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Changes in physical activity and sedentary time during adolescence: Gender differences during weekdays and weekend days

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Objectives: The objective of this study was to determine the gender-specific and time-segmented changes in accelerometer measured physical activity (PA) and sedentary time (ST) during adolescence.

Methods: The study population (N = 970) consisted of children from nine schools throughout Finland. At the baseline, the children were in grades 4-7 (ages 10-13). Five times during the two-year follow-up period, hip-worn accelerometers (ActiGraph GT3X+) were deployed for seven consecutive days in order to monitor the pupils' PA. The daily time spent in vigorous (VPA), moderate to vigorous (MVPA), and light physical activity(LPA), as well as sedentary time(ST), were assessed.

Results: Significant gender differences were observed in terms of the changes in MVPA and ST during the follow-up period. The total MVPA declined significantly in boys (by 2.2min/day/year from 60 min/d at baseline) but not in girls (49 min/d at baseline). The total ST increased both in boys (by 20.7%-points/y) and in girls (by 16.1%-points/y, $P < .001$). However, when we compared the results during the weekdays and weekend days separately, we observed that the declines in MVPA and increases in ST were greater in boys than in girls during the weekend days.

Conclusion: A greater decrease in PA and a greater increase in ST during adolescence were observed among boys than among girls, especially during weekend days. In order to diminish these unfavorable behavioral changes during adolescence, we encourage the separate tailoring of interventions for boys and girls and for weekdays and weekends.

KEYWORDS
accelerometer, adolescence, children, physical activity, school, sedentary time

1 | INTRODUCTION

According to the WHO 2010 physical activity recommendations, school-aged children should participate daily in at least 60 minutes of moderate to vigorous physical activity (MVPA).[1] However, as shown in recent global data with questionnaire and accelerometer measurements, less than one third of the underage population[2] and one fifth of adolescents comply with this recommendation.[3] Most of the recent studies in which physical activity (PA) has been measured with accelerometers agree that the decline in PA begins around the time of school entry and continues through adolescence.[4] The trajectory of change may differ between PA and sedentary time (ST)[5-7] and between boys and girls.[8-12]

Investigating the development of ST in school-aged children is important, even though the evidence of the independent effects of ST on young people's health and adiposity is still unconvincing.[13] ST may moderate the relationship between PA and cardiorespiratory fitness.[14] It is also well documented that, like insufficient childhood PA, sedentary behaviors[15] track from adolescence into adulthood.

Because school time constitutes a large part of the day, it plays an important role in the pupils' PA. Children's PA and sedentary behaviors vary among different segments of the week (eg Brooke et al 2014). The few previous studies that have investigated the accelerometer-measured PA or ST in some of the segmented time periods have found differences in the longitudinal changes among seg ments.[5,8,17-19] However, to the best of our knowledge, only one study has previously examined the longitudinal changes in objectively measured PA and ST separately for school and leisure time and for weekdays and weekend days,[5] and none have used five measurement points in the follow-up.

1.1 | Objective

This study identified the longitudinal changes and gender differences in varying intensities of accelerometer-measured PA and ST during adolescence among Finnish boys and girls. The results were analyzed separately for weekdays and weekend days and during weekdays for school hours and outside school hours.

Summary box

- We found the changes in physical activity during adolescence to vary among time segments and intensities and between sexes.
- ST increased and LPA decreased in boys and girls across all time segments.
- MVPA and VPA declined only in boys.
- The differences in physical activity between boys and girls were the greatest and most constant during school hours.

2 | MATERIALS AND METHODS

This study was a part of the Finnish Schools on the Move program. The pupils were recruited from nine schools throughout Finland that participated in a two-year follow-up study from 2013 to 2015. Of the 1,710 pupils in classes 4-7 (aged 9-15) who were invited to participate in the study, 970 (56.7%) participated. The basic descriptives of the study population (12.6 ± 1.3 y) at baseline are listed in Table 1 and during the follow-up in Appendix S2. The pupils' activity levels were measured five times (M1-M5), once during each spring and fall semester. The measurements in each school were always conducted in the same month. Because the follow-up study required individual identification, written consent was obtained from both the pupils and their guardians. The study protocol was approved by the Ethics Committee of the University of Jyväskylä.

Physical activity (PA) and sedentary time (ST) were measured with ActiGraph GT3X+ and wGT3X+ accelerometers (ActiGraph, Pensacola, Florida, USA), with a sampling frequency of 30 Hz. The pupils were instructed to wear the

TABLE 1 Descriptives at baseline (M1)

	Boys (n = 462)		Girls (n = 508)		Total (n = 970)		*t* test (boys-girls)
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	*P*-value
Age (y)	462	12.6 ± 1.3	507	12.5 ± 1.3	969	12.5 ± 1.3	.605
Height (cm)	429	156.7 ± 11.3	485	155.5 ± 9.5	914	156.1 ± 10.4	.090
Weight (kg)	429	46.5 ± 12.7	485	46.5 ± 10.6	914	46.5 ± 11.6	.978
BMI (kg/m2)	429	18.6 ± 3.3	485	19.1 ± 3.2	914	18.9 ± 3.2	.054
BodyFat (%)	429	15.3 ± 8.2	485	21.2 ± 7.5	914	18.4 ± 8.4	<.001
Shuttle-run (count)	410	47.5 ± 20.3	461	37.0 ± 15.9	871	41.9 ± 18.9	<.001

accelerometer on the right hip with an elastic band during their waking hours for seven days, except during water activities. Actilife software (release 5.0 or later) was used to initialize the accelerometers and download the data. A customized Visual basic macro for Excel software and widely used settings were used for data reduction. Monitor non-wear was calculated as periods of more than 30 min of consecutive zero counts. Separate analyses were conducted for entire weeks, for weekdays and for weekend days. The weekday analysis was further divided into school and out of school (leisure time) times based on data obtained from a diary kept by each pupil. For those pupils (6%) that did not return the diary, the curriculum provided by the school was used. The minimum acceptable wearing time during school hours was defined as 80% of the full school day. In addition, 500 min of measured wear time between 07:00 and 23:00 was required for a valid day. Both school and leisure time activity measures were calculated as daily averages for the pupils that met all conditions for at least two weekdays and one weekend day. In order to adjust for differences in the durations of school and leisure time, activity measures for those segments are expressed as minutes per hour (min/h). Cut-points based on Evenson et al[20] were used to calculate ST (<100 cpm), MVPA (>2295 cpm), and VPA (>4012 cpm). A 20 000 cpm upper limit was set to avoid any spurious data.[21]

The pupils' body weights and body fat percentages were assessed by utilizing the InBody 720 (Biospace Co, Soul, Korea) body composition analyser, and their heights were measured with a wall-mounted stadiometer to an accuracy of 0.1 cm. Each pupil's cardiorespiratory fitness was measured with a 20 m shuttle run test. For the test, the running speed was increased in one-minute intervals until each individual reached maximal voluntary exhaustion. The initial speed was 8.0 km/h, the following speed was 9.0 km/h, and thereafter the speed was increased in increments of 0.5 km/h per stage.[22,23] The results are expressed in terms of the number of completed laps.

2.1 | Statistical analysis

Descriptive statistics for the baseline (M1) in the spring of 2013 are presented as mean and standard deviations (mean ± SD). Pupil's *t* test was used to investigate the differences in the descriptive variables between boys and girls.

Because the data were clustered within school classes, multilevel modeling was used to examine changes in the Pupils'PA and ST during weekdays, weekend days, school time, leisure time, and during the whole week over time. A linear growth model was specified at within subject level (Level 1): The regression coefficient between time (measurement points M1-M5, 1-5) and PA/ST was estimated as random slope, and the model was adjusted for seasonal variation. Seasonal variation was taken into account by adding an indicator for the winter season (November, December, January, and February) in the model as a time-varying covariate.

The association of gender (girl)on the level and slope of PA/ST was tested for significance at the between-subject level (Level 2). The model was adjusted for belonging to program school and between class level (Level 3).To study the development of PA/ST separately in boys and girls, the mean estimates for level and slope were calculated for girls and boys by using the parameters of the model.

The unequal probabilities of selection (by age and sex) were accounted for in the modeling by using sampling weights. The sampling weights were constructed using information on population frequencies by sex and age obtained from the Official Statistics of Finland.[24] The descriptive statistics were calculated using SPSS 25.0 for Widows (SPSS Inc, Chicago, IL), and all further analyses were conducted using the Mplus statistical package (version 7). Missing data were assumed to be missing at random (MAR). The parameters of the models were estimated by using the full information maximum likelihood (FIML) method with robust standard errors, which produces unbiased parameter estimates under MAR.

3 | RESULTS

The number of participants with valid accelerometer data for at least two weekdays and one weekend day was 771 at baseline and 328 at the fifth follow-up measurement. The average daily wearing time in the baseline measurements was 795.4 ± 63.8 minutes for weekdays and 686.0 ± 88.5 minutes for weekend days. The pupils who participated in the study were more often girls (52%, vs. 40% of boys) compared with the non-participants. Of the 435 pupils who provided valid accelerometer data in the first measurement, 274 dropped out before the final measurement. The remaining pupils (M5 versus M1) were more likely to be girls (12%), to be younger (by 0.24 years), to have a higher BMI (by 0.6 kg/m^2), and to participate in less leisure time MVPA (by 4.7 min/d) than the pupils who dropped out.

To check the representativeness of our study population, we compared the questionnaire results for self-reported PA to the results of a nationwide Health Behaviour in School-aged Children survey.[25] When we compared the proportions of pupils who achieved the recommended 60 min of MVPA/day 7 days/wk, the results from these two samples were within 2-11%of each other at baseline and within 1-5%of each other at the fifth measurement (see Appendix S1).

Physical activity and sedentary time in all measurement points M1-M5 are presented in Appendix S3. On average, boys had higher levels of both MVPA (by 23%) and VPA (by 27%) and lower levels of ST (by 5.5%-points) than girls (Figures 1A,B; Table 2). This was the case for all analyzed

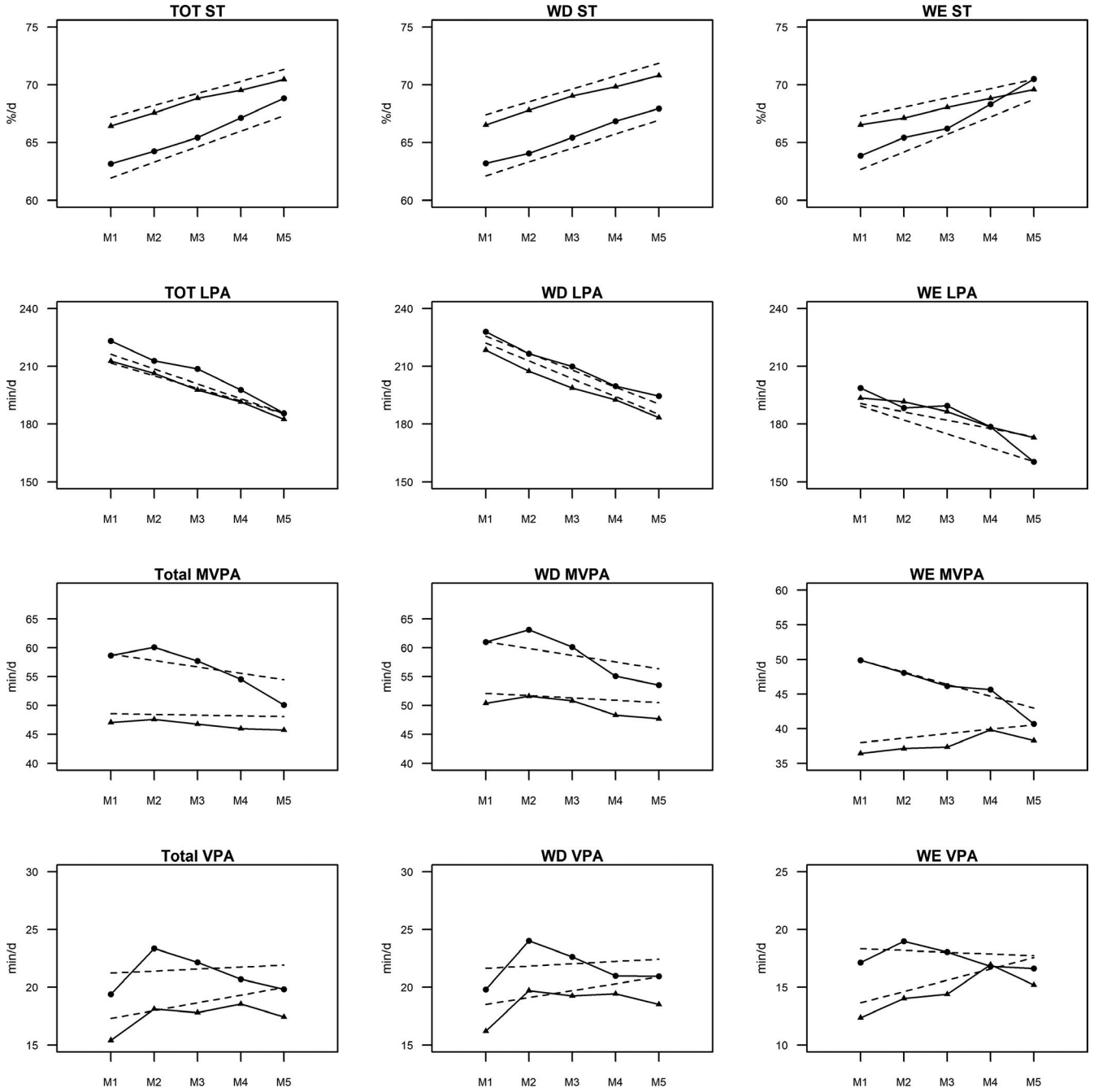

FIGURE 1 A, The development of sedentary time (ST), light physical activity (LPA), moderate to vigorous physical activity (MVPA), and vigorous physical activity (VPA) during the follow-up for the whole week (Total), weekdays (WD), and weekends (WE) in boys (●) and girls (▲). The dotted lines represent the mean growth curves in boys and girls (estimated by using the parameters of the linear growth curve model). B, The development of sedentary time (ST), light physical activity (LPA), moderate to vigorous physical activity (MVPA), and vigorous physical activity (VPA) during the follow-up for weekdays (WD) in boys (●) and girls (▲). The dotted lines represent the mean growth curves in boys and girls (estimated by using the parameters of the linear growth curve model). The weekdays (WD) are further divided into school time and leisure time based on the pupils' individual curricula

time segments (whole week, weekdays, weekend days, and school time and leisure time during weekdays). No gender differences were found in the levels of LPA in the analyzed time-segments, excluding leisure time. On an average day, boys accumulated 11.3 more minutes of MVPA and 4.4 more minutes of VPA than girls.

During weekdays (WD), PA was higher (LPA 1.4 min/h, MVPA 1.6 min/h, $P < .001$ and VPA 0.7 min/h, $P < .001$) and ST lower (by 3.0%, $P < .001$) during leisure time than during school hours in both sexes. The difference between leisure time and school time was larger in girls than in boys (MVPA $P = .001$, LPA and ST $P < .001$). During WD, the children

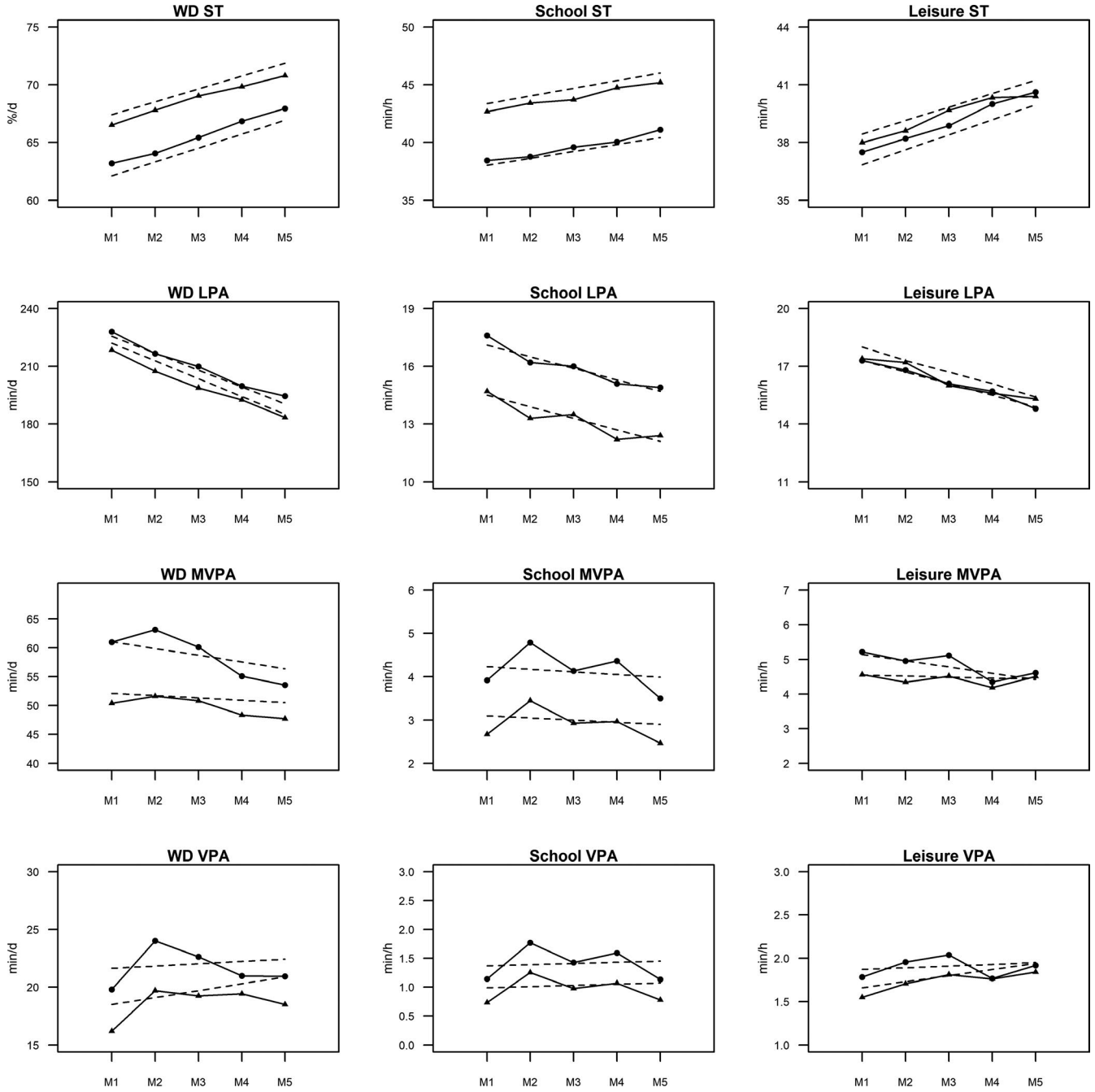

FIGURE 1 (Continued)

exhibited higher levels of LPA (30.1 min/d, $P < .001$), MVPA (12.7 min/d, $P < .001$) and VPA (3.3 min/d, $P < .001$) and lower levels of ST (by 0.3%, $P < .01$) than during weekend days (WE; Table 3). This difference in LPA was larger in boys than in girls ($P < .005$). The difference between WD and WE decreased for girls during the follow-up in terms of LPA (b = 2.495, $P < .05$) and MVPA (b = 1.535, $P = .001$) but not for boys.

During the two-year follow-up period, the boys' total MVPA decreased by an average of 2.2 min/d/y ($P < .001$), whereas no decrease was found in the girls (Figure 1; Table 3). For girls, the MVPA decreased only during school hours. A significant increase in VPA was found for girls (1.3 min/d/y, $P < .001$) but not for boys. Girls increased their VPA in all time segments except during school hours. The level of LPA decreased during the follow-up period for both girls and boys and within all analyzed time segments. The mean decrease in total LPA was 15.4 min/d/y for boys ($P < .001$) and 13.1 ($P < .001$) for girls.

Sedentary time increased significantly both for girls (16.1 min/d/y, $P < .001$) and boys (20.7 min/d/y, $P < .001$). ST increased in all time segments for both genders, but the increase was larger for boys ($P = .04$). The largest gender-associated difference (10.0 min/d/y) in the increase in ST was observed during weekend days. The change in ST was larger during weekdays than during weekend days ($b = -0.339$, $P = .016$.

TABLE 2 The association of gender (girl) on the level and slope of physical activity (PA) and sedentary time (ST). The level represents the initial status of PA/ST, and the slope represents the rate of change PA/ST over time.

	Level			Slope		
	b	SE	*P*	*b*	SE	*P*
Total						
Total ST	5.54	0.71	<0.001	-0.28	0.14	0.044
LPA	−5.29	4.05	0.192	1.15	0.96	0.231
MVPA	12.30	1.85	<0.001	1.17	0.47	0.013
VPA	−4.67	1.03	<0.001	0.44	0.27	0.111
Weekdays						
ST	5.41	0.65	<0.001	−0.07	0.13	0.590
LPA	−3.17	3.40	0.424	−0.42	0.91	0.647
MVPA	10.05	1.86	<0.001	0.63	0.46	0.167
VPA	−3.92	1.01	<0.001	0.37	0.26	0.155
Weekend days						
ST	5.35	0.98	<0.001	−0.69	0.25	0.006
LPA	−1.49	5.23	0.776	2.87	1.14	0.046
MVPA	14.76	2.61	<0.001	2.37	0.79	0.003
VPA	−6.01	1.38	<0.001	1.08	0.43	0.011
Weekday—school time						
ST	5.26	0.42	<0.001	0.09	0.09	0.357
LPA	−2.58	0.29	<0.001	−0.01	0.07	0.856
MVPA	−1.11	0.14	<0.001	−0.01	0.04	0.795
VPA	−0.38	0.07	<0.001	−0.01	0.02	0.535
Weekday—leisure time						
ST	1.77	0.44	<0.001	−0.09	0.10	0.356
LPA	0.67	0.32	0.036	−0.03	0.08	0.708
MVPA	−0.69	0.19	<0.001	0.10	0.05	0.042
VPA	−0.30	0.11	<0.001	0.05	0.03	0.134

Abbreviations: b, unstandardized regression coefficient; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SE, standard error; ST, sedentary time; VPA, vigorous physical activity.

4 | DISCUSSION

We found significant sex-associated differences in terms of physical activity at the baseline, which diminished during the follow-up period and were no longer statistically significant at the final assessment. Whereas the girl's MVPA remained relatively stable, the boys decreased their activity, especially during leisure time and on weekends. Sedentary time increased and LPA decreased for both genders.

4.1 | Levels of physical activity and sedentary time

On average, during the follow-up period, boys had more MVPA and VPA and less ST than girls. This gender difference was observed for all analyzed time segments. Previous studies with segmented accelerometer measured-PA have found similar sex differences during school time,[17,26,27] after-school,[18,19,26,27] and on weekends.[9,26]

Although we found the pupils to be less physically active during school hours than during leisure time, more PA and less ST was accumulated on weekdays than on weekend days. Previous results comparing the physical activity levels of school and weekday leisure time are contradictory and may vary depending on PA intensities[16] and on whether physical activity is expressed in relative (% of daytime) or absolute (min/d) values.[16] The difference between school and leisure time was larger for the girls because the boys were much more active in school than the girls. As in many previous studies, both boys and girls had less PA on weekend days than on weekdays. The currently observed 14 min/d difference in MVPA between weekdays and weekend days is almost identical to the results of a meta-analysis by Brooke et al (2014). However, our finding, that the participants were also more sedentary on weekends, contradicts most previous studies.[7,16] This could

TABLE 3 The level and slope of physical activity (PA) and sedentary time (ST) in boys (b) and girls (g). The level represents the initial status of PA/ST, and the slope represents the rate of change of PA/ST over time

		Level			Slope		
	Sex	***Mean***	**SE**	***P***	***Mean***	**SE**	***P***
Total							
ST	b	60.59	0.54	<0.001	1.35	0.11	<0.001
	g	66.13	0.43	<0.001	1.04	0.08	<0.001
LPA	b	223.55	2.91	<0.001	-7.71	0.73	<0.001
	g	218.26	2.77	<0.001	-6.56	0.58	<0.001
MVPA	b	60.03	1.49	<0.001	-1.11	0.37	0.003
	g	48.72	1.02	<0.001	-0.12	0.28	0.673
VPA	b	21.06	0.81	<0.001	0.17	0.22	0.423
	g	16.63	0.62	<0.001	0.67	0.18	<0.001
Weekdays							
ST	b	60.92	0.49	<0.001	1.20	0.10	<0.001
	g	66.30	0.42	<0.001	1.11	0.07	<0.001
LPA	b	234.39	2.74	<0.001	−8.80	0.67	<0.001
	g	231.22	2.85	<0.001	−9.22	0.57	<0.001
MVPA	b	62.23	1.47	<0.001	−1.17	0.36	<0.001
	g	52.53	1.08	<0.001	−0.40	0.27	0.145
VPA	b	21.43	0.78	<0.001	0.20	0.20	0.31
	g	17.90	0.64	<0.001	0.60	0.17	<0.001
Weekend days							
ST	b	61.14	0.78	<0.001	1.52	0.18	<0.001
	g	66.47	0.54	<0.001	0.80	0.14	<0.001
LPA	b	196.54	3.88	<0.001	−7.21	1.09	<0.001
	g	195.05	3.48	<0.001	−4.34	0.91	<0.001
MVPA	b	51.61	2.21	<0.001	−1.73	0.63	0.006
	g	37.37	1.39	<0.001	0.64	0.47	0.168
VPA	b	18.48	1.12	<0.001	−0.15	0.33	0.656
	g	12.66	0.79	<0.001	0.98	0.28	<0.001
School time							
ST	b	37.42	0.33	<0.001	0.60	0.07	<0.001
	g	42.72	0.26	<0.001	0.66	0.05	<0.001
LPA	b	17.65	0.21	<0.001	−0.59	0.06	<0.001
	g	15.08	0.21	<0.001	−0.60	0.04	<0.001
MVPA	b	4.29	0.12	<0.001	−0.06	0.03	0.051
	g	3.15	0.08	<0.001	−0.05	0.02	0.039
VPA	b	1.35	0.06	<0.001	0.02	0.02	0.213
	g	0.97	0.04	<0.001	0.02	0.01	0.136
Leisure time							
ST	b	36.06	0.34	<0.001	0.78	0.08	<0.001
	g	37.74	0.27	<0.001	0.70	0.06	<0.001
LPA	b	17.95	0.23	<0.001	−0.61	0.06	<0.001
	g	18.62	0.23	<0.001	−0.64	0.05	<0.001
MVPA	b	5.32	0.15	<0.001	−0.18	0.04	<0.001
	g	4.58	0.11	<0.001	−0.03	0.03	0.26
VPA	b	1.85	0.08	<0.001	0.02	0.02	0.315
	g	1.59	0.07	<0.001	0.07	0.02	<0.001

Abbreviations: b, unstandardized regression coefficient; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; SE, standard error; ST, sedentary time; VPA, vigorous physical activity.

be due to cultural variations (eg differences in sedentary time while in school). Compared to many other countries, Finland has relatively short schooldays, many recesses and a modest amount of homework. In addition, Finnish elementary school pupils have, by international comparison, a very high prevalence of active commuting to schools (77%), which may contribute to lower accumulated ST on weekdays.[2]

4.2 | Changes in physical activity and sedentary time

4.2.1 | MVPA

During the follow-up, total MVPA decreased for boys but not for girls. The greater decrease for boys meant that at the end of the two-year follow-up period, the gender difference in MVPA had mostly disappeared. The results from previous longitudinal studies with accelerometer-measured PA have been contradictory. The different results may be due to differences in age; it has been suggested that the decline in PA is faster for girls than for boys during childhood, whereas the opposite pattern occurs during adolescence.[28] This may be due to biological differences in maturity between the sexes; puberty begins earlier in girls than in boys.[29] In addition, the observed gender-associated difference in the decline of MVPA may partially be due to an inverse ceiling effect. The girls' lower initial level of MVPA makes further decreases less likely. This is comparable to the findings of Collings et al (2015), in which higher baseline levels of PA were associated with greater declines in PA and even a decline in ST over time.

The segmented analysis of the changes in MVPA reveals an interesting difference between genders: Whereas the boys' MVPA-levels decreased in all other time segments except during school time, the decrease in girls was only observed during school hours. There was a clear trend in the MVPA change, in which the boys' activity levels declined to the same level as that of the girls during leisure time and weekends, but the difference in school time remained constant. The lack of sex-associated differences in school-time MVPA development is similar to the results of previous studies[5,17,30] and may be due to the different gender roles in schools. It has been reported that in school, girls are more prone to concentrating on academic achievement, whereas boys obtain more credibility by being involved in sports, among other things.[31] However, the observed decrease in leisure-time MVPA for boys differs from the results of earlier studies, which found no decrease for boys, and, depending on the age group, either an increase[8] or a decrease[8,18] in the girls' MVPA.

4.2.2 | VPA

Interestingly, we found a significant (16%/y) increase in girls' VPA and no change for boys. For girls, the largest relative increase (31%/y) was found during weekends. Although boys had a higher average level of VPA during the follow-up period, the difference decreased in all segments and was nonexistent by the last measurement during weekends and leisure time (Figure 1). Similarly, a relatively more positive development in girls' VPA was found by Collings et al (2015), although in that study, the boys' VPA decreased and the girls' did not change at all.

4.2.3 | LPA and ST

During the follow-up period, LPA decreased for both girls (by 13.1 min/d/y) and boys (by 15.4 min/d/y).Most of the observed decrease in LPA was replaced by ST; the decrease was similar to the increase in ST. This is in line with earlier results in the same age group.[5,32] A greater increase in sedentary time was found for boys. Previous studies on ST changes in children and adolescents in similar age ranges have either found an equal decrease between genders[5,18,30,33,34] and a larger decrease in girls[10] or in boys.[7] Contrary to the study by Atkin et al,[35] we found a larger increase in ST on weekdays than on weekend days. A possible reason for the increased in ST with age are the later bedtimes, as the last waking hours of the day are more likely to be sedentary. Further, one explanation for the increase in weekday ST during the follow-up could be the increasing length of the school day with advancing pupil age.

We chose to use three different units for reporting the PA and ST for different segments of the week. We used the absolute amount (min/d) as the unit for whole day PA because it is the unit used in the PA recommendations for youth.[1] Daily ST was expressed in terms of % of weartime because weartime greatly affects the results of ST. The results for the segments of the day (school time and leisure time) are shown as min/h in order to eliminate the effect of segment duration on the results. This is particularly relevant in follow-up studies, in which the length of the school day differs among age groups and increases during the follow-up period. The relative units are a good indicator of the nature of the given segments. This information is relevant when deciding which segments to target in interventions. However, it should be noted that a change in the duration of a segment may affect the total accumulation of ST or MVPA during the day, even if the relative distribution of PAs remains the same. We also chose to use MVPA and VPA as PA intensities, even though they are not mutually exclusive. However, as most health benefits

and recommendations for children's PA are based around MVPA, we think it is more relevant than using MPA.

When planning targeted interventions, it is important to know where and how the relevant behavior changes in boys and girls. Previous interventions aimed at increasing young people's daily PA have generally had a small effect,[36] and although schools are a natural setting for interventions, because most of the population can be reached there for a major part of the day, the evidence for the efficacy of school-based interventions for whole-day PA is weak.[37] This may partially be due to compensation that attenuates the effects of PA increase during school time by a more inactive leisure time.[38] The consistently lower school-time PA in girls and the dramatically decreasing PA during weekends in boys can be used as targets when planning future interventions. Previous studies have found interventions that include both school and family components to be the most effective in youth.[39] Furthermore, although the average levels of PA may be lower during weekends, the most active children have been shown to maintain their weekday ST and PA levels during weekends.[40] Thus, the physically least active children may benefit the most from weekend intervention strategies.[40]

4.3 | Strengths and weaknesses

Despite its limitations in the accurate recording of swimming and cycling, the use of accelerometers is preferable compared with that of questionnaires due to the poor validity of questionnaires, especially in the pediatric population.[41] Accelerometers also enable more accurate comparisons of different time segments of the day because the activities during some parts of the day may be underestimated, and others overestimated, by self-report.[42]

Our follow-up consisted of five measurement points, which gave us better data for the analysis of the temporal directions of the association. Due to logistical reasons, the measurements in different schools were taken at different times from September to May. In order to minimize the effects of seasonality on our results, each successive measurement for a given school was always done in the same month. In addition, our models were adjusted by season.

The current study had a reasonably large subject population with a wide age range (grades 4-7 at the baseline) in adolescence. This may be a limitation because the move to middle school has been suggested to mark a particularly prominent decrease in PA.[8] Because two of the four grades we examined advanced from primary to middle school during the follow-up period, we did not divide the data on that basis. However, we believe that following this age range over a 2-year period provides a valid description of the changes in PA and ST taking place in adolescence.

We were able to separate the time segments very accurately. Unlike in most previous studies, we used the pupils' individual curricula to divide the weekdays into school and leisure time, allowing us to accurately capture the commuting to school activity. This is important because active commuting has been shown to be a significant source of PA in pupils.[43]

5 | PERSPECTIVE

We followed the changes in accelerometer-measured PA and ST during adolescence separately for boys and girls, for weekdays and weekend days, and for school time and leisure time. We found a decrease in LPA and an increase in ST during the two-year follow-up. However, a decline in MVPA and VPA was only observed in boys, and this decline was most profound during leisure time and weekend days. To the best of our knowledge, only one study has previously monitored changes in accelerometer-measured PA and ST separately for different segments of the day and the week.[5] These findings are an important addition to the knowledge base of PA changes in youth. To diminish these unfavorable behavioral changes in PA and ST during adolescence, we encourage the tailoring of separate interventions for boys and girls and for weekdays and weekend days.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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