Changes in student physical activity patterns from primary to secondary school: A 5-year longitudinal study

Kanzo Okazaki (kokazaki@mail.tohoku-gakuin.ac.jp)
Thoku-Gakuin University
Yuzo Koyama
Seikei Junior and Senior High School
Kazunori Ohkawara
University of Electro-Communications

Research Article

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Abstract

This study aimed to annually examine anthropometric characteristics and physical activity (PA) among children transitioning from fourth grade (9–10 years of age) to eighth grade (13–14 years of age) in Japan. The participants' (*n* = 63) age, grade, sex, weight, height, and body fat were recorded at baseline. Accelerometry assessments were performed annually following established protocols. Time spent on activities requiring ≥ 3 metabolic equivalents (METs), 1.6–2.9 METs, and ≤ 1.5 METs were defined as moderate-to-vigorous intensity PA (MVPA), light PA (LPA), and sedentary behavior (SB), respectively. Two linear mixed models were used to examine whether MVPA, LPA, and SB min/d changed over time. Fifty-five participants provided complete data. A significant, nonlinear, longitudinal decline in MVPA, an increase in SB, and a linear decline in LPA were observed. Changes in MVPA and SB were accelerated in seventh grade (12–13 years of age). Male sex and maintaining normal body fat were associated with higher levels of MVPA. Changes in LPA and SB were not associated with sex or body fat. During the transition period from primary to secondary school, MVPA and SB showed nonlinear accelerations. Sex and normal weight were associated with more time spent performing MVPA.

Introduction

A physically active lifestyle is beneficial for children and adolescents [1, 2]. With recent technological advancements, physical activity (PA) in terms of PA intensity in daily life can be estimated more accurately and objectively than before. PA is typically classified as moderate-to-vigorous intensity PA (MVPA), light-intensity PA (LPA), and sedentary behavior (SB). MVPA comprises activities that generally require significant movement and energy expenditure (≥ 3.0 metabolic equivalents [METs]), such as brisk walking or running. LPA refers to casual walking, household chores, or activities of daily living (1.6–2.9 METs). SB refers to activities like sitting that involve minimal movement and energy expenditure (≤1.5 METs) [3]. Since LPA is a part of daily activities, the focus of interest for ensuring a healthy lifestyle among children and adolescents has shifted to MVPA and SB. Guidelines regarding MVPA [4] and SB [5, 6] for children and adolescents are similar across the world. In a pooled analysis of 298 population-based surveys involving 1.6 million students, those aged 11–17 years showed a global trend toward insufficient PA based on current guidelines [7].

In this study, we focused on the changes in PA during the transition from primary to secondary school, as this is a critical developmental period and a turning point that may positively or negatively influence a child's social and physical environment [8, 9]. Long-term investigations with frequent data collection are necessary to gain a deeper understanding of the changes in PA that may occur during this transition. Recent systematic reviews have established that the period between childhood and adolescence is characterized by a decline in MVPA and an increase in SB [10, 11]. However, in a systematic review by Chong et al. [10], only six articles met their inclusion criteria for longitudinal and observational studies that reported repeated PA measurements, of which four measured MVPA, and only one study measured SB objectively with short (≤ 2 years) follow-up periods and few data collection points (in the first and/or second year of secondary school). The other systematic review [11] analyzed only changes in SB and reported that overall daily sedentary time increased during the transition from primary to secondary school. However, only four studies used objective measurement methods, and one study used three or more time points for data collection. Consequently, objectively collected data measuring the PA transition from primary to secondary school are needed to clarify long-term changes in PA patterns.

Although LPA constitutes part of the daily PA of children and adolescents, it has received much less research attention. Recent cross-sectional studies have shown that the proportion of objectively measured LPA comprised 26% [12] and 31% [13] of all PA. The proportions of LPA in these prior studies were higher than those of MVPA. Considering the changes in LPA, MVPA and SB may be useful for the effective promotion of health among youths. This is because LPA activities are part of daily activities and have the potential to enhance health [14, 15]. However, little is known about LPA changes that occur during a child's transition from primary to secondary school.

Given the above, we aimed to examine potential changes in objectively measured PA (MVPA, LPA, and SB) among children who transition from primary school (starting from fourth grade, 9–10 years of age) to secondary school (until eighth grade, 13–14 years of age) using longitudinal data collected annually. Our investigation also evaluated whether PA changes that occurred were linear or nonlinear. Our underlying rationale was that if a change involved a quadratic curve, health-promoting interventions may consider focusing on the specific grade wherein an accelerated change in PA was identified.

Results

Participants

Table 1 shows the descriptive statistics of all participants based on their responses at each wave of the survey. The mean age (± standard deviation [SD]) of the initial 63 participants was 9.9 ± 0.3 years, and 56% were female. Fifty-five participants (87%) responded and provided PA data during each annual wave over the five-year study period. Eight participants were lost to follow-up because they had changed schools. Approximately 85% of the participants had normal body fat percentages at the first wave, and this was maintained during the study.

Table 1
Descriptive statistics of participants (n = 55) in each assessment of this five-year longitudinal study on physical activity in children transitioning from primary to secondary school.

	Assessment 1	**Assessment 2**	**Assessment 3**	**Assessment 4**	**Assessment 5**
School grade	4th	5th	6th	7th	8th
Age, y (mean ± SD)	9.9 ± 0.3	10.9 ± 0.3	12.0 ± 0.2	12.9 ± 0.3	13.9 ± 0.3
Sex, n (%)					
Female	31 (56)	31 (56)	31 (56)	31 (56)	31 (56)
Male	24 (44)	24 (44)	24 (44)	24 (44)	24 (44)
Height, cm (mean ± SD)	140.0 ± 6.6	146.2 ± 7.0	152.6 ± 7.4	158.7 ± 7.0	162.6 ± 6.8
Weight, kg (mean ± SD)	33.2 ± 7.5	37.3 ± 8.9	41.6 ± 8.6	46.5 ± 8.5	50.8 ± 8.5
Body fat[a], n (%)					
Underweight	6 (11)	6 (11)	6 (11)	2 (4)	4 (7)
Normal	46 (84)	45 (82)	46 (84)	48 (87)	48 (87)
Obese	3 (5)	4 (7)	3 (5)	5 (9)	3 (5)

[a] Body fat refers to the percentage of overweight, calculated as the ratio of weight to the expected standard weight according to sex, age, and height.

SD, standard deviation.

Changes in PA in the linear mixed model (LMM)

Table 2 shows the mean ± SD of the accelerometer data. At each assessment, the following number of participants did not satisfy the criterion of valid device-wearing for at least 600 min/d: assessment 1 (*n* = 3), assessment 2 (*n* = 1), assessment 3 (*n* = 3), assessment 4 (*n* = 2), and assessment 5 (*n* = 3).

Table 2

Accelerometer data from participants who met the device-wearing criterion[a] in this five-year longitudinal study of physical activity in children transitioning from primary to secondary school.

	Assessment 1	**Assessment 2**	**Assessment 3**	**Assessment 4**	**Assessment 5**
Variable	**(n = 52)**	**(n = 54)**	**(n = 52)**	**(n = 53)**	**(n = 52)**
Daily physical activity, min (mean ± SD)					
MVPA	67 ± 20	67 ± 29	71 ± 24	65 ± 28	53 ± 23
LPA	325 ± 51	296 ± 57	321 ± 54	286 ± 53	271 ± 57
SB	418 ± 82	453 ± 83	455 ± 101	502 ± 98	512 ± 114
Wearing time, min, (mean ± SD)	810 ± 81	815 ± 98	846 ± 120	853 ± 115	836 ± 132

[a] The device-wearing criterion required that the accelerometer be worn for at least 600 min/d during each assessment.

Assessments 1, 2, 3, 4, and 5 took place in grades 4, 5, 6, 7, and 8, respectively.

MVPA, moderate-to-vigorous intensity physical activity; LPA, light-intensity physical activity; SB, sedentary behavior; SD, standard deviation.

Tables 3 and 4 show the results of the LMM analyses using restricted maximum likelihood (REML) methods without (LMM I) and with (LMM II) adjustments for the fixed effect of sex and the interaction between sex and grade, respectively. A significant decrease in MVPA and an increase in SB were observed with a curvilinear pattern. The regression coefficients (β) of grade^2 in LMM I (Table 3) were -2.3 (95% confidence interval [CI], -3.7 to -0.9; P = 0.002) for MVPA and 3.3 (95% CI, 0.4 to 6.2; P = 0.027) for SB, and those in LMM II (Table 4) were -2.3 (95% CI, -3.7 to -0.9; P = 0.002) for MVPA and 3.3 (95% CI, 0.4 to 6.3; P = 0.025) for SB. A statistically significant linear decrease in LPA was observed in LMM I (β of grade = -10.1, 95% CI, -19.8 to -0.3; P = 0.043), whereas LPA in LMM II demonstrated a linear decrease that was not statistically significant (P = 0.063).

Table 3
Linear mixed models using the restricted maximum likelihood method without adjustments for the fixed effect of sex and the interaction between sex and grade in this five-year longitudinal study on physical activity in children transitioning from primary to secondary school

	MVPA			**LPA**			**SB**		
	Estimate	*t*	*P*-value	Estimate	*t*	*P*-value	Estimate	*t*	*P*-value
Variable	(SE)			(SE)			(SE)		
Fixed part									
Intercept	10.08	0.75	0.453	101.07	4.10	**0.000**	-114.60	-3.62	**0.000**
	(13.41)			(24.64)			(31.67)		
Grade	5.73	1.93	0.055	-10.08	-2.04	**0.043**	4.12	0.65	0.513
	(2.98)			(4.95)			(6.29)		
$Grade^2$	-2.25	-3.17	**0.002**	-1.03	-0.89	0.374	3.31	2.23	**0.027**
	(0.71)			(1.16)			(1.48)		
Body fat									
Underweight	12.99	1.49	0.138	-11.24	-0.70	0.485	-4.85	-0.24	0.807
	(8.73)			(16.08)			(19.86)		
Normal	20.43	2.88	**0.004**	-7.56	-0.57	0.566	-13.74	-0.85	0.395
	(7.08)			(13.16)			(16.12)		
Obese	[Ref.]			[Ref.]			[Ref.]		
Accelerometer wear time	0.05	3.23	**0.001**	0.28	11.36	**0.000**	0.68	22.64	**0.000**

Estimated values of the fixed and random effects are reported by the regression coefficient and variance, respectively. Group effect describes the two groups recruited in grade 4 in 2015 (n=32) and 2016 (n=31), with differences at the time of baseline data collection.

MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; SB, sedentary behavior; SE, standard error; Ref, reference category.

	MVPA	LPA	SB
	(0.01)	(0.02)	(0.03)
Random effect			
Group			
Intercept	17.72	84.70	298.51
	(41.07)	(198.60)	(529.08)
Subjects (unstructured)			
Grade	5.18	52.14	64.44
	(9.80)	(31.55)	(48.41)
Intercept	185.33	1330.71	2038.15
	(83.10)	(396.49)	(621.55)
Grade, intercept	6.88	-73.25	-169.66
	(22.80)	(91.17)	(147.25)
Residual	354.45	936.07	1531.70
	(41.31)	(109.19)	(177.37)

Estimated values of the fixed and random effects are reported by the regression coefficient and variance, respectively. Group effect describes the two groups recruited in grade 4 in 2015 (n=32) and 2016 (n=31), with differences at the time of baseline data collection.

MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; SB, sedentary behavior; SE, standard error; Ref, reference category.

Table 4
Linear mixed models using the restricted maximum likelihood method with adjustments for the fixed effect of sex and the interaction between sex and grade in this five-year longitudinal study on physical activity in children transitioning from primary to secondary school

	MVPA			**LPA**			**SB**		
	Estimate	*t*	*P*-value	Estimate	*t*	*P*-value	Estimate	*t*	*P*-value
Variable	(SE)			(SE)			(SE)		
Fixed part									
Intercept	21.31	1.57	0.117	95.72	3.66	**0.000**	-121.18	-3.61	**0.000**
	(13.56)			(26.17)			(33.57)		
Grade	4.08	1.32	0.189	-9.80	-1.87	0.063	5.40	0.81	0.417
	(3.10)			(5.25)			(6.64)		
Grade^2	-2.26	-3.20	**0.002**	-1.04	-0.90	0.370	3.34	2.25	**0.025**
	(0.71)			(1.16)			(1.48)		
Female sex	-18.85	-3.85	**0.000**	10.99	0.92	0.359	7.51	0.50	0.618
	(4.90)			(11.97)			(15.05)		
Interaction between sex and grade	3.05	1.70	0.090	-0.45	-0.13	0.897	-2.52	-0.60	0.550
Body fat	(1.79)			(3.45)			(4.21)		
Underweight	14.39	1.72	0.087	-11.75	-0.73	0.468	-4.38	-0.22	0.827
	(8.39)			(16.16)			(20.00)		
Normal	21.18	3.12	**0.002**	-7.57	-0.57	0.566	-13.42	-0.83	0.409
	(6.80)			(13.20)			(16.21)		
Obese	[Ref.]			[Ref.]			[Ref.]		
Accelerometer wear time	0.04	3.10	**0.002**	0.28	11.10	**0.000**	0.69	22.20	**0.000**
	(0.01)			(0.02)			(0.03)		

Estimated values of the fixed and random effects are reported by the regression coefficient and variance, respectively. Group effect describes the two groups recruited in grade 4 in 2015 (n=32) and 2016 (n=31), with differences at the time of baseline data collection.

MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; SB, sedentary behavior; SE, standard error; Ref, reference category.

	MVPA	LPA	SB
Random effect			
Group			
Intercept	12.67	89.28	296.86
	(31.37)	(205.18)	(529.26)
Subjects (unstructured)			
Grade	4.16	54.80	66.91
	(4.35)	(32.31)	(49.33)
Intercept	100.10	1335.02	2080.88
	(52.13)	(401.93)	(635.93)
Grade, intercept	20.41	-76.87	-173.60
	(8.07)	(92.87)	(150.26)
Residual	353.51	936.44	1532.09
	(35.31)	(109.29)	(177.48)
Estimated values of the fixed and random effects are reported by the regression coefficient and variance, respectively. Group effect describes the two groups recruited in grade 4 in 2015 (n=32) and 2016 (n=31), with differences at the time of baseline data collection.			
MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; SB, sedentary behavior; SE, standard error; Ref, reference category.			

Figure 1 shows the longitudinal quadratic trends of the estimated marginal means of MVPA, LPA, and SB in LMMs I and II. MVPA declined at an accelerated rate after seventh grade in girls and after sixth grade in boys (Figure 1a). SB showed an accelerated increase after sixth grade in both sexes (Figure 1c). The linear change in LPA was different from the curvilinear changes observed in MVPA and SB (Figure 1b).

A sex-related main effect in MVPA was observed (β = -18.9; 95% CI, -28.5 to -9.2; $P < 0.001$). The time spent performing MVPA was higher among boys than among girls, and there was no interaction between sex and grade (Table 4). When compared to obese children, normal-weight children had a significant influence on the increase of MVPA in LMM I (Table 3; β = 20.4; 95% CI, 6.5 to 34.4; $P = 0.004$) and in LMM II (Table 4; β = 21.2; 95% CI, 7.8 to 34.6; $P = 0.002$). However, the percentage of overweight (POW) had no influence on the changes in LPA and SB. Figure 2 shows the composition of habitual PA based on the estimated marginal means of MVPA, LPA, and SB at each assessment. The range of SB changes (53–62%) was similar to that of LPA changes (32–40%), whereas the range of MVPA changes was smaller (6–8%) over time.

Discussion

The results of this longitudinal study showed that the decline in MVPA and increase in SB followed nonlinear functions in children transitioning from primary to secondary school (fourth to eighth grade; 9–14 years), whereas the decline in LPA was linear. This corresponded to an accelerated change in MVPA and SB among secondary school adolescents. Male sex and maintaining normal POW over the five years were associated with higher levels of MVPA. However, the changes in LPA and SB over time were statistically unrelated to sex and POW.

Our key finding of a decline in MVPA was consistent with the recent results reported by Farooq et al. [16], who examined longitudinal PA data at ages 7, 9, 12, and 15 years in the Gateshead Millennium Cohort Study in England. They found a distinct linear trajectory based on the estimated marginal MVPA means derived from their LMM when adjusted for sex, age, and the interaction between them. Unlike their findings, we demonstrated a nonlinear MVPA trajectory. Although the MVPA of girls in their study was less than the currently recommended 60 min/d [4] after 9 years of age and continued to decline afterward, the girls in our study showed a slight increase in MVPA until 12 years of age. Moreover, there was an accelerated decline in MVPA when both boys and girls advanced from primary to secondary school.

Several longitudinal studies have examined PA changes using an accelerometer in children transitioning from primary to secondary school [10, 11]. A current systematic review [10], which included studies from 1990 to 2019, found no further studies reporting SB data since the 2017 review by Pearson et al. [11]. In a longitudinal study similar to ours, Mitchell et al. [17] examined changes in SB (using a quantile regression model) at ages 9, 11, 12, and 15 years in children transitioning from primary to secondary school in the United States. They found a nonlinear increase in daily SB each year but no sex-specific SB changes over time. Our results provide further support for a nonlinear, sex-independent increase in SB in children transitioning from primary to secondary school. Moreover, the SB increase observed in our study was underpinned by more continuous data and detail. We observed a substantial increase when children transitioned to secondary school (after sixth grade). Compared to the findings of Mitchell et al. [17], our results revealed a slower SB increase over time. This may be explained by the baseline 442 min/d of SB in our cohort, which was more than the 320 min/d in their study. At ages 14 and 15 years, the gap in SB between our cohort (511 min/d) and their cohort (492 min/d) was considerably narrower. However, our results were comparable to other current studies in that they did not reflect a higher level of SB time among school-aged children [18, 19].

Previous studies found that the time spent performing LPA decreases as children grow into adolescents, but few examined whether this LPA change was linear or nonlinear [17, 20–22]. The LPA decrease in our cohort showed that adolescents in eighth grade spent 55 min less per day performing LPA than they did during fourth grade. This difference was smaller than that reported in a recent study based on pooled data from Europe, the United States, Brazil, and Australia from the International Children's Accelerometry Database [20]. The pooled data (n = 1088) showed an 85-min decrease in LPA (from 360 min to 275 min) among children aged 12–15 years. In addition, another longitudinal study [21] indicated an 86-min decrease in LPA (from 287 to 201 minutes) among 75 Spanish children aged 8.5–13.8 years.

In our cohort, this LPA decrease was linear over the five years with annual data collection, whereas the MVPA and SB changes were nonlinear. Thus, we conclude that the linear decline in LPA in children begins in primary school. The increased time spent in SB corresponded to the decrease in LPA in our analysis, indicating that time spent performing LPA is replaced by time spent in SB as children grow. Future studies should determine whether interventions focused on LPA may prevent an increase in SB.

Our results showed a temporal relationship between obesity and the changes in MVPA and SB, consistent with the conclusions from a previous systematic review by Elmesmari et al. [23] who concluded that accelerometer-measured MVPA for obese children and adolescents was less than that for non-obese children aged 10–19 years without marked differences in SB. In contrast, a previous longitudinal study in children aged 9–15 years indicated a possible association between time spent in SB and the body mass index (BMI) [17]. Subjects in the 90th BMI percentile showed that the time spent in SB was associated with a curvilinear increase in BMI. However, there were weak or non-existent associations between SB duration and BMI for individuals in the 10th, 25th, and 50th BMI percentiles. Although there was no significant difference in SB duration between non-obese and obese participants in our cohort, negative estimates were shown in the LMM, implying that less time was spent in SB among non-obese participants than among obese participants. Whether obesity is affected by an increase in time spent in SB as children advance from primary to secondary school needs further investigation since our cohort included few obese children. An overview evaluating interventions for preventing or treating pediatric and adolescent obesity found conflicting results on whether a decrease in BMI could be achieved by reducing SB time [24].

Our results need to be interpreted within the limitations of this study. First, this study was conducted in a limited geographic area in Tokyo, Japan. Further studies are needed to establish whether our findings can be replicated in more diverse populations. Second, although our findings were adjusted for covariates, residual confounding factors might have remained. Environmental, socioeconomic, and sociocultural confounding factors [25–27] were not considered in the analysis. Third, children did not maintain a record of the periods during which they wore the accelerometer. Hence, their activities might have been underestimated. However, the accelerometry methods, epoch length, non-wear time, and valid wearing minutes and days used in this study are widely used and accepted in child and adolescent populations [28].

In summary, we found that the time spent in MVPA, LPA, and SB changed as children transitioned from primary to secondary school. The strengths of this study include the identification of linear and nonlinear changes with repeated objective annual data collection at five time points in a cohort of children progressing from fourth to eighth grade. MVPA and SB showed accelerated changes after the transition to secondary school, whereas changes in LPA were linear. In addition, we found that MVPA changes may be associated with obesity among children and adolescents; however, our cohort included few obese children.

Methods

Study design and participants

This longitudinal study was conducted at a private primary school and a secondary school located in adjacent facilities in Tokyo, Japan. Data were annually collected (in either February or March) from 2015 to 2020. This study began with baseline data collection of children in fourth grade (9–10 years of age) in 2015 (n = 32) and 2016 (n = 31). The children attended the same class, which was randomly selected by the school administration. We administered annual surveys to these children over five consecutive years until they reached eighth grade (secondary school; 13–14 years of age). A total of 63 healthy children (56% girls) provided baseline data in 2015 and 2016 and were tracked over the five-year study period.

Before the start of the study and at each follow-up survey and data collection point, parents received complete information about the purpose and methods of the study through their children's teachers; parental written consent was returned to the teachers after the participants' parents had an opportunity to consider their child's participation. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study protocol was approved by the Ethics Committee of the Graduate School of Human Informatics Study, Tohoku Gakuin University (Reference number 2017R001), and only children with parental written informed consent for participation were included.

Measurements

Demographics and anthropometrics

Each participating child's age, grade, sex, body weight, and body height were obtained using a self-administered questionnaire. Body fat, defined as the POW, was assessed using Japanese cutoff values based on the national reference data for Japanese children [29]. Briefly, the POW is commonly utilized to assess childhood obesity in medical settings and schools in Japan and is calculated as the ratio of weight to the standard weight based on sex, age, and height. The POW criteria of obesity and being underweight are ≥ 20% and ≤ -20%, respectively; the normal range is -20–20%. These obesity and underweight criteria have been shown to correspond to BMI-for-age percentiles of > 86–89% and < 2–6%, respectively [29].

PA measurements

The habitual PA of participants was assessed using a triaxial accelerometer (HJA-750C Active style Pro, Omron Healthcare, Kyoto, Japan) measuring 40 × 52 × 12 mm and weighing 23 g, including batteries. This triaxial accelerometer gathers information on the time spent on ambulatory and non-ambulatory activities of varying intensities. The accuracy of this device has been reported in prior studies [30, 31]. Based on default predictive equations established for adults and the results of a prior study in children [32], the following conversion equations were used. Ambulatory activities were calculated as 0.6237 × MET value + 0.2411, and non-ambulatory activities were calculated as 0.6145 × MET value + 0.5573. The time spent on activities requiring ≥ 3 METs, 1.6–2.9 METs, and ≤ 1.5 METs were considered as MVPA, LPA, and SB, respectively. We used the macro program (ver. 190829) developed and distributed by the Japan Physical Activity Research Platform (http://paplatform.umin.jp) to process the accelerometer data.

The accelerometry methods, including the epoch length, non-wear time, and valid wearing minutes and days, were defined based on previous studies [28, 33]. Participants were asked to wear the accelerometer on their waist for ≥ 7 consecutive days during all waking hours, except while showering, bathing, or swimming. The accelerometers were set to record data during 10-s sampling intervals (epochs) throughout the entire wearing period. The non-wearing time within a day was defined as any period with > 10 min of consecutive zero counts. There were 600 valid wearing min/d for both school and non-school days. A minimum of four days, including one non-school day with 600 min of wearing time, were analyzed at each data collection point.

Statistical analyses

We used LMM with REML methods to examine whether daily MVPA, LPA, and SB times changed during the five-year transition from primary school to secondary school. Based on prior evidence, the model included the school grade (timecoded: 0, 1, 2, 3, and 4) and grade^2 (timecoded: 0, 1, 4, 9, and 16) in each wave of yearly time, sex, POW, and daily time spent wearing the accelerometer device as independent covariates in the fixed part of the model [17].

We considered two models of LMM: LMM I and II, which were run without and with adjustments for the fixed effects of sex and the interaction between sex and grade, respectively. These models allowed a random effect within the group where the initial assessment time differed. We also fit the models with the random effect of timecoded school grade in each participant. A quadratic trend was used to estimate the periods during which the MVPA, LPA, and SB had changed. All valid data at each collection time point were included in the analyses because LMMs are robust to missing data and can estimate longitudinal trends with incomplete datasets [34]. LMMs were used because they are robust to misisng data and can estimate longituinal trends with incomplete datasets. This allowed us to include all valid data collected at each time point in the analyses. A total of 52, 54, 52, 53, and 53 participants were analyzed in assessment 1, 2, 3, 4, and 5, respectively, of this five-year longitudinal study (Table 2).

All statistical analyses were performed using Stata for Windows version 15.1 (Stata, College Station, TX, USA). All significance tests were two-sided, and the results were considered statistically significant at $P <$ 0.05.

Declarations

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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public institution and did not play any role in the design and conduct of the study; collection, management, and analysis of the data; or preparation, review, and approval of the manuscript.

Author Contributions

Kanzo Okazaki designed the study. All authors contributed significantly to all components of the research conducted. Kanzo Okazaki performed the model fitting and collaborated with Kazunori Ohkawara for data analysis. Kanzo Okazaki wrote the first draft of the manuscript. All authors contributed to the discussion of the paper, critically revised the manuscript, and approved the version submitted for publication.

Additional Information

Competing Interests

The authors declare no competing interests.

Informed Consent

Informed consent was obtained from the parents of all individual participants included in the study.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study design was approved by the Ethics Committee of the Graduate School of Human Informatics Study, Tohoku Gakuin University (Reference number 2017R001).

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Figures

Figure 1

Quadratic trends for the different types of physical activity in linear mixed models I and II.

(a) Moderate-to-vigorous intensity physical activity (MVPA); (b) Light physical activity (LPA); (c) Sedentary behavior (SB).

Changes are expressed as estimated marginal means. The trends in linear mixed model I (solid line) were adjusted for body fat and accelerometer wearing time. The trends in linear mixed model II (dashed line and dotted line indicating girls and boys, respectively) were determined by adding the variables sex and the interaction between sex and grade.

SE, standard error.

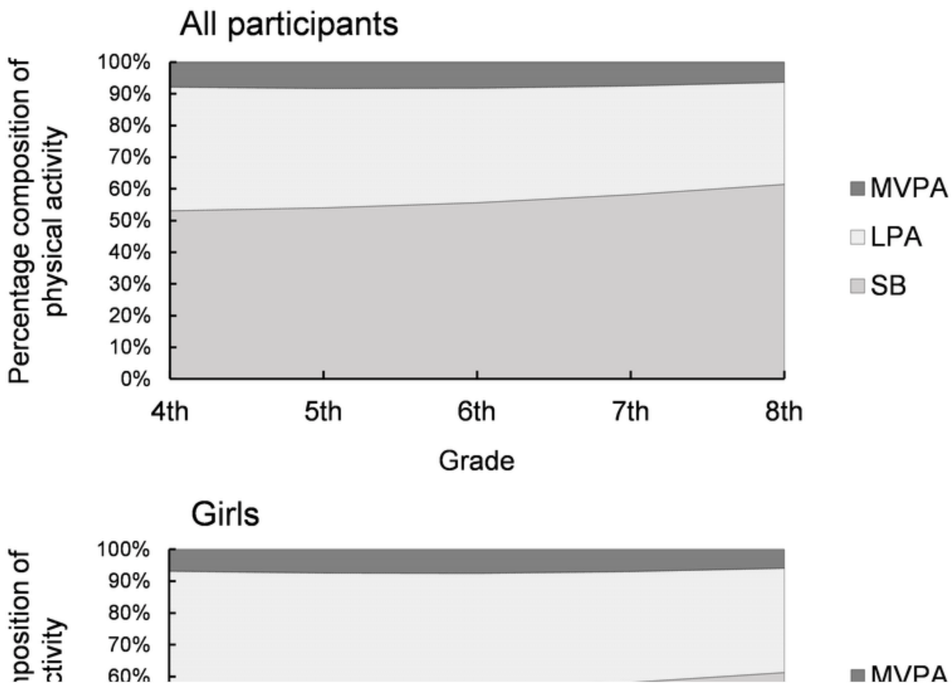

Figure 2

Composition of physical activity at each accelerometric assessment.

The percentage composition is based on the estimated marginal means of MVPA, LPA, and SB in linear mixed models I (all participants) and II (girls and boys).

MVPA, moderate-to-vigorous intensity physical activity; LPA, light-intensity physical activity; SB, sedentary behavior.