Physical Activity, Sedentary Behavior, and Academic Performance in Finnish Children

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ABSTRACT

SYVÄOJA, H. J., M. T. KANTOMAA, T. AHONEN, H. HAKONEN, A. KANKAANPÄÄ, and T. H. TAMMELIN. Physical Activity, Sedentary Behavior, and Academic Performance in Finnish Children. *Med. Sci. Sports Exerc.*, Vol. 45, No. 11, pp. 2098–2104, 2013. **Purpose**: This study aimed to determine the relationships between objectively measured and self-reported physical activity, sedentary behavior, and academic performance in Finnish children. **Methods**: Two hundred and seventy-seven children from five schools in the Jyväskylä school district in Finland (58% of the 475 eligible students, mean age = 12.2 yr, 56% girls) participated in the study in the spring of 2011. Self-reported physical activity and screen time were evaluated with questions used in the WHO Health Behavior in School-Aged Children study. Children's physical activity and sedentary time were measured objectively by using an ActiGraph GT1M/GT3X accelerometer for seven consecutive days. A cutoff value of 2296 counts per minute was used for moderate-to-vigorous physical activity (MVPA) and 100 counts per minute for sedentary time. Grade point averages were provided by the education services of the city of Jyväskylä. ANOVA and linear regression analysis were used to analyze the relationships among physical activity, sedentary behavior, and academic performance. **RESULTS**: Objectively measured MVPA ($P = 0.955$) and sedentary time ($P = 0.285$) were not associated with grade point average. However, self-reported MVPA had an inverse U-shaped curvilinear association with grade point average ($P = 0.001$), and screen time had a linear negative association with grade point average ($P = 0.002$), after adjusting for sex, children's learning difficulties, highest level of parental education, and amount of sleep. **Conclusions**: In this study, self-reported physical activity was directly, and screen time inversely, associated with academic achievement. Objectively measured physical activity and sedentary time were not associated with academic achievement. Objective and subjective measures may reflect different constructs and contexts of physical activity and sedentary behavior in association with academic outcomes. **Key Words:** ACADEMIC ACHIEVEMENT, MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY, SCREEN TIME, SCHOOL AGE, LEARNING

EPIDEMIOLOGY

It has been proposed that only 30%–40% of youth are sufficiently active according to current public health recommendations (9). In contrast, sedentary behavior, especially screen-based sedentary behavior, has increased during the last few decades, and today children spend 4–8 $h \cdot d^{-1}$ sedentary (25). Physical inactivity has been shown to be associated with higher levels of obesity, metabolic, and cardiovascular risk factors, depression symptoms, and lower physical fitness in children, whereas adequate physical activity may benefit them (23).

In addition to these health benefits, physical activity may have a beneficial effect on academic performance in children and youth (8,3,13,17,30). However, diverging results have also been reported (20,26,31), indicating a somewhat weak and inconsistent association between young people's physical activity and academic performance. Most of the previous studies used self-reported measures of physical activity and academic performance, with only a few reporting objectively measured physical activity in association with teacher-rated educational outcomes. In addition, previous studies were conducted in various countries with varying educational systems, which makes comparing the results difficult.

According to previous studies, media use (22,27), especially time spent viewing TV (10,11,15,29), playing videogames (14), and using the Internet (18), has a negative association with academic achievement in childhood. However, Borzekowski and Robinson (1), and Jackson et al. (14) reported a positive relationship between Internet/computer use and academic performance, and Munasib and Bhattacharya (24) reported no association between television viewing and academic achievement. Objectively measured sedentary time is a current topic of interest in physiology but has not been extensively studied from the psychological point of view. To our knowledge, no one has studied the association between objectively measured sedentary time and academic performance.

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The aim of this study was to examine the associations between objectively measured and self-reported physical activity, sedentary behavior, and teacher-rated academic achievement in children. We hypothesized that physical activity is directly, and sedentary behavior inversely, associated with academic achievement in childhood.

STUDY POPULATION AND METHODS

Participants. During spring 2011, 475 fifth and sixth graders from five schools in the Jyväskylä school district in Finland were invited to participate in the study. Fifty-eight percent (N = 277) of 475 eligible children participated in the study. The children were given an information pack containing a leaflet for themselves, a letter for their parents/guardians, and a consent form. Participation in the study was voluntary, and all participants and their parents were informed about their right to drop out of the study any time without a specific reason. Only children with a fully completed consent form (certificate of consent signed by a parent/guardian and the child) on the day of the first measurements were included in the study. The study was performed according to the principles of the Declaration of Helsinki and the Finnish legislation and was approved by the Ethics Committee of the University of Jyväskylä.

Academic achievement. Academic achievement scores (grades in individual school subjects and grade point averages [GPA]) were provided by the education services of the city of Jyväskylä. Individual grades were assessed in the following school subjects: native language (in most cases Finnish or Swedish), first foreign language (started in grade 3), mathematics, physics/chemistry, biology, history, geography, religion or ethics, visual arts, music, and physical education. The grades refer to numerical assessment on a scale of 4–10, where 4 denotes a failure (US grade: F) and 10 denotes excellent knowledge and skills (US grade: A). The GPA were calculated as means of the individual grades and were used as a measure of academic achievement in the analysis. A Finnish GPA of 5.0–5.9 equals 1.0 in US GPA, 6.0–6.9 equals 2.0, 7.0–8.9 equals 3.0, and 9.0–10.0 equals 4.0.

Self-reported physical activity and screen time. Children filled in a questionnaire concerning demographics, habits, amount of sleep, and so on. Self-reported physical activity and screen time were evaluated with questions used in the WHO Health Behavior in School-Aged Children study (6). Self-reported moderate-to-vigorous physical activity (MVPA) was measured with the following question: "Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?" The response categories were as follows: 0, 1, 2, …, 7 d. Before this question, the following short description about what kind of physical activity should be taken into count was found: "In the next question, physical activity is defined as any activity that increases your heart rate and makes you get out of breath some of the time." Examples of MVPA were running, walking quickly, rollerblading, biking, dancing, skateboarding, swimming, snowboarding, cross-country skiing, soccer, basketball, and Finnish baseball. Test–retest agreement for self-reported MVPA has been very good (ICC = 0.82) (21). Self-reported screen time was measured with the following question: "About how many hours a day do you usually a) watch television (including videos), b) play computer or video games, or c) use a computer (for purposes other than playing games, for example, e-mailing, chatting, or surfing the Internet or doing homework) in your free time?" There were response options for weekdays and weekends. The test–retest agreement for watching television (ICC = 0.72–0.74) and for playing computer or video games (ICC = 0.54–0.69) has been substantial and for using a computer (ICC = 0.33–0.50) fair to moderate (21). Daily screen time averages were calculated by adding these three questions including weekdays and weekends together.

Objectively measured physical activity and sedentary time. Children's physical activity was measured objectively by using the ActiGraph GT1M/GT3X accelerometer with one vertical axel. Children wore the accelerometer on the right hip with an elastic waistband during waking hours for seven consecutive days. Bathing, swimming, and other water activity periods were excluded. To collect data, the ActiLife accelerometer software (ActiLife version 5; http://support.theactigraph.com/dl/ActiLife-software) was used. Epoch length was 10 s, and nonwearing time was 30 min. For data reduction and analysis, a customized software was used. A cutoff value of 2296 counts per minute was used for MVPA (12) and 100 counts per minute for sedentary time. Children were included in the analysis if they had valid data for at least 500 $\text{min}\cdot\text{d}^{-1}$ on two weekdays and on one weekend day. Objectively measured sedentary time was standardized with daily monitoring time, which allowed the children, who had worn the accelerometers for different amounts of time per day, to be compared.

Potential confounders. The parent or the child's main caregiver filled in a questionnaire concerning family background. The mother's and father's education, family income, marital status, and children's learning difficulties were investigated. The highest level of parental education, which was calculated from the mother's and father's education, was categorized as 1 = tertiary level education and 0 = basic or upper secondary education. The marital status of the main carer was categorized as 1 = married or cohabiting and 0 = divorced or single/widow. Children's learning difficulties were evaluated with the following question: "Does your child have any diagnosed learning difficulties?" (categorization, 1 = yes and 0 = no or do not know).

Statistical analyses. The Statistical Package for the Social Sciences was used for the statistical analyses (SPSS, 2010, IBM SPSS Statistics 19 Core System User's Guide; SPSS Inc., Chicago, IL). Logarithmic transformations were used for variables with skewed distributions. Because the distribution of self-reported MVPA was negatively skewed, the distribution was reflected and logarithmically transformed and then reflected again to restore the original order of the

TABLE 1. Sample characteristics according to sex and all participants.

	Boys			Girls			All			
	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	*P*[a]
Age (yr)	12.2	0.7	123	12.2	0.6	154	12.2	0.6	277	0.765
GPA (4–10)[b]	8.07	0.72	122	8.37	0.57	153	8.24	0.66	275	<0.001
Objectively measured MVPA ($min \cdot d^{-1}$)[c]	59.9	22.3	95	56.3	17.1	125	57.9	19.5	220	0.623
Objectively measured sedentary time ($\%\cdot d^{-1}$)[d]	39.6	3.5	95	40.8	3.1	125	40.3	3.3	220	0.006
Self-reported screen time ($h \cdot d^{-1}$)	3.82	1.96	121	3.49	1.86	154	3.63	1.91	275	0.095

[a]*P* values for sex differences (*t*-test).
[b]The GPA (scale 4–10, where 10 is the highest GPA one can earn) was calculated from the grades in the following individual school subjects: native language (in most cases Finnish or Swedish), first foreign language (started in grade 3), mathematics, physics/chemistry, biology, history, geography, religion or ethics, visual arts, music, and physical education.
[c]MVPA measured with the ActiGraph accelerometer using a cutoff value 2296 counts per minute.
[d]Sedentary time measured by the ActiGraph accelerometer using a cutoff value 100 counts per minute and expressed as percentage of daily monitoring time ($\%\cdot d^{-1}$).

variable ($-\ln((\max + 1) - y)$). The distributions of self-reported screen time and objectively measured MVPA were positively skewed. To measure sex differences, the independent samples *t*-test was used. The cross-sectional associations among physical activity, sedentary behavior, and academic achievement were examined with ANOVA and linear regression analysis. For the ANOVA, children were divided into tertile groups (33% each) according to the amount of objectively measured MVPA (1, tertile ≤47.0 min; 2, tertile 47.1–65.0 min; 3, tertile ≥65.1 min) and sedentary time (1, tertile ≤38.4%; 2, tertile 38.5%–41.4%; 3, tertile ≥41.5%). In addition, children were classified into groups according to the self-reported MVPA (1 = 0–2 $d \cdot wk^{-1}$, 2 = 3–4 $d \cdot wk^{-1}$, 3 = 5–6 $d \cdot wk^{-1}$, 4 = 7 $d \cdot wk^{-1}$) and screen time (1 = 0.00–1.99 $h \cdot d^{-1}$, 2 = 2.00–2.99 $h \cdot d^{-1}$, 3 = 3.00–3.99 $h \cdot d^{-1}$, 4 = 4.00–4.99 $h \cdot d^{-1}$, 5 = ≥5.00 $h \cdot d^{-1}$).

Before the multiple regression, the Pearson's correlation coefficients for continuous variables were calculated to estimate associations between single variables and GPA. To investigate whether the associations between self-reported or objectively measured MVPA and GPA are quadratic, quadratic terms were calculated using an equation $x^2 = ((x - \text{mean}(x)) \times (x - \text{mean}(x))$, where x is the logarithmically transformed self-reported MVPA or logarithmically transformed objectively measured MVPA. After that we used enter approach for the multiple regression. To calculate change in R^2, the variables of interest were added to the second block one by one, and all other variables of the model (potential confounders and other variables of interest) were added to the first block. The change in R^2 for all variables of interest was calculated and tested for significance. To study whether the assumptions of the regression analysis were fulfilled, we examined the distribution of model residuals. Sample characteristics were summarized descriptively, using mean and SD values for continuous data and frequencies and percentages for categorical data. The level for statistical significance was determined as $P < 0.05$. The star symbols are used to illustrate statistical significance in the figures and tables (***$P < 0.001$, **$P < 0.01$, *$P < 0.05$).

RESULTS

The mean age of the children was 12.2 yr, and 56% of the children were girls (Table 1). In 79% of families, the highest level of parental education was tertiary level education. Seventy-six percent of parents were married or cohabiting. Seven percent of children had a diagnosed learning difficulty.

On the basis of the teacher ratings, girls had higher GPA compared with boys ($t_{228} = 6.26$, $P < 0.001$) (Table 1). Boys reported MVPA for at least 60 $min \cdot d^{-1}$ more often than girls ($t_{239} = 8.10$, $P = 0.049$) (Table 2). On the basis of objective measurements, children had, on average, 58 min of MVPA per day, with no statistically significant difference between boys and girls ($t_{162} = 5.34$, $P = 0.623$) (Table 1). However, girls spent more of their waking hours sedentary than boys ($t_{218} = 2.71$, $P = 0.006$). On average, children reported 3.6 h of screen time per day, with no statistically significant difference between boys and girls ($t_{273} = 1.11$, $P = 0.095$) (Table 1).

According to the ANOVA, a high level of self-reported MVPA was associated with a high GPA ($F_{3, 268} = 6.56$, $P < 0.001$) (Fig. 1a). Children who were physically active at least 60 $min \cdot d^{-1}$ for 5–6 $d \cdot wk^{-1}$ had the highest GPA (8.41), whereas children who were physically active 0–2 $d \cdot wk^{-1}$ had the lowest GPA (7.83). Screen time was inversely associated with GPA ($F_{4, 268} = 7.08$, $P < 0.001$) (Fig. 1b). Children who had less than 2 $h \cdot d^{-1}$ of screen time had the highest GPA (8.5), whereas children who had more than 5 $h \cdot d^{-1}$ of screen time had the lowest GPA (8.0). Objectively measured MVPA ($F_{2, 216} = 0.17$, $P = 0.843$) and sedentary time ($F_{2, 216} = 0.46$, $P = 0.635$) were not associated with GPA (Figs. 1b and 1c).

According to Pearson's correlation coefficients, self-reported screen time was negatively associated with GPA ($P < 0.001$) (Table 3), whereas objectively measured MVPA ($P = 0.955$) or sedentary time ($P = 0.285$) had no significant association with GPA. The quadratic term for self-reported MVPA was associated with GPA ($P < 0.001$) (Table 3), whereas the quadratic term for objectively measured MVPA was not

TABLE 2. Self-reported MVPA.

Self-Reported MVPA (Active Days per Week)[a]	Boys (%)	Girls (%)	All (%)
0–1	5.0	1.3	2.9
2	1.7	7.2	4.7
3	7.4	13.1	10.6
4	19.8	15.0	17.2
5	19.0	22.2	20.8
6	13.2	22.9	18.6
7	33.9	18.3	25.2
n	123	154	277
P[b]	0.049		

[a]The percentages of children who were physically active for at least 60 $min \cdot d^{-1}$ during 0–1, 2, 3, 4, 5, 6, or 7 $d \cdot wk^{-1}$ according to self-reports.
[b]*P* values for the sex differences (*t*-test).

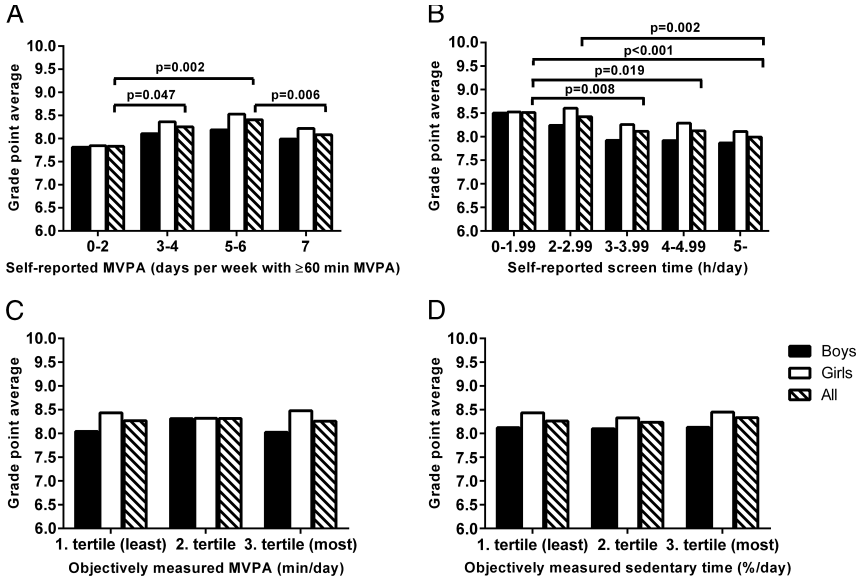

FIGURE 1—GPA with self-reported MVPA (A), self-reported screen time (B), objectively measured MVPA (C), and objectively measured sedentary time (D). Results from ANOVA.

($P = 0.123$). According to multiple regression analysis, self-reported MVPA had an inverse U-shaped curvilinear association with GPA (Fig. 2a, Table 3), and screen time had a linear negative association with schools' grade average, after adjusting for sex, learning difficulties, the highest level of parental education, and amount of sleep (Fig. 2b, Table 3). The adjusted R^2 for the model was 0.305. The regression model residuals were normally distributed.

DISCUSSION

Summary of results. In this study, self-reported physical activity was directly, and screen time inversely, associated with academic achievement in children. Objectively measured physical activity and sedentary time were not associated with academic achievement.

Self-reported physical activity and academic achievement. Our finding of a positive association between self-reported physical activity and academic achievement is consistent with previous studies that reported MVPA is associated with high levels of academic performance (13,17,30). In addition, Donelly et al. (8) reported that adding 90 min of MVPA to children's school week resulted in improvements in academic achievement during the 3-yr intervention time. However, in our study, the relationship between self-reported MVPA and academic achievement was curvilinear. It seems that five to six times per week may be the optimal amount of MVPA from the perspective of academic achievement. It may be that some of the most active children spend time in physical activities at the expense of time devoted to homework. A positive association between physical activity and academic achievement may be due to effects of physical

TABLE 3. Regression analysis of GPA.

	Pearson's Correlations	Regression Model		
		B (SE)	Beta (SE)	ΔR^{2a}
Children's learning difficulties[b]	−0.368***	−0.697*** (0.139)	−0.297*** (0.139)	
The highest level of parental education[c]	0.247***	0.307** (0.087)	0.207** (0.087)	
Amount of sleep ($h \cdot d^{-1}$)	0.211***	0.114* (0.052)	0.129* (0.052)	
Sex (female)	0.223***	0.176* (0.072)	0.144* (0.072)	
Self-reported MVPA[d]	0.003	0.065 (0.061)	0.067 (0.061)	0.004
Quadratic self-reported MVPA[e]	−0.247***	−0.337** (0.104)	−0.199** (0.104)	0.035**
Self-reported screen time ($h \cdot d^{-1}$)[f]	−0.276***	−0.198** (0.062)	−0.193** (0.062)	0.033**
R^2		0.328		
Adjusted R^2		0.305		
N		212		

The level of statistical significance: ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.
[a]The change in R^2 , self-reported MVPA, quadratic self-reported MVPA, and screen time were added to the model one by one.
[b]Parental report of child's diagnosed learning difficulties categorized as 1 = yes and 0 = no or do not know.
[c]The highest level of parental education categorized as 1 = tertiary level education and 0 = basic or upper secondary education.
[d]The distribution of self-reported MVPA was reflected and transformed logarithmically and reflect again to restore the original order of the variable ($-\ln((\max + 1) y)$).
[e]To measure quadratic association between self-reported physical activity and GPA, quadratic term was formed with the following equation: quadratic self-reported MVPA = $((x - \text{mean}(x)) \times (x - \text{mean}(x))$, where x is the logarithmically transformed self-reported MVPA ($-\ln((\max + 1) - y)$).
[f]Distribution of self-reported screen time was transformed logarithmically ($\ln(y)$).
B, unstandardized coefficient; Beta, standardized coefficient; ΔR^2, change in R^2.

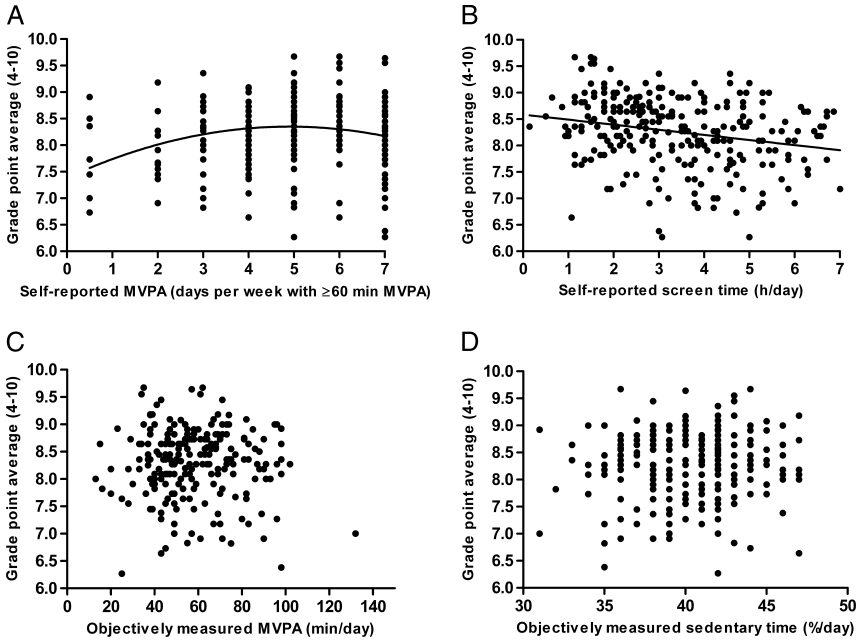

FIGURE 2—GPA with self-reported MVPA (A), self-reported screen time (B), objectively measured MVPA (C), and objectively measured sedentary time (D). Results from the regression analysis.

activity on children's cognitive function. Davis et al. (7) and Chaddock et al. (4) suggested that regular physical activity enhances executive functions. Likewise, Castelli et al. (2) and Kamijo et al. (16) in their intervention studies observed that increased physical activity had a positive influence on children's executive functions and working memory.

Objectively measured physical activity and academic achievement. In this study, objectively measured MVPA was not associated with children's academic achievement. Our results support those of LeBlanc et al. (20), who reported that objectively measured MVPA was not associated with academic performance in children. In contrast, Kwak et al. (19) found that objectively measured vigorous physical activity was associated with academic achievement in girls, but not in boys. However, Kwak et al. (19) studied adolescents (15–16 yr), whereas we and LeBlanc et al. (20) studied children age 10–12 yr. Furthermore, in the present study, physical activity was measured during seven consecutive days, whereas LeBlanc et al. (20) and Kwak et al. (19) measured physical activity for 3 and 4 d, respectively.

Explanations for the inconsistencies between self-reported and objectively measured MVPA in association with academic achievement. The inconsistency between the subjective and the objective measures of physical activity in association with academic achievement may be due to the difficulty estimating one's overall physical activity. According to Corder et al. (5), 40% of inactive children age 10 yr old overestimated their physical activity compared with the objective measure. However, nowadays, skill-specific types of physical activities based on body movements are common among children but may not be seen in activity counts. For example, skateboarding is a skill-specific physical activity, which requires balance and agility, but hardly accumulates activity counts. Therefore, self-reported MVPA may better illustrate different types of activity, including skill-specific activity, whereas accelerometer-measured MVPA mainly illustrates cardiovascular activity. Objective and subjective measures may reflect different constructs and contexts of physical activity in association with academic outcomes.

Sedentary behavior and academic achievement. According to this study, self-reported screen time was inversely associated with academic performance. This finding is in line with previous studies (22,27), supporting the hypothesis of time displacement (28). Time displacement theory suggests that the time spent in front of the screen may simply displace time spent in other activities such as doing homework, reading books, or sleeping, which may independently affect academic performance. There may be certain dispositions in media use, especially intense and exciting sensations, which increase the desire for these kinds of experiences and are incompatible with concentrated effort reading and writing (28). In addition, attention difficulties, frequent failure to do homework, and negative attitude toward school have been reported to mediate the association between television viewing at the age of 14 yr and academic failure at the age of 22 yr (15). In the present study, objectively measured sedentary time was not associated with academic achievement. This might be because objective measures of sedentary time do not specify the elements of sedentary behavior. It is reasonable to suggest that some of the sedentary activities performed (e.g., doing homework and reading) benefit learning and academic achievement.

Strengths and limitations. To our knowledge, this is the first study to examine the associations of objectively measured and self-reported physical activity on teacher-rated academic achievement. Our study sample is representative

regarding physical activity, showing that the level of physical activity of Finnish school-age children is comparable with that reported in international results (6). Because of the cross-sectional design, conclusions regarding causality of the observed relationships cannot be drawn. In addition, the time spent doing homework, reading, or performing other activities that may benefit academic achievement was not investigated, limiting more precise examination of sedentary behavior. Moreover, the detailed content of screen-based sedentary behavior was not assessed, limiting the interpretation of the results regarding screen-based sedentary behavior. Inconsistency in physical activity results may be due to the accelerometer method itself. The accelerometer does not measure swimming, cycling, or similar activities. Furthermore, 1 wk or less of objective measurement may not be long enough to depict children's usual physical activity.

Future research. More research, especially more randomized controlled trials and longitudinal studies, is needed to clarify the relationship between physical activity and academic achievement. Besides, more information about the factors that may explain the association between physical activity and academic performance is needed. In future studies, longer accelerometer wearing times and, preferably, several measurement periods during the school year should be considered. Moreover, the inconsistency between the subjective and objective measurements related to educational outcomes observed in this study offers an interesting viewpoint for future studies to consider. We recommend that future studies use subjective and objective measurements to examine physical activity, sedentary behavior, and academic achievement. Furthermore, methods should assess not only the amount but also different types of physical activity and sedentary behavior more precisely.

CONCLUSIONS

In conclusion, self-reported, but not objectively measured, physical activity and sedentary behavior were associated with academic achievement in children. Self-reported MVPA had an inverse U-shaped curvilinear relationship with GPA, whereas self-reported screen time had a linear negative relationship with GPA.

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