, Chau V, Brant R, Synnes AR, et al. Head circumference, total cerebral volume and neurodevelopment in preterm neonates. Arch Dis Child Fetal Neonatal Ed. 2022;107:181-7.
[29] Coronado R, Ruíz AM, Arjonilla JG, Roig-Quilis M. Concordance between a head circumference growth function and intellectual disability in relation with the cause of microcephaly. An Pediatr (Barc) 2015;83:109-16. Spanish.
[30] Kishi R, Kobayashi S, Ikeno T, Araki A, Miyashita C, Itoh S, et al. Ten years of progress in the Hokkaido birth cohort study on environment and children's health: cohort profile-updated 2013. Environ Health Prev Med. 2013;18:429-50.
[31] Kishi R, Araki A, Minatoya M, Hanaoka T, Miyashita C, Itoh S, et al. The Hokkaido Birth Cohort Study on Environment and Children's Health: cohort profile-updated 2017. Environ Health Prev Med. 2017;22:46.
[32] Kono Y. Outcomes of very low birth weight infants in Neonatal Research Network of Japan (NRNJ). J Jpn Soc Perinat Neonat Med 2020;56:203-12. Japanese.
[33] Schlaudecker EP, Munoz FM, Bardají A, Boghossian NS, Khalil A, Mousa H, et al. Small for gestational age: case definition & guidelines for data collection, analysis, and presentation of maternal immunisation safety data. Vaccine 2017;35:6518-28.
[34] Kagami M, Nakamura A, Inoue T, Kawashima S, Hara K, Fuke T, et al. Imprinting defects and copy number variations in short children born small for gestational age [Poster Presentation]. Horm Res Paediatr 2019; 91 (Suppl. 1): I–VI. Available from: https://abstracts.eurospe.org/hrp/0092/hrp0092rfc12.3.
[35] Finken MJJ, van der Steen M, Smeets CCJ, Walenkamp MJE, de Bruin C, Hokken-Koelega ACS, et al. Children born small for gestational age: differential diagnosis, molecular genetic evaluation, and implications. Endocr Rev 2018;39:851-94.
[36] Tamura N, Hanaoka T, Ito K, Araki A, Miyashita C, Ito S, et al. Mediating factors between parental socioeconomic status and small for gestational age in infants: results from the Hokkaido Study on environment and children's health. Matern Child Health J 2021;25:645-55.
[37] Jamshed S, Khan F, Chohan SK, Bano Z, Shahnawaz S, Anwar A, et al. Frequency of normal birth length and its determinants: a cross-sectional study in newborns. Cureus 2020;12:e10556.
[38] Itabashi K, Miura F, Uehara R, Nakamura Y. New Japanese neonatal anthropometric charts for gestational age at birth. Pediatr Int 2014;56:702-8.
[39] Nakai A, Miyachi T, Okada R, Tani I, Nakajima S, Onishi M, et al. Evaluation of the Japanese version of the Developmental Coordination Disorder Questionnaire as a screening tool for clumsiness of Japanese children. Res Dev Disabil 2011;32:1615-22.
[40] Blank R, Smits-Engelsman B, Polatajko H, Wilson P. European Academy for Childhood Disability (EACD): recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). Dev Med Child Neurol 2012;54:54-93.
[41] Wilson BN, Crawford SG, Green D, Roberts G, Aylott A, Kaplan BJ. Psychometric properties

of the revised Developmental Coordination Disorder Questionnaire. Phys Occup Ther Pediatr 2009;29:182-202.
[42] van der Vlugt ER, Verburg PE, Leemaqz SY, McCowan LME, Poston L, Kenny LC, et al. Sex- and growth-specific characteristics of small for gestational age infants: a prospective cohort study. Biol Sex Differ 2020;11:25.
[43] Palatnik A, De Cicco S, Zhang L, Simpson P, Hibbard J, Egede LE. The association between advanced maternal age and diagnosis of small for gestational age. Am J Perinatol 2020;37:37-43.
[44] Luo Z, Jose PE, Huntsinger CS, Pigott TD. Fine motor skills and mathematics achievement in East Asian American and European American kindergartners and first graders. Br J Dev Psychol 2007;25:595-614.
[45] Bogin L. Patterns of Human Growth, 2nd edition: Cambridge University Press; 1999.
[46] Karlberg J, Albertsson-Wikland K. Growth in full-term small-for-gestational-age infants: from birth to final height. Pediatr Res 1995;38:733-9. Erratum in: Pediatr Res 1996;39:175.

(vii) Figure legends*;

Figure 1. Flow diagram of the participants included in the statistical analysis selected from the Hokkaido Study on Environment and Children's Health.

SGA, small for gestational age; HC, head circumference; DCDQ-J, Developmental Coordination Disorder Questionnaire Japanese version.

Figure 2. Estimated differences in DCDQ-J scores associated with the presence of SGA (Figure 2A) or small HC (Figure 2B).

CI, confidence interval; SGA, small for gestational age; HC, head circumference.

Tables with their legends

Table 1. Characteristics of children and mothers according to the presence of SGA or small HC from the Hokkaido Study on Environment and Children's Health

	SGA			**small HC**		
	SGA (N=113)	Non-SGA (N=3770)	Overall (N=3883)	Small HC (N=350)	Non-small HC (N=3498)	Overall (N=3848)
Mother:						
Age at birth						
Median [IQR]	32.0 [29.0, 34.0]	32.0 [28.0, 35.0]	32.0 [28.0, 35.0]	31.0 [28.0, 34.0]	32.0 [28.0, 35.0]	32.0 [28.0, 35.0]
Smoked during pregnancy						
Smoked during pregnancy	29 (25.7%)	549 (14.6%)	578 (14.9%)	64 (18.3%)	504 (14.4%)	568 (14.8%)
Did not smoke during pregnancy	83 (73.5%)	3193 (84.7%)	3276 (84.4%)	283 (80.9%)	2968 (84.8%)	3251 (84.5%)

Child:						
Weeks at birth						
Median [IQR]	39 [38, 40]	39 [38, 40]	39 [38, 40]	39 [38, 40]	39 [38, 40]	39 [38, 40]
≦36	11 (9.7%)	125 (3.3%)	136 (3.5%)	12 (3.4%)	122 (3.5%)	134 (3.5%)
37≦	102 (90.3%)	3645 (96.7%)	3747 (96.5%)	338 (96.6%)	3376 (96.5%)	3714 (96.5%)
Sex						
Female	62 (54.9%)	1890 (50.1%)	1952 (50.3%)	215 (61.4%)	1722 (49.2%)	1937 (50.3%)
Male	51 (45.1%)	1880 (49.9%)	1931 (49.7%)	135 (38.6%)	1776 (50.8%)	1911 (49.7%)
Weight at birth						
Median [IQR]	2400 [2210, 2580]	3050 [2820, 3300]	3040 [2800, 3290]	2760 [2530, 2980]	3060 [2840, 3320]	3030 [2800, 3290]
Age (months) at answering DCDQ-J						
Median[IQR]	61 [60, 65]	61 [60, 65]	61 [60, 65]	61 [60, 65]	61 [60, 65]	61 [60, 65]
DCDQ-J Total						
Median[IQR]	53.0 [44.0, 61.0]	55.0 [48.0, 62.0]	55.0 [48.0, 62.0]	54.0 [47.0, 61.8]	55.0 [48.0, 62.0]	55.0 [48.0, 62.0]
DCDQ-J Control during movement						
Median[IQR]	21.0 [17.0, 23.0]	21.0 [18.0, 24.0]	21.0 [18.0, 24.0]	21.0 [18.0, 24.0]	21.0 [18.0, 24.0]	21.0 [18.0, 24.0]
DCDQ-J Fine motor						
Median [IQR]	15.0 [12.0, 19.0]	16.0 [13.0, 18.0]	16.0 [13.0, 18.0]	16.0 [12.0, 18.0]	16.0 [13.0, 18.0]	16.0 [13.0, 18.0]

DCDQ-J General coordination						
Median [IQR]	18.0 [15.0, 21.0]	18.0 [15.0, 21.0]	18.0 [15.0, 21.0]	18.0 [15.0, 21.0]	18.0 [15.0, 21.0]	18.0 [15.0, 21.0]

IQR, inter-quartile range in the 75th and 25th percentile

SGA, Small for Gestational Age; HC, Head Circumference; IQR, Interquartile Range; DCDQ-J, Developmental Coordination Disorder Questionnaire - Japanese version

Data set: Hokkaido Study on Environment and Children's Health Cohort

Table 2. Univariate linear regression analysis results for DCDQ-J in SGA patients and those with small HC

DCDQ-J	SGA								small HC						
	β	95% CI Lower	95% CI Upper	Std. Error	*t*	*Pr(>/t/)*		Effect Size (R_squared)	β	95% CI Lower	95% CI Upper	Std. Error	*t*	*Pr(>/t/)*	Effect Size (R_squared)
Total	-2.25	-4.19	-0.30	0.99	-2.26	0.02	*	<0.01	-0.72	-1.86	0.43	0.58	-1.23	0.22	<0.01
Control During Movement	-0.96	-1.78	-0.13	0.42	-2.27	0.02	*	<0.01	-0.38	-0.87	0.10	0.25	-1.55	0.12	<0.01
Fine Motor	-0.61	-1.30	0.08	0.35	-1.72	0.09	.	<0.01	-0.14	-0.54	0.27	0.21	-0.66	0.51	<0.01
General Coordinator	-0.68	-1.45	0.09	0.39	-1.73	0.08	.	<0.01	-0.20	-0.65	0.25	0.23	-0.86	0.39	<0.01

β, Estimated score difference due to the presence of SGA or small HC; DCDQ-J, Developmental Coordination Disorder Questionnaire - Japanese version; SGA, Small for Gestational Age; HC, Head Circumference; CI, Confidence Interval; Std. Error, Standard Error.

*P< 0.05, P< 0.1 as revealed using univariable linear regression analysis

Data set: Hokkaido Study on Environment and Children's Health Cohort

Table 3. Multivariate linear regression analysis results for DCDQ-J in SGA patients or those with small HC

Outcome	Predictors	SGA							Predictors	small HC						
		β	95% CI Lower	95% CI Upper	Std. Error	*Pr(>|t|)*		Effect Size (R_squared)		*β*	95% CI Lower	95% CI Upper	Std. Error	*Pr(>|t|)*		Effect Size (R_squared)
Total	SGA	-2.27	-4.20	-0.33	0.42	0.02	*	0.03	Small HC	-1.05	-2.19	0.09	0.58	0.07	.	0.03
	Child sex	-3.03	-3.68	-2.38	0.14	<0.01	***		Child sex	-3.09	-3.75	-2.44	0.33	<0.01	***	
	Did not smoke during pregnancy	1.37	0.46	2.29	0.20	<0.01	**		Did not smoke during pregnancy	1.46	0.54	2.38	0.47	<0.01	**	
	Mother's age at birth	-0.11	-0.17	-0.04	0.02	<0.01	**		Mother's age at birth	-0.11	-0.18	-0.04	0.04	<0.01	**	
Control During Movement	SGA	-0.90	-1.73	-0.07	0.42	0.03	*	<0.01	Small HC	-0.38	-0.87	0.11	0.25	0.13		<0.01
	Child sex	0.09	-0.18	0.37	0.14	0.51			Child sex	0.07	-0.35	0.21	0.14	0.64		
	Did not smoke during pregnancy	0.34	-0.05	0.73	0.14	0.09	.		Did not smoke during pregnancy	0.37	-0.47	0.07	0.20	0.07	.	
	Mother's age at birth	-0.04	-0.07	-0.01	0.02	0.00	**		Mother's age at birth	-0.05	-0.07	-0.01	0.02	<0.01	**	
Fine Motor	SGA	-0.67	-1.33	0.00	0.34	0.05	*	0.09	Small HC	-0.38	-0.76	0.02	0.20	0.06	.	0.09
	Child sex	-2.20	-2.42	-1.97	0.11	<0.01	***		Child sex	-2.21	1.98	2.43	0.11	<0.01	***	
	Did not smoke during pregnancy	0.61	0.30	0.92	0.16	<0.01	***		Did not smoke during pregnancy	0.65	-0.70	-0.26	0.16	<0.01	***	
	Mother's age at birth	-0.04	-0.06	-0.02	0.01	<0.01	***		Mother's age at birth	-0.04	-0.06	-0.02	0.01	<0.01	***	
General Coordination	SGA	-0.70	-1.43	0.11	0.39	0.08	.	0.02	Small HC	-0.29	-0.74	0.16	0.23	0.21		0.02
	Child sex	-0.93	0.67	1.19	0.13	<0.01	***		Child sex	-0.95	-1.21	-0.69	0.13	<0.01	***	
	Did not smoke during pregnancy	0.43	-0.59	-0.09	0.19	0.02	*		Did not smoke during pregnancy	0.45	0.08	0.82	0.19	0.02	*	

Mother's age at birth	-0.02	-0.05	0.01	0.01	0.14	Mother's age at birth	-0.02	-0.05	0.01	0.01	0.13

β, Estimated score difference due to the presence of SGA or small HC, adjusted for child sex (male), maternal smoking during pregnancy, and maternal age at child's birth

CI, Confidence Interval; SGA: Small for Gestational Age; HC: Head Circumference.

***P< 0.001, **P< 0.01, *P< 0.05, P< 0.1 as revealed using multivariable linear regression analysis

Data set: Hokkaido Study on Environment and Children's Health Cohort

Abbreviations

ADHD- Attention Deficit Hyperactivity Disorder

ASD - Autism Spectrum Disorder

DCD - Developmental Coordination Disorder

DCDQ - Developmental Coordination Disorder Questionnaire

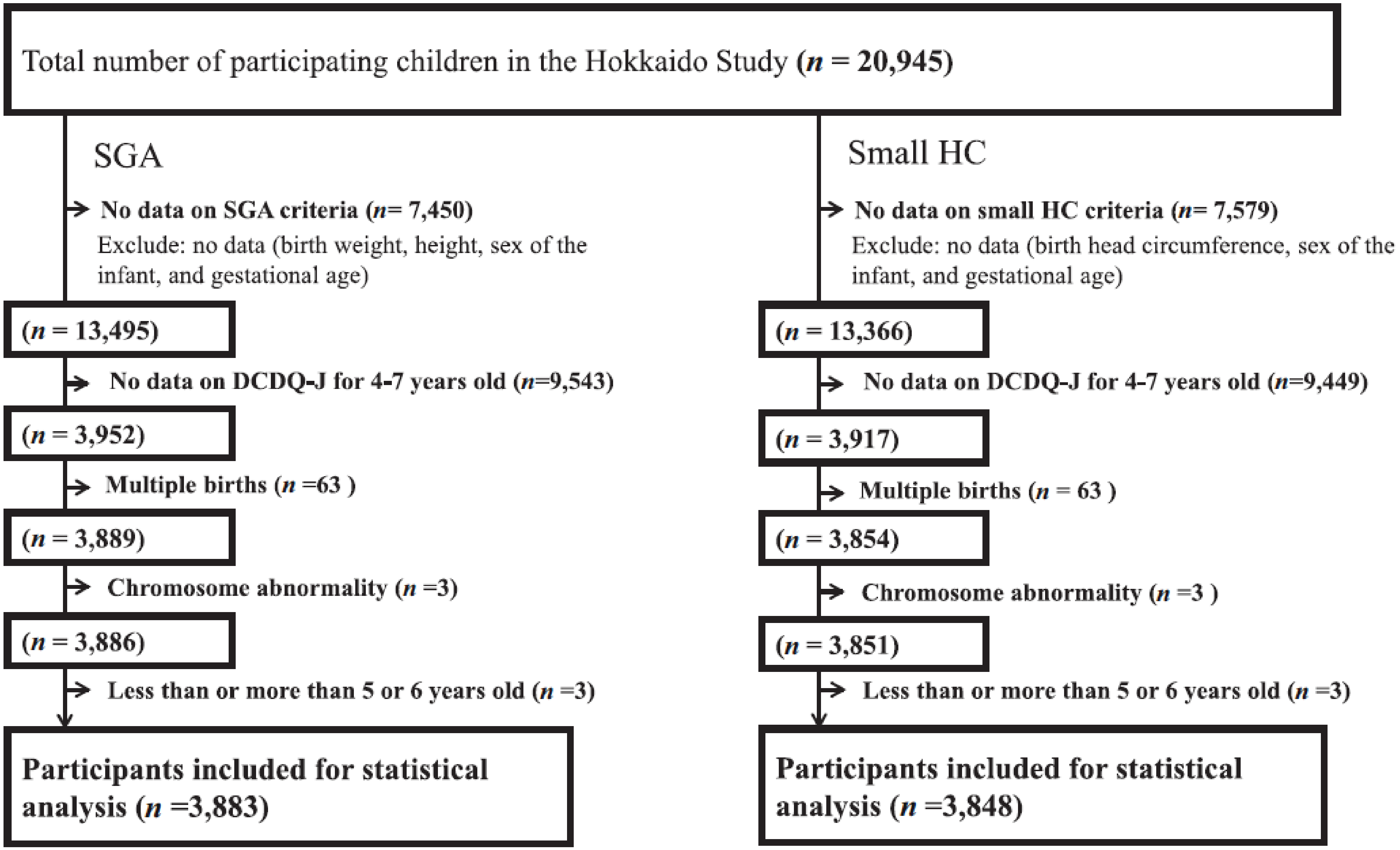
DCDQ-J - Japanese version of the Developmental Coordination Disorder Questionnaire

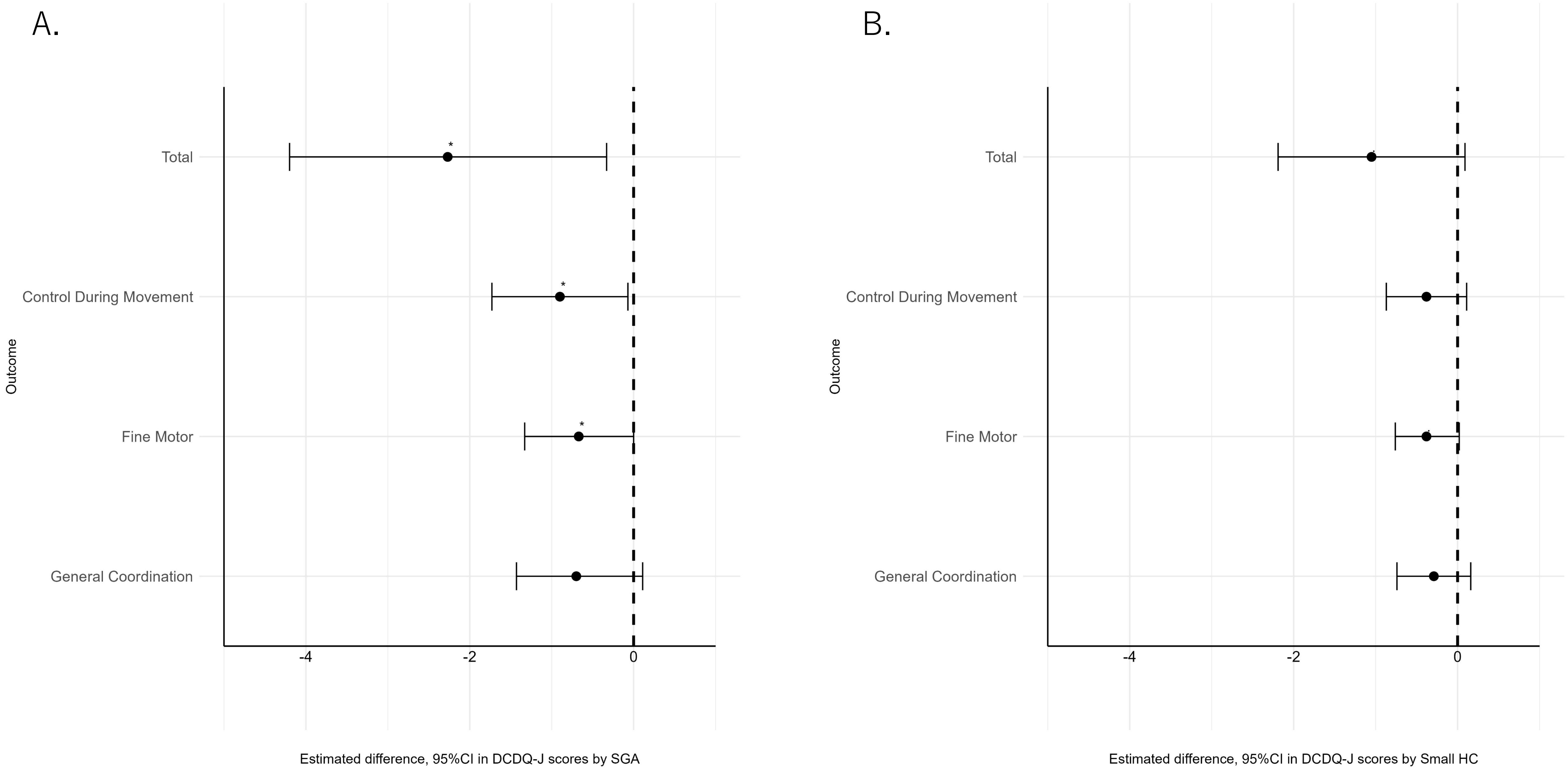
DSM-5TR - Diagnostic and Statistical Manual of Mental Disorders Text Revision

HC - Head Circumference

SGA - Small for Gestational Age

SD - Standard Deviations


Total number of participating children in the Hokkaido Study (n = 20,945)
SGA
No data on SGA criteria (n= 7,450)
Exclude: no data (birth weight, height, sex of the infant, and gestational age)
(n = 13,495)
No data on DCDQ-J for 4-7 years old (n=9,543)
(n = 3,952)
Multiple births (n =63)
(n = 3,889)
Chromosome abnormality (n =3)
(n = 3,886)
Less than or more than 5 or 6 years old (n =3)
Participants included for statistical analysis (n =3,883)
Small HC
No data on small HC criteria (n= 7,579)
Exclude: no data (birth head circumference, sex of the infant, and gestational age)
(n = 13,366)
No data on DCDQ-J for 4-7 years old (n=9,449)
(n = 3,917)
Multiple births (n = 63)
(n = 3,854)
Chromosome abnormality (n =3)
(n = 3,851)
Less than or more than 5 or 6 years old (n =3)
Participants included for statistical analysis (n =3,848)



A.
Total
Control During Movement
Fine Motor
General Coordination
Outcome
-4
-2
0
Estimated difference, 95%CI in DCDQ-J scores by SGA
B.
Total
Control During Movement
Fine Motor
General Coordination
Outcome
-4
-2
0
Estimated difference, 95%CI in DCDQ-J scores by Small HC