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Fitness and Screen Time at Age 13 Relates to Academic Performance at Age 16

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ABSTRACT

Aim: Investigate the longitudinal relationship between physical activity, organised physical activity, fitness, screen time and academic performance among Swedish adolescents.

Methods: Data from 1139 adolescents at age 13, included vigorous physical activity (accelerometry), fitness (submaximal ergometer test), screen time and organised physical activity participation (self-reported) and academic performance (math and Swedish grades at ages 13 and 16 from registry). Academic performance at age 16 was categorised as A–D (higher grades or pass) or E, F (fail or at-risk of failing). Multilevel logistic regression models were used to examine the relationships while adjusting for gender, parental education, parental country of birth and academic performance at age 13.

Results: Higher fitness at age 13 was associated with increased odds of receiving A–D at age 16 (OR: 1.04 per mL, 99% CI 1.00, 1.07, $p=0.003$). High screen time during weekdays was associated with reduced odds (OR: 0.40, 99% CI 0.20, 0.81, $p=0.001$) compared to low screen time.

Conclusion: Academic performance at the end of compulsory school (age 16) was related to fitness and screen time 3 years earlier. These findings create a paradigm for future randomised controlled trials to explore how influencing these factors might affect academic performance.

1 | Introduction

Academic achievement, at the end of compulsory school, is frequently highlighted as pivotal for future educational attainment and employment stability. In Sweden, compulsory school is 10 years (grades 0–9). Following completion of compulsory school, typically around age 16, most adolescents choose to attend upper secondary school (high school) for an additional 3 years, although attendance is not mandatory [1]. The upper secondary school aims to 'provide a good foundation for work, further studies, personal development, and active participation in the life of society' [2]. Students often feel significant pressure to achieve high grades by the end of compulsory school, as admission to upper secondary school is largely based on these grades. Most upper secondary schools accept students with the highest grades, provided they have passing grades (E or above on

Abbreviations: COVID-19, Coronavirus Disease 2019; GIH, The Swedish School of Sport and Health Sciences; PISA, Program for International Student Assessment.

Summary

- Research exploring the longitudinal relationship between lifestyle factors, such as physical activity, screen time and later academic performance is scarce.
- Low fitness and high screen time were associated with higher odds of receiving a low grade at the end of compulsory school.
- Physical activity at age 13 was not associated with academic performance at age 16.

an A–F scale) in mathematics, Swedish, English and five other subjects [2]. Students not meeting these criteria could enrol in introductory programs aimed to help students become eligible for upper secondary school, prepare for the labour market, or progress to other forms of education [2].

Academic achievement at the end of compulsory school has been found to predict outcomes in adulthood, such as educational attainment and university performance [3]. Furthermore, low performance at the end of compulsory school has also been linked to future mental health problems. For instance, a Swedish cohort study showed that the incident rate ratio for suicide was higher among those with the lowest grades at age 16 compared to those with the highest grades after controlling for confounding factors [4].

Although academic performance is influenced by various genetic, environmental and educational factors, it has been suggested that modifiable factors, such as physical activity, fitness or screen time, could also play a role. For example, in a longitudinal study, screen time was linked to lower academic performance, while self-reported physical activity was associated with higher grades, but only in physical education [5]. Furthermore, there is cross-sectional evidence linking fitness to academic performance [6]. A study in children indicate that the association between fitness and academic performance may vary by gender, with significant relationships observed primarily among girls [7]. However, the evidence for longitudinal associations between fitness and academic performance remains inconclusive [6].

There is a lack of longitudinal studies investigating physical activity, participation in organised physical activity, fitness, screen time and later academic performance in the same sample using robust estimates, such as accelerometer-measured physical activity and accounting for confounding variables.

Therefore, this study aimed to investigate the longitudinal relationships between accelerometer-based vigorous physical activity, organised physical activity, fitness, screen time and academic performance among Swedish adolescents, analysing the entire sample and stratifying by gender.

We hypothesise that:

1. Higher levels of vigorous physical activity at age 13 will be associated with higher odds of receiving a high or a passing grade (A–D) at age 16.
2. Participation in organised physical activity at age 13 will be associated with higher odds of receiving a high or a passing grade (A–D) at age 16.
3. Higher levels of fitness at age 13 will be associated with higher odds of receiving a high or a passing grade (A–D) at age 16.
4. Lower screen time at age 13, will be associated with higher odds of receiving a high or a passing grade (A–D) at age 16.

2 | Methods

2.1 | Study Design, Setting and Participants

This longitudinal study utilised data from the study "Physical Activity for Healthy Brain Functions in School Youth" among Swedish adolescents [8]. The baseline measurement was conducted from September to December 2019 at age 13. The follow-up measure, focusing on academic performance (grades at age 16), was collected from the same sample in the spring of 2022, during the COVID-19 pandemic.

The recruitment and data collection for the baseline measures are described in more detail elsewhere [8]. In brief, all schools within a 2–3-h drive from Stockholm, Sweden, were invited to participate in the study ($n = 558$). School inclusion was capped at 40 schools for feasibility reasons, ensuring diversity in geographical location, school type and parental education levels. Six schools dropped out before the data collection due to time constraints, leaving a final sample of 34 schools. A total of 1139 grade 7 students (mean age 13.4 years) from these schools participated (73% of 1556 eligible students). Since the questionnaires were in Swedish, proficiency in Swedish served as an inclusion criterion.

2.2 | Ethics Statement

Approval for the study was obtained from the Swedish Ethical Review Authority (reference no. 2019-03579 and 2021-01235). All participating adolescents and their parents provided informed consent before the baseline measures.

2.3 | Data Collection

At baseline, all participants visited the laboratory (class-wise) at the Swedish School of Sport and Health Sciences (GIH) in Stockholm, Sweden, where they completed a questionnaire about screen-time use and participation in organised physical activity, underwent a fitness test, and were provided with a hip-worn accelerometer to measure their physical activity. Data on parental education and student academic performance were obtained from Statistics Sweden. Participants received a 300 SEK gift card as compensation for their participation in the study.

2.3.1 | Academic Performance (Outcome)

Academic performance was obtained from official records provided by Statistics Sweden at two time points (baseline at age 13 and follow-up at age 16).

The variables of interest were final grades in math and Swedish language (both native and second language variations). In the Swedish school system, an A represents the highest possible grade, whereas an F indicates a failing grade. An outcome variable for academic performance at age 16 was created by categorising adolescents into two groups: those achieving A–D grades (denoting high or passing grades) in both math and Swedish and those obtaining E, F grades (denoting fail or at-risk for failing) in either or both subjects.

Furthermore, a variable representing average academic performance at age 13 was included as a confounding factor in the analyses. This variable was created by converting alphabetic grades to numeric values (one representing an F and six representing an A), then averaging the numeric grades from math and Swedish by summing them and dividing by two.

2.3.2 | Baseline Measures (Predictors)

2.3.2.1 | Vigorous Physical Activity. Physical activity was assessed using a hip-worn accelerometer (model GT3X+, Actigraph, LCC, Pensacola, FL, USA) with a 30 Hz sampling rate. The adolescents wore the accelerometer during waking hours, except during water-based activities, for seven consecutive days after visiting the research centre. Data were processed in Actilife (v6.13.3) as uniaxial data, using 5-s epoch time intervals. To capture only waking hours, individual time filters were applied in Actilife, based on reported awake/sleep times from questionnaires. Non-wear time was defined as 60 min of zero counts with no spike tolerance. Vigorous-intensity physical activity intensity was categorised using cut-off counts by Evenson, defined as > 4012 counts per minute [9].

A day was considered valid if it contained at least 500 min of wear time, and at least three valid days (including at least one weekday and one weekend day) were required to be included in the analyses. Time spent in vigorous physical activity was expressed in minutes per day, presented as the average minutes per day over the measurement period. The statistical models were controlled for wear time.

2.3.2.2 | Fitness. Cardiovascular fitness was estimated using the Ekblom-Bak test, a submaximal ergometer test, described in more detail elsewhere [10]. In brief, the adolescents were instructed to pedal for 8 min at 60 rpm. A standardised work rate of 32 watts was applied during the first 4 min. The work rate was adjusted individually for the last 4 min to achieve a steady-state heart rate of over 120 beats per minute. The adolescents' heart rates were monitored and recorded during the last minute of each level of work [10]. Maximal oxygen consumption (millilitres of oxygen per kilogram of body weight per minute, mL/kg/min) was estimated using the change in heart rate between two different workloads while accounting for gender and age. Prepubertal boys (self-reported Tanner stage 1–2) were estimated using the equation designed for females, as recommended by Björkman and colleagues [10].

2.3.2.3 | Participation in Organised Physical Activity. Participation in organised physical activity was self-reported in the questionnaire using the following question, 'Are you active in any sports club/organisation? (e.g., football, swimming, dancing, scouts, gym)?' (yes/no). Adolescents who reported no participation were used as a reference group.

2.3.2.4 | Screen Time. Screen time during weekdays and weekends was self-reported in the questionnaire using the following questions: 'During a normal weekday/weekend day, approximately how much time do you spend using a screen (not including schoolwork) including a cell phone, TV, computer, iPad? (for example, to play games, watch TV, chat, watch serials, YouTube, Snapchat, and Instagram)' using the following answers: 'not at all', 'less than 1 h', '1–2 h', '3–4 h', '5–6 h' or '7 h or more'. These were grouped into three categories: low (≤ 2 h), medium (3–4 h), and high (≥ 5 h or more) screen time, with low screen time serving as the reference group.

2.3.2.5 | Other Variables. Data on parental education was obtained from Statistics Sweden and categorised into two groups: short education (≤ 12 years) or long education (> 12 years), based on the parent within the family with the longest education.

In the questionnaire, the adolescents reported their gender (girl, boy or other) and their parents' birth country (both parents born in Sweden, both parents born abroad or one parent born in Sweden and one born abroad). Furthermore, pubertal status was self-reported by the adolescents using Tanner drawings [11]. In this study, this measure was used to distinguish between prepubertal and pubertal boys when estimating their fitness (as described above).

2.4 | Statistics

Data was analysed using Stata/SE version 18 (Stata Corp LLC, College Station, TX, USA). Descriptive statistics were used to summarise the data, such as means and standard deviations or frequencies and proportions. As shown in Tables 1 and 2, group differences were assessed using *t*-tests or χ^2-tests.

Multilevel logistic regression with two levels (individual and school) was used to investigate the relationship between predictors at age 13 (fitness, vigorous physical activity, participation in organised physical activity and screen time) and academic performance at age 16 (grouped into A–D or E, F). This approach accounted for the nesting of students within schools, enabling the analysis of factors at both the school and student levels. In the models, gender, parental education, parental country of birth and academic performance at age 13 were used as confounders. All models were performed in the whole sample and stratified by gender. The predictors were run in separate models rather than in the same model, which would reduce power, especially when stratifying by gender. Results from models which included all predictors together, are provided in the Supporting Information (Tables S3 and S4), along with crude versions of the main results (Table S1). To address multiple comparisons in the logistic regression models, we applied the False Discovery Rate approach by Benjamini-Hochberg, using a false discovery rate of 5% [12]. As a result, the significance level was set to alpha = 0.01, and the findings are reported with 99% confidence intervals.

TABLE 1 | Baseline characteristics at age 13, stratified by academic performance group at age 16 (mean ± SD unless otherwise specified).

	All	Fail or at-risk of failing (E, F)	Higher grades or pass (A–D)	*p*
Total, *n* (%)	1139	422 (38.6)	670 (61.4)	
Gender				**0.005**
Girls, *n* (%)	580 (51.0)	192 (45.6)	364 (54.3)	
Boys, *n* (%)	558 (49.0)	229 (54.4)	306 (45.7)	
Parental education				**< 0.001**
Short ≤ 12 years, *n* (%)	372 (33.8)	216 (51.8)	150 (22.5)	
Long > 12 years, *n* (%)	730 (66.2)	201 (48.2)	518 (77.5)	
Parental country of birth				**< 0.001**
Both parents born in Sweden *n* (%)	656 (59.3)	213 (52.7)	428 (65.1)	
One parent born in Sweden *n* (%)	168 (15.2)	64 (15.8)	100 (15.2)	
Both parents born abroad *n* (%)	283 (25.6)	127 (31.4)	129 (19.6)	
Fitness				**0.0014**
Estimated $V0_2$ max (mL/kg/min)	49.5 (10.1)	50.02 ± 12.7	52.45 ± 11.4	
Vigorous physical activity				**0.0005**
Average min per day/week)	21.4 (12.0)	19.41 ± 11.86	22.33 ± 11.94	
Participation in organised physical activity				**< 0.001**
Yes	788 (72.0)	243 (61.5)	521 (79.3)	
No	306 (28.0)	152 (38.5)	136 (20.7)	
Screen-time weekdays				**< 0.001**
Low (≤ 2 h)	360 (32.0)	115 (27.8)	228 (34.2)	
Medium (3–4 h)	515 (45.7)	171 (41.3)	327 (49.1)	
High (≥ 5 h)	251 (22.3)	128 (30.9)	111 (16.7)	
Screen-time weekends				**0.004**
Low (≤ 2 h)	178 (15.9)	72 (17.5)	97 (14.6)	
Medium (3–4 h)	412 (36.7)	126 (30.6)	270 (40.5)	
High (≥ 5 h)	533 (47.5)	214 (51.9)	299 (44.9)	

Note: Group differences were analysed with a *t*-test (continuous variables) or χ^2 test (categorical variables). Fitness: Estimated maximal oxygen consumption, ($V0_2$ max) expressed in mL/kg/min, vigorous physical activity; minutes spent in vigorous physical activity. Bold values indicate *p* values reaching statistical significance.

After conducting the multilevel logistic regression, the Stata margins command was used to predict outcomes based on the fitted model for different groups of adolescents. For instance, the probability of receiving an A–D grade at age 16 if the participant had a specific fitness level or grade at age 13. These predictions were made while keeping all other confounding variables at their average values.

3 | Results

A total of 1139 adolescents, with a mean age of 13.4 years, participated in the study. Among them, 51% were girls, and 66% had parents with long education. The baseline characteristics of the sample, stratified by academic performance at age 16, are provided in Table 1.

Table 1 shows the descriptive data that presents the mean differences or proportions between the two groups (fail or at-risk of failing, E, F, and higher grades or pass, A–D). Among the adolescents with higher grades or a passing grade (A–D) at age 16, a significantly larger proportion were girls, had parents with higher education, and had two parents born in Sweden. Additionally, this group engaged in higher levels of vigorous physical activity, had better fitness, were more likely to participate in organised sports, and had lower screen time at age 13. Baseline characteristics stratified by gender are presented in Supporting Information (Table S1).

TABLE 2 | Academic performance at age 13 and 16 by gender (frequency and proportion (%).

	Age 13				Age 16			
	All $n=1054$	**Girls $n=538$**	**Boys $n=515$**	***p***	**All**	**Girls**	**Boys**	***p***
Math grade				0.398				0.728
A, *n* (%)	139 (13.2)	67 (12.5)	72 (14.0)		165 (15.7)	79 (14.7)	86 (16.7)	
B, *n* (%)	199 (18.9)	108 (20.1)	91 (17.7)		143 (13.6)	77 (14.3)	66 (12.8)	
C, *n* (%)	207 (19.6)	103 (19.1)	104 (20.2)		215 (20.4)	117 (21.8)	98 (19.0)	
D, *n* (%)	218 (20.7)	120 (22.3)	97 (18.8)		164 (15.6)	79 (14.7)	85 (16.5)	
E, *n* (%)	214 (20.3)	107 (19.9)	107 (20.7)		307 (29.1)	157 (29.2)	149 (28.9)	
F, *n* (%)	77 (7.3)	33 (6.1)	44 (8.5)		60 (5.7)	29 (5.4)	31 (6.0)	
Swedish grade				**< 0.001**				**< 0.001**
A, *n* (%)	97 (9.2)	70 (13.0)	27 (5.3)		158 (15.0)	118 (22.0)	40 (7.8)	
B, *n* (%)	221 (21.0)	143 (26.6)	78 (15.2)		198 (18.8)	121 (22.5)	76 (14.8)	
C, *n* (%)	263 (25.0)	146 (27.2)	117 (22.8)		285 (27.1)	148 (27.6)	137 (26.7)	
D, *n* (%)	232 (22.1)	103 (19.2)	128 (24.9)		169 (16.1)	69 (12.9)	100 (19.5)	
E, *n* (%)	169 (16.1)	59 (11.0)	110 (21.4)		196 (18.6)	64 (11.9)	132 (25.7)	
F, *n* (%)	70 (6.7)	16 (3.0)	54 (10.5)		46 (4.4)	17 (3.17)	29 (5.6)	

Note: Bold values indicate *p* values reaching statistical significance.

A total of 1054 adolescents had data on academic performance at both time points. Table 2 shows the academic performance (grades in math and Swedish) at ages 13 and 16, both for the whole sample and stratified by gender. Girls had higher grades in Swedish (but not math) at ages 13 and 16, $p<0.001$. When dichotomising the grades into fail or at-risk of failing (E, F) or higher grades or pass (A–D), 65% of the total sample was classified into the A–D group for math at age 13 and 73% at age 16. For Swedish, 77% of the sample were in the A–D category at both ages. A significant gender difference was observed in Swedish grades. At age 16, 85% of girls were in the A–D category compared to 69% of boys. Similarly, at age 13, 86% of girls and 68% of boys achieved A–D grades.

3.1 | Associations Between Physical Activity, and Organised Physical Activity at Age 13 and Academic Performance at Age 16

As seen in Table 3, time spent in vigorous physical activity or participation in organised physical activity at age 13 was not significantly related to academic performance at age 16.

3.2 | Associations Between Fitness at Age 13 and Academic Performance at Age 16

Fitness level at age 13 was significantly related to academic performance at age 16 across the entire sample. More specifically, for each 1 mL increase in fitness, the odds of receiving grade A–D at age 16 was 4% higher (odds ratio: 1.038). The results are presented in Table 3.

3.2.1 | Predicted Probabilities (Results Not Shown)

Given that the units of fitness are small (1 mL/kg/min), we used the same model to predict the probability of receiving an A–D at age 16 for adolescents that had a fitness level 1 SD above or below the gender mean while keeping the other confounders constant.

The model predicted a 67% probability of receiving an A–D among adolescents with fitness levels 1 standard deviation above the mean, for both girls and boys. The 99% confidence interval (CI) for this prediction was 60%–73% for girls and 61%–74% for boys. For adolescents with fitness levels 1 standard deviation below the mean, the predicted probability of receiving an A–D was 60% (99% CI of 53%–66% for girls and 53%–67% for boys).

3.2.2 | Predicted Probabilities Based on Academic Performance at Age 13 (Results Not Shown)

We also predicted the probability of receiving an A–D at age 16 among adolescents that had a fitness level 1 SD above or below the gender mean, and who received an average grade of E or F at age 13. Among adolescents with fitness above the mean, who received of E at age 13, their predicted probability to improve their grades to an A–D at age 16 were 18% among girls (99% CI: 8%–28%) and 19% among boys (99% CI: 9%–29%). The corresponding probabilities among adolescents with fitness levels below the mean, who had received an average grade of E at age 13, were 11% for both girls and boys. The 99% confidence interval was 4%–17% for girls and 4%–18% for boys.

TABLE 3 | Adjusted results from multilevel logistic regression (treating schools as clusters)[a].

Predictor (grade 7)	All					Girls					Boys				
	n	Odds ratio	*p*	Lower 99% CI	Upper 99% CI	*n*	Odds ratio	*p*	Lower 99% CI	Upper 99% CI	*n*	Odds ratio	*p*	Lower 99% CI	Upper 99% CI
Fitness	914	**1.038**	**0.003**	**1.005**	**1.072**	513	1.038	0.055	0.987	1.091	401	1.038	0.029	0.993	1.086
Vigorous physical activity (min)	816	1.012	0.236	0.986	1.040	444	0.997	0.828	0.957	1.038	371	1.020	0.172	0.983	1.059
Org physical activity, yes	983	1.375	0.152	0.775	2.437	503	1.223	0.556	0.507	2.954	479	1.434	0.240	0.651	3.161
Screen-time Weekdays	1007					517					489				
Low (≤ 2 h)		Ref					Ref					Ref			
Medium (3–4 h)		0.655	0.070	0.359	1.195		0.783	0.496	0.311	1.973		0.458	0.019	0.194	1.083
High (≥ 5 h)		**0.401**	**0.001**	**0.199**	**0.810**		**0.309**	**0.005**	**0.106**	**0.901**		0.464	0.047	0.171	1.256
Screen-time Weekend	1005					518					486				
Low (≤ 2 h)		Ref					Ref					Ref			
Medium (3–4 h)		0.975	0.934	0.450	2.115		1.010	0.983	0.304	3.356		0.993	0.986	0.339	2.901
High (≥ 5 h)		0.805	0.447	0.385	1.680		1.135	0.779	0.353	3.651		0.544	0.118	0.200	1.489

Note: Bold values indicate *p* values reaching statistical significance.
[a]Adjusted for parental education, parental country of birth, gender, average grade in math and Swedish in grade 6, and wear-time (in the vigorous physical activity model).

Among adolescents with fitness levels above the mean, who had received an average grade of F at age 13, the predicted probability of improving their grades to an A–D by age 16 was 4% (99% CI: 0%–7% for girls and 1%–7% for boys). The corresponding probabilities for adolescents with fitness levels below the mean were 2% (99% CI: 0%–4% for girls and boys).

3.2.3 | Predicted Probabilities Based on Parental Education Level (Results Not Shown)

We also predicted the probability of receiving grades A-D at age 16 among adolescents with fitness levels 1 SD above or below the gender mean at age 13, considering whether their parents had long or short education. Among adolescents who had a fitness above the mean at age 13 and parents with long education, the probability of receiving an A–D at age 16 was 69% among girls (99% CI: 62%–76%) and 70% among boys (99% CI: 63%–77%). For adolescents with the same fitness level but with parents with short education, the corresponding probability was approximately 63% among girls (99% CI: 55%–71%) and 64% among boys (99% CI: 56%–72%).

Among adolescents who had a fitness below the mean at age 13 and had parents with long education, the probability of receiving an A–D at age 16 was 62%, with a 99% CI of 55%–69% among girls and 55%–69% among boys. The corresponding probability among adolescents with the same fitness level but had parents with short education was 56% (99% CI: 48%–63% for girls and 48%–65% for boys).

3.3 | Association Between Screen Time at Age 13 and Academic Performance at Age 16

As seen in Table 3, adolescents who had high screen time (≥5 h) during weekdays at age 13 had lower odds of receiving grades A–D at age 16 (odds ratio: 0.401), compared to the low screen time group (≤2 h). Screen time during weekend days at 13 did not significantly predict academic performance at age 16.

3.3.1 | Predicted Probabilities (Results Not Shown)

The probability of receiving an A–D at age 16 for each screen time group at age 13 was predicted using the margins command in Stata following the fitted screen time model. These results are summarised in Figure 1.

3.4 | Gender-Stratified Analysis

The models stratified by gender are provided in Table 3. As seen, the estimates (odds ratios) for the stratified analysis were similar to the estimates in the non-stratified models. However, in the gender-stratified analysis, only screen time on weekdays emerged as a significant predictor of academic performance at age 16, and this association was observed only among girls. Specifically, girls in the high screen time group on weekdays had lower odds of receiving grades A–D (odds ratio: 0.309), compared to those in the low screen time group. None of the other baseline variables predicted academic performance at age 16 after adjusting for multiple comparisons.

3.5 | Sensitivity Analyses

Sensitivity analyses were conducted to examine the effects of the used accelerometer criteria (three valid days) and the influence of accounting for academic performance at age 13. Additionally, sensitivity analyses were performed to investigate if using fat percentage as a confounder in all models and vigorous physical activity in the screen time models would influence the results. Overall, the findings from these analyses were consistent with those from the main models (further details are provided in the Supporting Information S1). To evaluate the consistency of behaviours such as vigorous physical activity, screen time and participation in organised physical activity over time. Results from a follow-up measure in about half of the adolescents 1.5 years after the baseline are presented in the Supporting Information (Table S5).

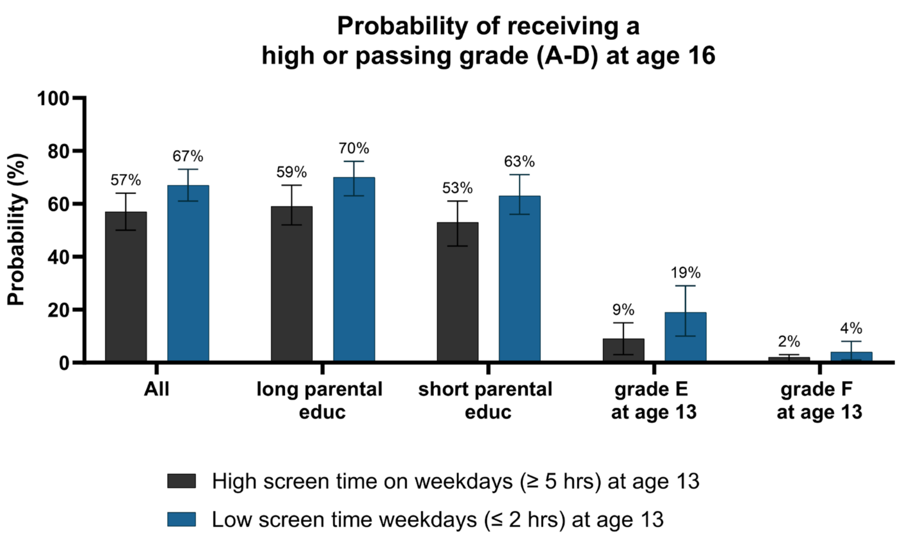

FIGURE 1 | The probability of receiving a high or passing grade (A–D at age 16 based on screen time group, parental education and grade at age 13. Probabilities are generated using the margins command in Stata, following the main screen time model, using 99% confidence intervals.

4 | Discussion

To our knowledge, this is the first longitudinal study to explore the association of accelerometer-based physical activity, participation in organised physical activity, screen time and fitness with academic performance in the same sample. Our findings indicated that fitness level and weekday screen time at age 13 predicted academic performance at age 16. Additionally, among those with low grades (E or F) at age 13, their predicted probability of improving to grades A–D at age 16 was higher if they had higher fitness or lower screen time at age 13.

In the Swedish context, academic performance at the end of compulsory school (grade 9 or age 16) holds significant importance for admission to upper secondary schools. Consequently, students who achieve the lowest grade levels (E or F) at age 16 face the risk of either not gaining admission to upper secondary schools or, if admitted, may lack the necessary tools to succeed academically. Given the established link between academic performance at the end of compulsory school, educational attainment, university performance [3], and incident rates ratio for suicide later in life [4], it is concerning that the group with low academic performance at age 16 also demonstrated suboptimal lifestyle habits as early as age 13. For example, our findings indicated that the group receiving grades E, F at age 16 exhibited lower fitness levels, engaged less in vigorous physical activity, and had higher screen time compared to the group receiving grades A–D. This presents a significant challenge for this group, not only are they less likely to succeed academically, but their low fitness levels, lack of physical activity, and excessive screen time could also have negative consequences for their future physical health [13].

With regards to the predictors, high screen time during weekdays at age 13 was linked to reduced odds of achieving high academic performance at age 16. This association was significant in the overall sample and among girls. For boys, although the odds were similar, they did not remain significant after adjusting for multiple comparisons. These findings are in line with a study by Poulain et al., which found low computer/internet use to predict higher grades in math [5]. However, Poulain et al. did not differentiate between weekday and weekend screen time.

In our study, we found that only weekday screen time significantly predicted academic performance, while weekend screen time did not. This difference may be because the proportion of adolescents spending 5h or more using screens was larger on weekends (48%), compared to on weekdays (22%). On weekends, adolescents likely have fewer obligations, allowing for more screen time without sacrificing other activities like homework or physical activity. However, spending five or more hours using screens after school on weekdays leaves little time for essential activities like homework, potentially impacting academic success. This was highlighted in a report by the Swedish Media Council, where adolescents themselves reported difficulties in limiting their screen time, and that their screen time means giving up time for other important activities, such as homework or physical activity [14]. Furthermore, a recent Program for International Student Assessment (PISA) report from the OECD on digital devices and academic performance found that students who reported more than 5h of leisure screen time per day had a mean mathematics score of 430, compared to a mean score of 490 for students who reported up to 1h of screen time per day [15]. Additionally, the report revealed that about one-third of Swedish students were distracted by their own or other classmates' use of digital devices during the majority of their mathematics lessons [15].

However, it is important to acknowledge that screen time usage can fluctuate over time. In a follow-up, conducted approximately 1.5 years after the baseline in a subgroup of the sample, 61% of adolescents with high screen time at age 13 remained in the high screen time group on weekdays, and 83% on weekends. On the contrary, only 32% of adolescents in the low screen time group maintained low screen time on weekdays, and 21% on weekends, with the remainder exhibiting an increase in screen time.

These findings suggest that low screen time at age 13 may provide additional time for homework and other activities, which potentially contribute to stronger academic performance later. This effect may persist even if screen time increases subsequently. Nevertheless, it should be noted that the follow-up was conducted during the COVID-19 pandemic, a period associated with increased screen time, especially in the adolescent population [16, 17]. Therefore, the observed increases may be attributed to pandemic-related social restrictions, and a less pronounced increase might have been observed under normal conditions.

Given the link between high screen time at age 13 and higher odds of being at risk of failing or failing at age 16, it is important for schools, parents, and professionals to help adolescents develop more balanced screen habits that do not interfere with other activities. Reducing excessive screen time could create more opportunities for activities that strengthen academic performance, such as homework, reading, as well as physical activity. Our findings showed that adolescents with high screen time were less likely to engage in vigorous physical activity compared to those with lower screen time, highlighting the importance of addressing this issue.

With regards to physical activity, we did not find participation in organised physical activity at age 13 to significantly predict academic performance in the adjusted model. Interestingly, in the crude models, this predictor was significant. However, as adolescents with parents with long education participated to a greater extent in organised physical activity, perhaps this might explain why the effect disappeared after adjusting for parental education, emphasising the need to control for confounding variables.

Previous research has highlighted high dropout rates from sports participation among older adolescents, a factor that could potentially also impact our findings [18]. For instance, a previous longitudinal study found that those who continued participation in organised sports throughout childhood and adolescence had higher academic performance at the end of school and were more likely to study at university [18]. However, in the follow-up measure of a subgroup of adolescents, we found that 88% of those who were active in organised physical activity at age 13 remained active 1.5 years later. However, it is important to note that since most adolescents (72%) reported participating in organised physical activity, the question may have been too broad. Factors such as the type, intensity, or duration of physical activity could moderate this association. For example, participation in open-skilled or complex sports, like tennis or basketball, which require players to adjust their movements and strategies continuously, has been associated with improved executive functions and math performance in children [19]. Therefore, future studies should consider examining these factors when exploring the longitudinal association between participation in organised physical activity and adolescent academic performance.

In the current study, we also did not find physical activity, more specifically vigorous physical activity at age 13 to predict academic performance at age 16. Given that our study assessed academic performance using a composite score of grades in Swedish and math, our findings align with those of Poulain et al., who similarly found that self-reported physical activity did not predict grades in German or math. However, they did observe that non-organised physical activity was positively associated with grades in physical education [5]. However, a Finnish study found that self-reported physical activity at age 12 predicted grade point average at age 15, and years of post-compulsory education in adulthood, also after adjusting for parental education and other confounding factors [20]. It is important to acknowledge that the Finnish study and our study used different measures of physical activity. The Finnish study relied on self-reported physical activity, while our study utilised accelerometery, which requires at least 3 days of valid accelerometer measurements. In our sensitivity analysis, we found vigorous physical activity to be a significant predictor of academic performance at age 16 when using less stringent criteria (including participants with at least one valid day of accelerometer data). This makes it difficult to determine if the lack of significance in our main analysis was due to a reduction in statistical power caused by the exclusion of 167 participants when applying the most stringent criteria or because there was no association. Although there was no significant association between participation in organised physical activity or vigorous physical activity at age 13 and academic performance 3 years later, we found that fitness at age 13 significantly predicted academic performance at age 16 in the whole sample. When examining the results by gender, the odds remained consistent, but the p-values did not reach significance, suggesting a potential issue with statistical power in the gender-stratified analysis.

Interestingly, we also found that having higher fitness levels increased the probability of progressing from a low grade (E or F) at age 13 to an A–D at age 16. While we only used fitness data from age 13 as a predictor, these findings go in line with a previous study that suggested that improvements in fitness were associated with improved grade point average, among those with the lowest grade point average [21]. However, among those with low academic performance (who had an E or F at age 13), having high fitness levels (or low screen time) at age 13 increased their probability of grade improvement over time.

Given that intervention studies have shown that physical activity improves fitness in this age group [22], our finding of inconclusive evidence between vigorous physical activity and fitness as predictors may be unexpected, especially since the majority (75%) of the adolescents in the follow-up either remained in the same tertile or increased their vigorous physical activity 1.5 years after baseline. However, it is important to note that physical activity is a behaviour, while fitness is a capacity influenced by multiple factors, including genetics [23], particularly before puberty. One possible explanation for the positive association between fitness and academic performance is neural efficiency. Research suggests that adolescents with higher fitness levels are better at allocating attentional resources and solving cognitive tasks more efficiently [24]. Future studies should explore the mechanisms linking fitness and academic performance, particularly in adolescents.

In relation to parental education, our findings revealed that adolescents with parents who had long education had higher grades, compared to those with parents who had short education. Additionally, we observed that the probability of progressing from a low grade (E or F) at age 13 to an A–D at age 16 was greater among adolescents whose parents had long education. This could be attributed to the fact that parents with more academic experience may be better equipped to provide their adolescents with the necessary resources for academic success, such as homework assistance and effective study techniques. This puts adolescents with parents of short education backgrounds at a disadvantage, as we found them to have lower grades and less likelihood of grade improvement. Consequently, these adolescents may encounter more obstacles in pursuing further education, particularly if their parents lack the means to support their educational progress based on their own experiences. Therefore, it is important for schools to offer academic support, such as homework support, to all students, with particular emphasis on addressing the needs of this group, to mitigate future disparities.

4.1 | Strengths and Limitations

The strengths of the current study include a relatively large sample of Swedish adolescents with varied demographic backgrounds, using robust measures such as accelerometery to measure physical activity and register-based school grades. Another strength of the study is the follow-up measure conducted on a subgroup of the sample 1.5 years after the baseline. This allowed us to assess the stability of these behaviours over time. While it would have been ideal with data from the entire sample at multiple time points, this smaller follow-up still provides valuable context for interpreting the findings. To our knowledge, this is the first longitudinal study investigating the influence of accelerometer-based physical activity, participation in organised physical activity, screen time and fitness on academic performance within the same study. While this approach adds to the research field, it also increases the number of statistical models, particularly when stratifying by gender and including both adjusted and crude analyses. This increases the risk of type-1 errors. To address this, we adjusted our significance level for multiple testing. Another limitation is that we did not specify the type of screen time used by adolescents, which restricts the conclusions we can draw from our findings. It is important to note that our study was conducted in Sweden, which may limit the generalisability of our findings. For instance, in the Swedish context, academic performance at age 16 is crucial for progressing to secondary school. However, in other countries, this grade and age may not carry the same level of importance.

5 | Conclusions

This study found that fitness level and weekday screen time in age 13 predicted academic performance at age 16, highlighting the influence of factors related to lifestyle habits on academic achievement. We also found that among those with low academic performance at age 13, having high fitness or low screen time increased their predicted probability of grade improvement at age 16. Furthermore, having parents with long education increased this probability further. These findings are of importance for teachers, parents and professionals working with adolescents, and emphasise the need to support adolescents to develop more balanced screen habits to create more opportunities for activities that strengthen academic performance, such as homework, reading, as well as physical activity. Furthermore, schools should consider providing additional academic support for adolescents from families with low educational attainment. Such interventions could help reduce disparities among adolescents and improve their prospects for future success.

Author Contributions

Karin Kjellenberg: conceptualization, investigation, formal analysis, project administration, writing – original draft, data curation, visualization. **Björg Helgadottír:** conceptualization, investigation, visualization, data curation, supervision, resources, writing – review and editing, project administration. **Örjan Ekblom:** conceptualization, investigation, funding acquisition, writing – review and editing, supervision. **Gisela Nyberg:** conceptualization, investigation, funding acquisition, writing – review and editing, project administration, supervision, data curation, resources.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

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