The association between obesity and sedentary behavior or daily physical activity among children with Down's syndrome aged 7–12 years in Japan: A cross-sectional study

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ABSTRACT

Background: An assessment of the adverse health effects of obesity in children with Down's syndrome (DS) is required to develop programs that facilitate the acquisition of healthy behaviors. Individuals with DS are often obese. These individuals must develop health related behaviors in childhood. For this reason, it is necessary to clarify the factors associated with obesity in children with DS.

Aims: This study had two purposes. The first was to assess the obesity and to evaluate the sedentary behavior (SB) and physical activity of Japanese elementary school children with Down's syndrome. The second was to investigate the association between obesity and SB or moderate to vigorous physical activity (MVPA).

Methods and procedures: Ninety-three children (male/female: 51/42) with DS in elementary school grades 1 to 6 (aged 7–12 years) participated in this study in Japan. Physical characteristics were obtained from the questionnaire completed by their parents. The questionnaire provided information on regular school checkups. SB and MVPA were evaluated using a triaxial accelerometer.

Results: Approximately 20% of the children with DS were obese. Nearly half of the children with DS achieved 60 min of MVPA. SB time was significantly longer in the upper grades (aged 11–12 years) than in the lower grades (aged 7–8 years). Comparing weekdays and weekend days, the middle (aged 9–10 years) and upper grades had significantly shorter MVPA times on weekend days. The frequency of obesity was significantly associated with shorter MVPA times in the lower grades and longer SB time in the middle grades.

Conclusions and implications: Children with DS may increase their SB time as their age group (grade category) increases. Increasing opportunities for MVPA during weekends may increase physical activity. The observed relationship between obesity and SB time or MVPA time may apply only to younger and middle grade children with DS. Further investigation is necessary to confirm these relationships.

1. Introduction

Obesity is a major social problem worldwide. Addressing the rising incidence of obesity is an urgent health concern (Bell and Bhat, 1992; Melville et al., 2005; Rubin et al., 1998). Individuals with Down's syndrome (DS) are often obese (Whitt-Glover, O'Neill and Stettler, 2006; Izquierdo-Gómez, Martinez-Gómez, Villagran, Fernhall and Veiga, 2015a; Basil et al., 2016; Bertapelli et al., 2016), and hence at a higher risk for a variety of lifestyle diseases. Major characteristics of DS include a short stature, mild intellectual disability, and poor muscle tone, all of which are risk factors for physical inactivity and obesity (Phillips and Holland, 2011). Developing health programs to promote the acquisition of healthy behaviors, beginning in childhood, are crucial to prevent obesity and the resulting increase in morbidity.

There are nearly 50,000 individuals with DS in Japan. Owing to advances in modern medicine, they enjoy an average life expectancy of over 60 years (Bittles and Glasson, 2004; Cupples, 2013). Extending their life expectancy further requires new health promotion strategies and initiatives aimed at chronic disease prevention, beginning in childhood. However, in Japan such efforts have been hampered by the lack of local...
epidemiological data on health and disease among those with DS. Japan’s high life expectancy and low obesity rates are well known. In the general population, according to the National Health and Nutrition Survey in Japan (The National Institute of Health and Nutrition, 2017), 26.9% of men and 15.6% of women are overweight, while only 5.9% and 4.0%, respectively, are obese. Obesity rates among otherwise healthy elementary school children ranged from 4.4% (school grade 1) to 9.7% (school grade 6) for boys, and from 4.4% (school grade 1) to 8.7% (school grade 6) for girls (The Ministry of Education, Culture, Sports, Science and Technology, 2017). However, the prevalence of obesity and its risk factors among adults and children with DS are unknown. Evaluating the adverse health effects of obesity among children with DS and investigating their associations with physical activity (PA) and other preventive factors are key steps in the development of effective health promotion programs for this population.

Regardless of age, regular PA is crucial for good health. The 71st World Health Assembly recently adopted targets of 10% and 15% reductions in physical inactivity by 2025 and 2030, respectively (Physical Activity Guidelines Advisory Committee, 2018). The World Health Organization (WHO) Global Recommendations on Physical Activity (2010) recommends that children engage in at least 60 min per day of moderate to vigorous physical activity (MVPA), in addition to generally reducing inactivity. The recommendations are the same for children with disabilities, insofar as possible.

There have been limited reports of sedentary behavior (SB) and PA in children with DS using a triaxial accelerometer. Whitt-Glover et al. (2006) examined physical activity in 3 to 10-year-old children with DS and their siblings in the United States. The authors reported that children with DS had less vigorous intense activity than their siblings. Esposito et al. (Esposito et al., 2012) reported that few children with DS (8–16 years of age) met the WHO recommendations (MVPA ≥60 min/day), and PA decreased with increasing age in the United States. Izquierdo-Gomez et al. (Izquierdo-Gomez et al., 2014) reported that adolescents with DS in Spain (11–20 years of age) reported an increase in SB time and a decrease in PA with age. This suggests that reducing SB time is important to increase physical activity. Furthermore, Izquierdo-Gomez et al. (Izquierdo-Gomez, Veiga, Villagra and Diaz-Cueto, 2015b) noted that social and environmental factors are associated with SB time in adolescence.

Children with DS have been reported to be more obese than children without DS (Whitt-Glover et al., 2006; Izquierdo-Gomez et al., 2015a; Basil et al., 2016; Bertapelli et al., 2016). In general, obesity is associated with PA (Ekland et al., 2004; Mitchell et al., 2013), and therefore children should be encouraged to reduce SB and increase PA. However, Esposito et al. (2012) reported that body fat percentage and body mass index (BMI) increased with age in children with DS. However, this was not associated with SB or PA. Izquierdo-Gomez et al. (2015b) reported that BMI and body fat percentage were not associated with PA in adolescent DS children aged 11–20 years.

Even though children with DS are reported to be more obese and have more SB and less PA, there is no assessment of obesity, BS, or PA in Japan for this population. Furthermore, factors associated with increased obesity, such as sex, age, SB or MVPA time, have not been examined. Therefore, this study had two purposes. The first was to assess obesity and evaluate SB and physical activity in Japanese elementary school children with DS. The second was to investigate the association between obesity and SB or MVPA.

2. Material and methods

2.1. Subjects and procedure

Children with DS in grades 1 to 6 of elementary school (aged 7–12 years) were recruited from 2015 to 2017, with the assistance of staff at School C and the Japanese DS Society (JDS). School C, located in Tokyo, is a special needs elementary school with a current enrollment of approximately 80 children with intellectual disabilities. The JDS is the largest DS advocacy organization in Japan, with a membership of approximately 5,700 individuals with DS as well as their families and supporters.

The study procedure was as follows. First, the researchers obtained the consent of the principal and a parent representative from School C, after an explanation of the study’s significance and methods both verbally and in writing. Next, consent was requested from all parents (or guardians) of children at the school, after providing them with verbal and written explanations. The executive board of the JDS was also requested to support the study, and received verbal and written explanations. Then, a study overview, invitation to participate, and recruitment form were mailed to all households of children with DS enrolled at School C. Parents and guardians who returned the recruitment form were then sent a consent form, and the researchers contacted them individually by phone to provide an additional explanation of the study. We obtained consent from the participants through the following steps. We explained the study method to the parents. Subsequently, the parents explained the study method to the child and confirmed the child’s consent. The consent form was signed by the parent and was agreed to by the child and their parent. A signed consent form was submitted and signed informed consent.

The research staff sent the parents who had consented, a full set of study materials: a questionnaire, a triaxial accelerometer with a cover and a rubber belt, and a reply envelope. The researcher called each parent to explain how to wear the triaxial accelerometer and how long it would be worn. The researchers explained that data with a triaxial accelerometer wearing time of less than 10 h/day would be excluded from the analysis. All children completed wearing the triaxial accelerometer.

Parents were asked to return the questionnaire and the triaxial accelerometer to the researchers at the end of a 2-week monitoring period. This study was approved by the Research Ethics Committee of the Tokyo Metropolitan University.

2.2. Measurement items and methods

2.2.1. Physical characteristics

Parents completed the questionnaire with the child’s sex, age, grade, height, and weight. Although the height and weight were obtained from the parent’s questionnaire, these values were measured once every two months by school nurses who were trained in anthropometry measurement procedure. They used a standardized method based on a manual by the Ministry of Education, Culture, Sports, Science and Technology in Japan. Note that the weight and height were not simultaneously measured with physical activity. These were obtained through school health check up events within 1–3 months from the physical activity measurement. Body mass index (BMI); (kg/m²) was calculated as weight (kg) divided by height squared (m²). Obesity was assessed according to the criteria of the Japanese Society for Growth and Development and the Japan Pediatric Endocrine Society. In the Japanese Infant BMI Percentile Curve, boys at or above the 87th percentile and girls at or above the 89th percentile are considered obese.

2.2.2. Physical activity

Physical activity was monitored using a triaxial accelerometer (Active style PRO HJA-750C, Omron Healthcare Co., Ltd., Kyoto, Japan) enclosed in a special cover, attached to the child’s waist using a rubber belt. This device’s validity has previously been demonstrated (Ohkawara et al., 2011; Hikihara et al., 2012). Children wore the device continuously for a two-week period during the normal school year, including weekend days, except when impractical (e.g., when swimming, changing clothes, or bathing).

The triaxial accelerometer data were imported into a computer once the device was returned at the end of the monitoring period. Data were analyzed only if available for more than three weekdays and more than one weekend day, in which the device was worn for at least 600 min/day (and removed for less than 120 min). The average time of SB and each PA...
intensity per day was calculated by METs recorded every 10 s as follows: the average number of weekdays and weekend days minutes spent in SB (METs ≤1.5) and MVPA (METs >3.0) were calculated for each individual, and then the average values were calculated. For all-day data, average values were calculated by weighting 5 weekdays and 2 weekend days (weighted data = \( (\text{average for weekdays} \times 5) + (\text{average for weekend days} \times 2) \)/7). For the purposes of this study, a “weekend day” was defined as any day on which the child did not attend school, regardless of whether it was a Saturday or Sunday.

### 2.3. Statistical analysis

On all-days, weekdays, and weekend days, we confirmed the relationship of SB and MVPA with each age group and grade categories, as well as gender. On all-days, weekdays, and weekend days, SB and MVPA interacted with the age groups and grade categories. On all-days and weekdays, MVPA interacted with gender. In this study because the sample size was not sufficient, we adopted grade categories. Therefore, data were analyzed at three grade levels: lower (grades 1 and 2: aged 7–8 years), middle (grades 3 and 4: aged 9–10 years), and upper (grades 5 and 6: aged 11–12 years). Gender was used as a covariate. The subject's physical attributes are presented as means (with 95% confidence intervals [CI]) or total numbers (with percentages [%]). The numbers (and %) of children who achieved the benchmark of 60 or more minutes per day of MVPA (‘MVPA60\(\text{+}\)’) are provided separately by grade level and day category (all-day, weekdays vs. weekend days). The proportion of children classified as obese was compared between grade levels using chi-square (\(\chi^2\)) tests, and apparent significant differences were adjusted using post-hoc Bonferroni correction for multiple comparisons. The same was performed for children classified as MVPA60\(\text{+}\). Percentages of children with MVPA60\(\text{+}\) on weekdays versus weekend days were compared using McNemar’s test.

SB and MVPA times are presented as means (95% CI) by grade level and day category. Corresponding analysis of covariance was used to compare various SB and MVPA times between weekdays and weekend days with sex, and weekend days accelerometer wearing times as independent variables. Analysis of covariance was used to compare SB and MVPA time between grade levels with sex, school type, and accelerometer wearing times as independent variables. Post-tests were performed using Bonferroni’s correction, showing combinations of groups where significant differences were found.

The association between BMI and SB or MVPA times was tested using multiple regression analysis, and the results are presented as standardized regression coefficients (\(\beta\)) with 95% CI. Since there were significant differences in accelerometer wearing times by grade level and day category, the following were adopted as covariates: sex, grade level, school type, and accelerometer wearing times. Statistical analyses were performed using IBM SPSS statistics 23.0 (IBM Co., Tokyo, Japan). Two-tailed significance was set at 5%.

### 3. Results

According to the criteria, all 93 children (male/female: 51/42) were included in the analysis. Table 1 lists their physical attributes. Obesity was observed in 18% of the children according to BMI. The prevalence of obesity did not differ significantly according to grade level. No child was classified as underweight.

Table 2 compares the percentages of children classified as having an MVPA60\(\text{+}\) level of activity by grade level and day category. The percentage of children engaged in MVPA60\(\text{+}\) was 51% (71% in the lower grades, 50% in the middle grades, and 43% in the upper grades, respectively).

SB and MVPA times are shown in Table 3 for each grade level and day category. SB time on weekdays and weekend days were 246 and 253 min in the lower grades, 287 and 265 min in the middle grades, and 301 and 308 min in the upper grades, respectively. SB time on weekdays and weekend days in the upper grades was longer than in the lower grades (\(p < 0.001\) for each). In the middle grades, the MVPA time on weekend days was significantly shorter than the MVPA time on weekdays (\(p = 0.004\)). Even in the upper grades, the MVPA time on weekend days was significantly shorter than the MVPA time on weekdays, 49 vs. 61 minutes (\(p < 0.001\)). On the other hand, there was no significant difference in SB and MVPA time on weekdays and weekend days for the lower grades.

The association between obesity and SB or MVPA time by grade level is shown in Table 4. In the lower grades, a higher BMI was significantly associated with shorter MVPA times on weekend days (\(p = 0.015\)). In the middle grades, a higher BMI was significantly associated with longer SB times on weekdays and weekend days (\(p = 0.018\), \(p = 0.009\), respectively). In the upper grades, there was no significant association between BMI and SB or MVPA time.

### 4. Discussion

This is the first report to assess obesity and daily SB and MVPA times in children aged 7–12 years with DS in Japanese elementary schools, and to identify factors associated with obesity. The percentage of children with DS who were obese was approximately 20%. Approximately half of the children achieved the MVPA60\(\text{+}\) target. These results did not

### Table 1. Shows physical characteristics of the sample.

|          | Lower \(n=17\) | Middle \(n=34\) | Upper \(n=42\) | \(p\)  | Multiple comparisons |
|----------|----------------|-----------------|----------------|-------|---------------------|
| Height (cm) | \(111.7 (108.9–114.4)\) | \(121.0 (118.6–123.5)\) | \(132.3 (130.1–134.5)\) | <0.001 | Lower < Middle, Lower < Upper, Middle < Upper |
| Weight (kg) | \(21.0 (18.2–23.9)\) | \(24.9 (23.1–26.7)\) | \(32.5 (30.2–34.9)\) | <0.001 | Lower < Upper, Middle < Upper |
| Body mass index (kg/m²) | \(16.7 (15.1–18.3)\) | \(16.8 (16.1–17.6)\) | \(18.4 (17.5–19.4)\) | 0.022 | Middle < Upper |
| Obesity | 3 (17.6) | 6 (17.6) | 8 (19.0) | 0.254 |

Values are mean (95% Confidence interval) or number (percentages). School grade indicates Lower, first and second graders; Middle, third and fourth graders; Upper, fifth and sixth graders in elementary school.

The relative body weight was calculated as [ body weight (kg) - standard weight for sex, and height (kg) ]/standard weight (kg) \times 100. Obesity participants were classified according to sex- and age-specific cut offs proposed by the Body Mass Index Percentile Chart for Japanese Children. 

\(p1\) compared between school grades by one-way ANOVA; apparently significant differences were corroborated by post-hoc Bonferroni correction (\(p < 0.016\); i.e., 0.05/3).

\(p2\) compared between school grades by chi-square (\(\chi^2\)) test; apparently significant differences were corroborated by post-hoc Bonferroni correction (\(p < 0.016\); i.e., 0.05/3).

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support the belief that children with DS were physically inactive in Japan. Obesity was associated with a long SB time or a short MVPA time. Physical activity may be less on weekend days and decrease with age. For health promotion from childhood, it is necessary to develop a health program that reduces SB time and increases MVPA time, for example, by increasing opportunities for spontaneous outdoor activities, such as play.

The prevalence of obesity among children in this study was 18% when evaluated in terms of BMI. The prevalence of obesity among children with DS in Japan may be lower than that in the US and Europe. Estimates of obesity, defined as a BMI at or above the 85th percentile, among children with DS in other countries, include 42% in the United States (n = 104, age range: 8–16) (Esposito et al., 2012) and 52% in Spain (n = 100, age range: 11–20) (Izquierdo-Gomez et al., 2014). Apart from ethnic differences, the lower obesity rate observed among Japanese children with DS may be attributable to the influence of lifestyle and environment. Nevertheless, our estimate continues to exceed that of the general elementary school population in Japan (4.4%–9.7%) (The Ministry of Education, Culture, Sports, Science and Technology, 2017), echoing similar findings from a recent literature review by Bertapelli et al. (2016). However, the question remains as to how obesity rating

### Table 2. The percentages of children who performed ≥60 min of MVPA by school grade subgroup and day type.

| Day type | All n = 93 | Lower n = 17 | Middle n = 34 | Upper n = 42 | p1 | Multiple comparisons |
|----------|------------|-------------|--------------|-------------|----|---------------------|
|          | n (%)      | n (%)       | n (%)        | n (%)       |    |                     |
| All-days |            |             |              |             |    |                     |
|          | 47 (50.5)  | 12 (70.6)   | 17 (50.0)    | 18 (42.9)   | 0.155 |                     |
| Weekdays |            |             |              |             |    |                     |
|          | 52 (55.9)  | 13 (76.5)   | 17 (50.0)    | 22 (52.4)   | 0.165 |                     |
| Weekend days | 33 (35.5) | 10 (58.8)   | 14 (41.2)    | 9 (21.4)    | 0.017 | Lower > Upper       |

Values are number (percentages).

School grade indicates Lower, first and second graders; Middle, third and fourth graders; Upper, fifth and sixth graders in elementary school.

p1 compared between school grades by chi-square (χ²) test; apparently significant differences were corroborated by post-hoc Bonferroni correction (p* < 0.016; i.e., 0.05/3).

p2 compared weekdays and weekend days by McNemar’s test.

### Table 3. Sedentary behavior and physical activity by school grade subgroup and day type.

| Day type | Lower n=17 | Middle n=34 | Upper n=42 | p1 | Multiple comparisons |
|----------|------------|-------------|------------|----|---------------------|
|          | Mean (95% CI) | Mean (95% CI) | Mean (95% CI) |    |                     |
| All-days | SB (min/day) | 248 (226–271) | 280 (256–305) | 305 (289–320) | 0.003 | Lower < Upper       |
|          | MVPA (min/day) | 75 (65–85) | 59 (52–66) | 58 (52–64) | 0.043 | Lower > Upper       |
| Weekdays | SB (min/day) | 246 (225–268) | 287 (261–312) | 301 (284–318) | 0.012 | Lower < Upper       |
|          | MVPA (min/day) | 76 (67–86) | 62 (54–70) | 61 (54–67) | 0.173 |                     |
| Weekend days | SB (min/day) | 253 (221–285) | 265 (238–292) | 308 (289–327) | 0.002 | Lower < Upper, Middle < Upper |
|          | MVPA (min/day) | 73 (58–87) | 53 (46–60) | 49 (43–55) | 0.003 | Lower > Middlegg Lower > Upper |
| Weekdays vs. Weekend days | SB p2 | 0.258 | 0.004 | 0.221 | 0.509 | 0.004 | <0.001 |

Values are mean (95% Confidence interval).

School grade indicates Lower, first and second graders; Middle, third and fourth graders; Upper, fifth and sixth graders in elementary school.

SB: Sedentary behavior, MVPA: Moderate to vigorous physical activity.

p1 compared between school grades by covariance (ANCOVA), and adjusting for sex, school type and all-day wearing time (or weekday wearing time, weekendday wearing time). Apparently significant differences were corroborated by post-hoc Bonferroni correction (p < 0.016; i.e., 0.05/3).

p2 compared between weekdays and weekend days by paired ANCOVA models. Analyses were adjusted for weekday wearing time, and weekend day wearing time in the single-subgroup models.

### Table 4. The correlations of time in sedentary behavior and physical activity with overweight and obesity, separately by school grade subgroup.

| day type | Physical activity status in intensity-specific categories | Lower n=17 | Middle n=34 | Upper n=42 | p |
|----------|--------------------------------------------------------|------------|--------------|-------------|----|
|          | β (95% CI) | p           | β (95% CI) | p           |    |
| Obesity  | All-days  | SB          | 0.26 (-0.02-0.06) | 0.342 | 0.65 (0.01-0.03) | 0.010 | -0.16 (-0.03-0.01) | 0.364 |
|          |           | MVPA        | -0.51 (-0.15-0.01) | 0.028 | 0.08 (-0.04-0.06) | 0.709 | -0.09 (-0.07-0.04) | 0.541 |
|          | Weekdays  | SB          | 0.20 (-0.03-0.06) | 0.447 | 0.64 (0.00-0.03) | 0.018 | -0.11 (-0.03-0.01) | 0.511 |
|          |           | MVPA        | -0.42 (-0.16-0.01) | 0.087 | 0.17 (-0.03-0.06) | 0.436 | -0.03 (-0.05-0.04) | 0.847 |
|          | Weekends  | SB          | 0.43 (-0.02-0.06) | 0.220 | 0.58 (-0.03-0.03) | 0.009 | -0.05 (-0.02-0.02) | 0.792 |
|          |           | MVPA        | -0.54 (-0.11-0.01) | 0.015 | -0.16 (-0.06-0.03) | 0.429 | -0.20 (-0.09-0.02) | 0.214 |

Values are standardized regression coefficients (β) and 95% Confidence interval. SB: Sedentary behavior, MVPA: Moderate to vigorous physical activity.

Obesity participants were classified according to sex- and age-specific cut-offs proposed by the Body Mass Index Percentile Chart for Japanese Children.

p Correlations of obesity with time were tested using multiple regression analysis adjusted for sex, school type, school grade, all-day wearing time (or weekday wearing time, weekend wearing time).
criteria should account for growth retardation, short stature, and other physical features characteristic of children with DS. There is a critical need to assist this population and establish healthy behaviors that can prevent obesity while they are in their childhood years.

Over half of the participants engaged in MVPA60 per day. The corresponding rates in previous studies include 21% in the United States (age range: 8–16 years) (Esposito et al., 2012) and 43% in Spain (age range: 11–20 years) (Izquierdo-Gomez et al., 2014). Nearly all the children in our study engaged in MVPA for at least 50 min per day. No previous studies conducted in Japan have evaluated MVPA60 among children with DS. However, based on the results of a study conducted among children in the general population, it has been estimated that healthy children aged 9–12 years engage in an average of 65.8 (SD ± 19.9) minutes of MVPA per day (Tanaka et al., 2018). Thus, the WHO recommendation that children should engage in at least 60 min of MVPA per day appears to be a realistic goal for Japanese children with DS.

Our finding that children in the higher grades engaged in more SB time is consistent with the findings of previous research (Izquierdo-Gomez et al., 2014; Phillips and Holland, 2011; Shields et al., 2009). However, the finding that children are more sedentary on non-school days differs from our finding that there was no significant difference in sedentary time between weekdays and weekend days (Izquierdo-Gomez et al., 2014). Children in the upper grades were less active than children in the lower grades, with significantly longer SB time and shorter MVPA. This trend, of less PA in older children, has been noted in similar studies with individuals with DS covering broader age ranges (Esposito et al., 2012; Izquierdo-Gomez et al., 2014). Esposito et al. (2012) suggested that this difference may be explained by the greater opportunity to engage in spontaneous activities (play) among younger children. Similar age-related differences are also likely to have been present among our study participants. In addition, children in our study were less active on weekend days than weekdays, which is similar to the findings of previous studies of healthy Japanese children (Adachi et al., 2006). In Spain, Izquierdo-Gomez et al. (2014) reported that adolescents with DS were less physically active on both weekdays and weekend days, whereas adolescents in general were more active on weekend days than on weekdays. It has been emphasized that social and environmental barriers are likely to be the reason for the lack of physical activity on weekend days in children with DS, despite the promotion of physical activity in the community as well as in school. We speculate that Japanese children with DS may not benefit from weekend activities related to school life. This includes walking to school or physical education at school, in addition to the potential impact of social and environmental barriers. On the other hand, there was no significant difference in MVPA time between weekdays and weekend days among children in lower grades. This may be attributed to their greater level of spontaneous play. In any case, there is a need to improve the social environment to promote physical activity through targeted health programs.

We observed different associations of SB and MVPA time with obesity according to grade level. Namely, obesity was associated with longer daily MVPA time among children in the lower grades (aged 7–8 years) (the subgroup with the highest level of MVPA) while obesity was associated with longer daily SB time among children in the middle grades (aged 9–10 years). Previous studies have failed to discover significant correlations between obesity and PA among children with DS aged 8–16 years (Esposito et al., 2012). We did not observe any significant correlation of obesity with SB or MVPA times among children in the upper grades (aged 11–12 years). The evidence collected by one review article of studies on healthy children did not support the conclusion that greater time spent in sedentary activities acts as a risk factor for obesity (Biddle, García Bengoechea and Wiesner, 2017a; Biddle, García Bengoechea, Pedisic, Bennie, Vergeer and Wiesner, 2017b). Our observed correlations between obesity and SB and MVPA times may only hold true for younger children with DS. Regardless, individuals with DS spend long periods of time in sedentary behavior (Agiovlasitis et al., 2019; Izquierdo-Gomez et al., 2014). The potential health benefits of reducing SB are high (Healy et al., 2008). Future studies should expand the age criteria to include people with DS in both adolescence and adulthood. An investigation of the health effects of PA using a longitudinal design is essential.

Our study has several limitations. First, no causal relationship between obesity and PA can be established due to its’ cross-sectional design. To clarify the health benefits of encouraging PA among children with DS, further evaluation is required by means of cohort and interventional studies. Second, data on height and weight for children were obtained from self-report questionnaires by parents. Although these values were measured by the school nurse through school health checkup events, a transcription error may have occurred. These anthropometric data were not measured simultaneously with physical activity. Third, PA was evaluated using an existing algorithm developed for use in the general population. Esposito et al. (2012) and Izquierdo-Gomez et al. (2014) noted that children with DS were quite likely to face constraints on PA and spend less time doing vigorous exercise than other children. Future research should consider potentially adopting monitoring devices that can evaluate non-locomotive behavior and different cutoff values for intensity measurements. Fourth, it was unclear which type of activity contributed most to reaching MVPA60+, as the child’s specific activity was not recorded. Likewise, restrictions in static movements due to differences in physical function were not considered. This means that their effects could not be verified. In addition, behavior records were not recorded separately for school time and after school time on weekdays in this study. In the future, as reported by Izquierdo-Gomez et al. (2014), it is essential to consider SB times and MVPA times during school time and after school time, especially for physical education classes, on weekdays. Fifth, PA may have been underestimated, as the triaxial accelerometer was removed during swimming and bathing. Despite these limitations, our study continues to possess considerable merit for its’ focus on the association between obesity and SB or MVPA times among Japanese children with DS. Children grow rapidly and develop their behaviors during the elementary school years. Our evidence showing the importance of developing programs to encourage PA outside the school (e.g., by increasing opportunities to go out on weekend days) will underlie future community-based health promotion strategies for Japanese children with DS. Furthermore, the results of this study, which revealed that children with DS have a higher proportion of obesity than children without DS, highlights the importance of childhood obesity prevention programs in less obese areas, such as Japan.

5. Conclusion

The percentage of children with DS who were obese was approximately 20%. Although approximately half of the children with DS achieved 60 min of MVPA, it was suggested that children with DS may increase their SB time and decrease their MVPA time with age. Increasing opportunities for MVPA during weekend days may increase physical activity. Shorter MVPA times in the lower grades and longer SB times in the middle grades was significantly associated with the frequency of obesity. Further investigation is required to confirm these relationships.

Declarations

Author contribution statement

E. Yamanaka: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

T. Inayama: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

I. Kita: Conceived and designed the experiments.

K. Ohokawara: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

K. Okazaki: Contributed reagents, materials, analysis tools or data.
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**Competing interest statement**

The authors declare no conflict of interest.

**Additional information**

No additional information is available for this paper.

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