




Are active school transport and leisure-time physical activity associated with performance and wellbeing at secondary school? A population-based study

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Background: Physically active pupils may be better and more resilient learners. However, it is unclear whether walking or cycling to school yields similar educational and school-related mental health benefits as leisure-time physical activity. We examined the associations of active school transport and leisure-time moderate-to-vigorous physical activity with perceived academic performance, competency in academic skills, school burnout and school enjoyment. **Methods:** We included 34 103 Finnish adolescents (mean age 15.4 years; 53% girls) from the 2015 School Health Promotion study cohort. For the analyses, we used logistic regression, adjusting for major socio-demographic, environmental, lifestyle and physical activity covariates. **Results:** Active school transport was positively associated with educational outcomes and school enjoyment, but not with school burnout. For example, compared with non-active transport, 10–30 min of daily active school transport was linked to 30% [odds ratio (OR) 1.30, 95% confidence interval (CI) 1.21–1.40] and 17% (OR 1.17, 95% CI 1.08–1.27) higher odds of high perceived academic performance and high reading competency, respectively. Leisure-time physical activity was robustly associated with all outcomes. For example, compared with the inactive, the most physically active adolescents had 86% higher odds of high perceived academic performance (OR 1.86, 95% CI 1.66–2.08), 57% higher odds of high competency in mathematics (OR 1.57, 95% CI 1.39–1.77) and 40% lower odds of school burnout (OR 0.60, 95% CI 0.52–0.69). **Conclusions:** Compared with active school transport, leisure-time physical activity was more strongly associated with educational and school-related mental health outcomes. Nevertheless, walking or cycling to school might lead to improvements in classroom performance and school enjoyment.

Introduction

Physical inactivity among adolescents is a global public health problem. In Finland, 69% of boys and 82% of girls aged 11–17 years do not meet the physical activity (PA) guidelines.¹ Based on the national physical functioning capacity statistics, the concerning trend has contributed to the decrease in cardiorespiratory and muscular fitness of Finnish youth over the past decade.² Simultaneously, academic competency and school wellbeing have declined. For example, performance in measured mathematical and reading literacy are at an all-time low,³ and 20% of lower secondary school pupils experience burnout symptoms.⁴ While increase in PA would improve physical fitness among young people,⁵ it might also help to tackle these school-related challenges.

Being physically active can improve brain health via different neurobiological pathways. For example, engaging in regular PA induces neural growth, vascularization and synaptic plasticity in various brain regions, including the hippocampus—an area that is essential for human learning and memory.^{6,7} There has also been a growing interest in the relationship of PA with cognition and academic performance. Some recent reviews have suggested that PA improves either one or both;^{8–11} however, the evidence is

inconclusive and primarily focused on preadolescents and children.^{12,13} On the other hand, curricular physical education and classroom-based PA interventions have shown positive effects on academic performance somewhat consistently.^{14,15}

Despite the promising results from school-based interventions, few studies have focused on educational outcomes of active school transport (AST), that is, walking or cycling to school. As only a single bout of exercise can induce short-term improvements in processing speed and executive function,^{9,16} AST could boost working memory, attention and cognitive flexibility in classrooms. Regardless of several potential cognition-enhancing mechanisms, earlier findings on the impact of AST have been inconsistent.^{17,18} Moreover, most of the prior studies have been limited by small sample sizes and insufficient adjustments for leisure-time PA and socioeconomic status, which are major predictors of active transport behaviour¹⁹ and academic achievement.²⁰

Regular PA can also prevent school burnout by reducing mental and physical exhaustion.^{21,22} Nonetheless, to the best of our knowledge, earlier research has not examined this relationship with AST, of which type and intensity often differs from leisure-time PA. While walking or cycling to school may not be associated with chronic stress,²³ they could help to reduce school-related exhaustion and

other features of burnout. For example, potential AST-induced improvements in classroom performance could help to cope with educational demands, fostering a sense of personal accomplishment.

We examined whether AST—a key factor for achieving more physically active and sustainable cities—and leisure-time moderate-to-vigorous physical activity (MVPA) demonstrate divergent associations with perceived academic performance, self-reported competency in academic skills, school burnout and school enjoyment among 15- to 16-year-old Finnish adolescents. We hypothesize that AST is positively associated with educational outcomes and with better school-related mental health; however, the associations are expected to be stronger for leisure-time MVPA.

Methods

School health promotion study

The School Health Promotion (SHP) study⁴ is used to monitor the well-being, health and schoolwork of Finnish youth biennially in March–April. The study is conducted by the Finnish Institute for Health and Welfare (THL) and every primary (in fourth or fifth grade) and secondary (in eighth or ninth grade) school pupil is offered a chance to participate. The data are gathered by an anonymous and voluntary classroom-administered questionnaire, which comprises various welfare-, lifestyle- and school-related topics. The results guide the planning and evaluation of health promotion activities at school, regional and national levels. The data are also used in research and for strategy and policy development. The data collection of the SHP study is approved by the ethical committee of the THL (THL/1407/6.02.01/2014).

Study design

Using the nationwide SHP study data, we conducted a population-based cross-sectional study, which aimed to investigate associations of AST and leisure-time MVPA with educational and school-related mental health outcomes among adolescents. We used the data from 2015, the latest survey round that collected AST-related information. Various sociodemographic and environmental factors, lifestyle behaviours and other PA types were treated as confounders.

Participants

Nearly half (43%; $N = 50\,404$) of all eighth and ninth graders from Finnish comprehensive schools participated in the 2015 round of the SHP study. Informed by the THL, participants with implausible answers ($N = 1694$) were removed from the study. We also excluded those with missing answers in exposure, outcome, or confounding variables ($N = 8051$) to be able to run complete case analyses. We also excluded participants with over 10 kilometres one-way distance to school ($N = 6556$) as the prevalence of AST reduced drastically at longer distances, potentially due to free school transport organized by the municipalities. The final analytical sample comprised 34 103 adolescents.

Exposures

Daily AST time was self-reported with response to the question: 'How much time do you typically spend walking or cycling to school? Consider traveling to bus stops as well', as in our previous work.²³ The response options included non-active (car/motor vehicle or public transport), <10 min, 10–30 min and more than 30 min.

Weekly leisure-time MVPA was also self-reported with response to the question: 'During your leisure-time, how many hours per week do you spend doing exercises that increase sweating and breathing rate?'. The response options included non-active, 30 min, 1 h, 2–3 h, 4–6 h and 7 h or more.

Outcomes

We used perceived academic performance and self-reported competency in academic skills as educational outcomes. School burnout and school enjoyment were used as school-related mental health outcomes.

Perceived academic performance was measured with an item: 'How do you rate your academic performance at the moment?'. We categorized 'excellent' and 'good' responses as indicators of high academic performance. 'Average' and 'poor' responses were categorized as indicators of low academic performance.

The academic skills included concentration in classroom, writing, reading and mathematics. The competency categorizations were based on self-reported difficulties in these skills. We categorized participants with 'a lot' or 'quite a lot' difficulties as low-competency pupils. Those with 'only a little' or 'not at all' difficulties were categorized as high-competency pupils.

The school burnout indicator was based on a question: 'Have you experienced the following feelings related to your schoolwork?'. The indicator comprised three sub-questions: (i) I feel overwhelmed by my schoolwork, (ii) I wonder whether my schoolwork has any meaning and (iii) I have feelings of inadequacy in my schoolwork. The response options were never (scored as 0), few times a month (scored as 0), few days a week (scored as 1) and almost daily (scored as 2). Dichotomization categorized students to those who experience more than one type of burnout symptom several days a week, and those who do not. The total score of three or more indicated school burnout.⁴ The sub-questions were based on the validated School Burnout Inventory,²⁴ while the comprehensive survey had space for only three sub-questions. Each of the questions represented one of the three dimensions of school burnout (exhaustion at school, cynicism towards the meaning of school and sense of inadequacy at school).

School enjoyment was measured with a question: 'Do you enjoy going to school at the moment?'. 'A lot' and 'quite a lot' responses were categorized as high school enjoyment, and 'only a little' and 'not at all' as low school enjoyment.

Covariates

Based on the literature^{19,20} and data availability,⁴ we identified key factors associated with PA behaviour, academic achievement and school-related mental health. As a result, we included the following self-reported covariates: school grade, sex, country of birth, household financial situation, parents' education level, distance to school, smoking, snus use (a Scandinavian tobacco product), electric cigarette use, lifetime cannabis use, alcohol consumption, breakfast consumption on school days and either leisure-time MVPA or AST (depending on the exposure). We also controlled for weight status and sleep quality in sensitivity analyses as they can both confound or mediate the studied associations.

Statistical analyses

We investigated the distribution of study population characteristics across AST, leisure-time MVPA, perceived academic performance and school burnout groups. Tests of differences across groups were conducted by chi-square test (χ^2).

We used logistic regression models to investigate associations of AST and leisure-time MVPA with perceived academic performance, competency in academic skills, school burnout and school enjoyment. The models were adjusted first for school grade and sex, then secondly for other sociodemographic and environmental factors (country of birth, household financial situation, parents' education level and distance to school), and thirdly for lifestyle behaviours. Lastly, in the main model, we adjusted for the other PA type (AST models were adjusted for leisure-time MVPA and vice versa). Non-active categories were used as reference groups for all regression analyses. We also used orthogonal polynomial trend analysis to

test for linear relationships across PA levels and confirmed the absence of multicollinearity with variance inflation factors.

In sensitivity analyses, we separately included weight status and sleep quality into the model with all other covariates. We also separately excluded participants with a personal study plan (used for pupils with special educational needs; $N=2163$; 6% of the analytical sample), those whose studying was negatively affected by a noisy or restless study environment ($N=3643$; 11%), and finally those who were bullied in school once a week or more often ($N=1615$; 5%). All these factors were also self-reported.

All analyses were performed using R (4.2.1) and RStudio (1.4.1106) software. Results from the regression analyses are presented as odds ratios (ORs) with 95% confidence interval (CI).

Results

Descriptive characteristics of the study population

Of all participants (mean age 15.4 years; 53% girls), 45% reported engaging in AST for 10–30 min a day, 31% for <10 min and 9% for more than 30 min. Nearly every seventh adolescent (15%) reported using primarily non-active transport modes. Non-AST was more prevalent among ninth than eighth graders, boys than girls, alcohol and snus users, smokers, inconsistent breakfast consumers, overweight individuals and adolescents with shorter distance to school. No prominent differences in socioeconomic status indicators were observed between the groups. Comprehensive participant characteristics by AST groups are reported in [table 1](#).

More than half of the participants (53%) engaged in leisure-time MVPA for at least 4–6 h a week. Furthermore, 26% of the adolescents participated in 2–3 h of weekly leisure-time MVPA, 10% participated 1 h and 6% participated 30 min per week. However, 5% did not engage in leisure-time MVPA at all. Eighth graders and girls were more physically active than ninth graders and boys, respectively. Higher levels of leisure-time MVPA were also more prevalent among normal weight (or underweight) adolescents and those with better socioeconomic background or fewer high-risk lifestyle behaviours. Additionally, prevalence of non-active transport was higher among adolescents who did not engage in leisure-time MVPA. Comprehensive participant characteristics by leisure-time MVPA groups are reported in [Supplementary table S1](#).

Adolescents with high perceived academic performance (62%) were more likely to be girls and to have a better socioeconomic background, lifestyle and health than youth with low perceived academic performance. Apart from sex, similarly distributed characteristics were observed for participants without school burnout (13%). Comprehensive participant characteristics by perceived academic performance and school burnout groups are reported in [Supplementary tables S2 and S3](#).

Association of AST with educational outcomes

We observed a positive association between AST and perceived academic performance after the main multivariable adjustments ([figure 1](#)). Compared with non-active transportation, walking and cycling to school for 10–30 min a day was associated with the highest odds of high performance (OR 1.30, 95% CI 1.21–1.40), followed by more than 30 min (OR 1.26, 95% CI 1.14–1.40) and less than 10 min (OR 1.14, 95% CI 1.05–1.23).

Compared with the non-active transportation group, pupils engaging in 10–30 min of daily AST also had higher odds of high competency in concentration in classroom (OR 1.13, 95% CI 1.03–1.23), writing (OR 1.12, 95% CI 1.03–1.21), reading (OR 1.17, 95% CI 1.08–1.27) and mathematics (OR 1.10, 95% CI 1.02–1.19). No clear associations were observed for low- (<10 min) and high-dose (>30 min) groups in the main regression model ([figure 1](#)).

Compared with the crude models, inclusion of lifestyle behaviour variables had the largest effect on the ORs across all outcomes.

In sensitivity analyses, additional adjustments or exclusions did not affect the ORs for perceived academic performance. However, after weight status adjustment, more than 30 min of daily AST was also associated with higher odds of high competency in reading (OR 1.16, CI 95% 1.03–1.31) and mathematics (OR 1.13, 95% CI 1.01–1.27) (see [Supplementary table S4](#)).

Association of leisure-time MVPA with educational outcomes

Even the smallest dose of leisure-time MVPA, 30 weekly minutes, was associated with 18% higher odds of high perceived academic performance compared with inactivity (OR 1.18, 95% CI 1.02–1.36). The odds increased linearly with the amount of weekly PA, being 86% higher for the most physically active group (OR 1.86, 95% CI 1.66–2.08) ([Supplementary figure S1](#)).

Leisure-time MVPA was also positively associated with competency in all academic skills ([Supplementary figure S1](#)). The strongest relationships were observed for mathematics and concentration in classroom. For example, adolescents who engaged in MVPA for 7 h or more had 57% higher odds of high competency in mathematical skills than non-active participants (OR 1.57, 95% CI 1.39–1.77).

Compared with the crude models, socioeconomic and lifestyle behaviour variables had the largest effect on the ORs. In sensitivity analyses, adjusting for health status variables or excluding individuals with school- or learning-related challenges did not have a major effect on the findings (see [Supplementary table S5](#)).

Association of AST with school-related mental health

AST was not associated with school burnout in the main regression model ([figure 2](#)). However, 11% (OR 0.89, 95% CI 0.81–0.99) lower odds of burnout were observed for the ‘10–30 min’ group after excluding participants with special educational needs (see [Supplementary table S6](#)).

We also observed a positive linear association between AST and school enjoyment ([figure 2](#)). The largest dose, more than 30 min a day, was associated with 31% higher odds (OR 1.31, 95% CI 1.19–1.45), followed by 10–30 min (OR 1.25, 95% CI 1.16–1.34) and less than 10 min (OR 1.16, 95% CI 1.07–1.25).

Compared with the crude models, lifestyle behaviour variables again attenuated the observed associations the most. Sensitivity analyses did not affect the findings (see [Supplementary table S6](#)).

Association of leisure-time MVPA with school-related mental health

Leisure-time MVPA, starting from ‘30 min’ to ‘7 h or more’ a week, was associated with lower odds of school burnout (from 24% to 40%) and higher odds of high school enjoyment (from 35% to 90%) compared with inactivity—both in a dose–response manner ([Supplementary figure S2](#)).

Again, compared with the crude models, socioeconomic and lifestyle behaviour variables had the most prominent effect on the associations. In the sensitivity analyses, the findings remained practically unchanged (see [Supplementary table S7](#)).

Discussion

We studied the associations of AST and leisure-time MVPA with perceived academic performance, self-reported competency in academic skills (concentration in classroom, writing, reading and mathematics), school burnout and school enjoyment among Finnish adolescents. AST, at any dose, was positively associated with perceived academic performance, while only moderate doses were linked to high competency in academic skills. We also observed a positive linear relationship between AST and school enjoyment; however, the results for school burnout were inconclusive.

Table 1 Characteristics of the analytical sample by daily AST

| Characteristics | Non-active N = 5206 | <10 min N = 10 485 | 10–30 min N = 15 398 | >30 min N = 3014 |
|--|------------------------|-----------------------|-------------------------|---------------------|
| Sociodemographic | | | | |
| School grade | | | | |
| 8 | 1395 (26.8) | 5417 (51.7) | 8460 (55.0) | 1667 (55.3) |
| 9 | 3811 (73.2) | 5086 (48.3) | 6938 (45.0) | 1347 (44.7) |
| Sex | | | | |
| Boy | 2959 (56.8) | 5168 (49.3) | 6757 (43.9) | 1281 (42.5) |
| Girl | 2247 (43.2) | 5317 (50.7) | 8641 (56.1) | 1733 (57.5) |
| Country of birth | | | | |
| Finland | 5002 (96.1) | 9877 (94.2) | 14 822 (96.3) | 2871 (95.2) |
| Other | 204 (3.9) | 608 (6.8) | 576 (3.7) | 143 (4.7) |
| Household financial situation | | | | |
| Very good | 1062 (20.4) | 1922 (18.3) | 2688 (17.5) | 533 (17.7) |
| Good | 2512 (48.3) | 5075 (48.4) | 7610 (49.4) | 1379 (45.7) |
| Fair | 1303 (25.0) | 2764 (26.4) | 4073 (26.4) | 826 (27.4) |
| Poor or very poor | 329 (6.3) | 724 (6.9) | 1027 (6.7) | 276 (9.2) |
| Level of education (mother) | | | | |
| Higher education | 1801 (34.6) | 3780 (36.0) | 6188 (40.2) | 1202 (39.9) |
| Secondary education | 3095 (59.4) | 5953 (56.8) | 8414 (54.6) | 1624 (54.9) |
| Primary education | 310 (6.0) | 752 (7.2) | 796 (5.2) | 188 (6.2) |
| Level of education (father) | | | | |
| Higher education | 1459 (28.0) | 3289 (31.4) | 5482 (35.6) | 1056 (35.0) |
| Secondary education | 3213 (61.7) | 6085 (58.0) | 8630 (56.0) | 1691 (56.1) |
| Primary education | 534 (10.3) | 1111 (10.6) | 1286 (8.4) | 267 (8.9) |
| Environmental | | | | |
| Distance to school | | | | |
| 0–1 km | 622 (11.9) | 4897 (46.5) | 2486 (16.1) | 136 (4.5) |
| 1.1–2 km | 880 (16.9) | 1828 (17.4) | 4178 (27.1) | 557 (18.5) |
| 2.1–3 km | 975 (18.7) | 925 (8.8) | 3460 (22.5) | 729 (24.2) |
| 3.1–5 km | 1372 (26.4) | 1021 (9.8) | 3136 (20.4) | 1020 (33.8) |
| 5.1–10 km | 1357 (26.1) | 1832 (17.5) | 2138 (13.9) | 572 (19.0) |
| Lifestyle behaviour | | | | |
| Alcohol consumption | | | | |
| Yes, once a week or more often | 259 (5.0) | 308 (3.0) | 319 (2.1) | 83 (2.7) |
| Yes, once or twice a month | 1374 (26.4) | 1785 (17.0) | 2161 (14.0) | 409 (13.6) |
| No, never or rarely | 3573 (68.6) | 8392 (80.0) | 12 918 (83.9) | 2522 (83.7) |
| Smoking | | | | |
| Yes, daily | 633 (12.2) | 774 (7.4) | 846 (5.5) | 225 (7.5) |
| Yes, occasionally | 643 (12.3) | 872 (8.3) | 1151 (7.5) | 193 (6.4) |
| No | 3930 (75.5) | 8839 (84.3) | 13 401 (87.0) | 2596 (86.1) |
| Snus use | | | | |
| Yes, daily | 298 (5.7) | 310 (2.9) | 313 (2.1) | 58 (1.9) |
| Yes, occasionally | 600 (11.5) | 720 (6.9) | 789 (5.1) | 163 (5.4) |
| No | 4308 (82.8) | 9455 (90.2) | 14 296 (92.8) | 2793 (92.7) |
| Electric cigarette use | | | | |
| Yes, daily | 165 (3.2) | 155 (1.5) | 175 (1.1) | 57 (1.9) |
| Yes, occasionally | 517 (9.9) | 578 (5.5) | 689 (4.5) | 149 (4.9) |
| No | 4524 (86.9) | 9752 (93.0) | 14 534 (94.4) | 2808 (93.2) |
| Cannabis use | | | | |
| Yes, at least five times | 150 (2.9) | 227 (2.2) | 273 (1.8) | 71 (2.4) |
| Yes, one to four times | 322 (6.2) | 501 (4.8) | 559 (3.6) | 125 (4.1) |
| No, never | 4734 (90.9) | 9757 (93.0) | 14 566 (94.6) | 2818 (93.5) |
| Breakfast consumption (on school days) | | | | |
| Every morning | 2902 (55.7) | 6250 (59.6) | 9792 (63.6) | 1823 (60.5) |
| Three to four times | 843 (16.2) | 1695 (16.2) | 2409 (15.7) | 485 (16.1) |
| Once or twice | 553 (10.6) | 1073 (10.2) | 1438 (9.3) | 306 (10.1) |
| More seldom | 908 (17.5) | 1467 (14.0) | 1759 (11.4) | 400 (13.3) |
| Health status | | | | |
| Weight | | | | |
| Normal weight or underweight | 3942 (82.6) | 8206 (85.1) | 12 165 (85.7) | 2323 (84.1) |
| Overweight or obese | 832 (17.4) | 1440 (14.9) | 2037 (14.3) | 438 (15.9) |
| Sleep quality (adequate sleep) | | | | |
| Yes, almost always | 958 (18.6) | 2151 (20.7) | 2879 (18.9) | 602 (20.2) |
| Yes, often | 2675 (51.8) | 5395 (51.9) | 8109 (53.1) | 1444 (48.5) |
| Rarely, never, or cannot tell | 1528 (29.6) | 2844 (27.4) | 4282 (28.0) | 932 (31.3) |
| Physical activity | | | | |
| Leisure-time MVPA (weekly) | | | | |
| Non-active | 368 (7.1) | 535 (5.1) | 649 (4.2) | 150 (5.0) |
| 30 min | 317 (6.1) | 660 (6.3) | 813 (5.3) | 151 (5.0) |
| 1 h | 565 (10.8) | 1080 (10.3) | 1521 (9.9) | 297 (9.9) |
| 2–3 h | 1331 (25.6) | 2627 (25.1) | 4062 (26.4) | 827 (27.4) |
| 4–6 h | 1364 (26.2) | 2852 (27.2) | 4254 (27.6) | 828 (27.5) |
| 7 h or more | 1261 (24.2) | 2731 (26.0) | 4099 (26.6) | 761 (25.2) |

Values are numbers (percentages). All variables globally significantly different between active school transport groups at $P < 0.001$. MVPA, moderate-to-vigorous physical activity.

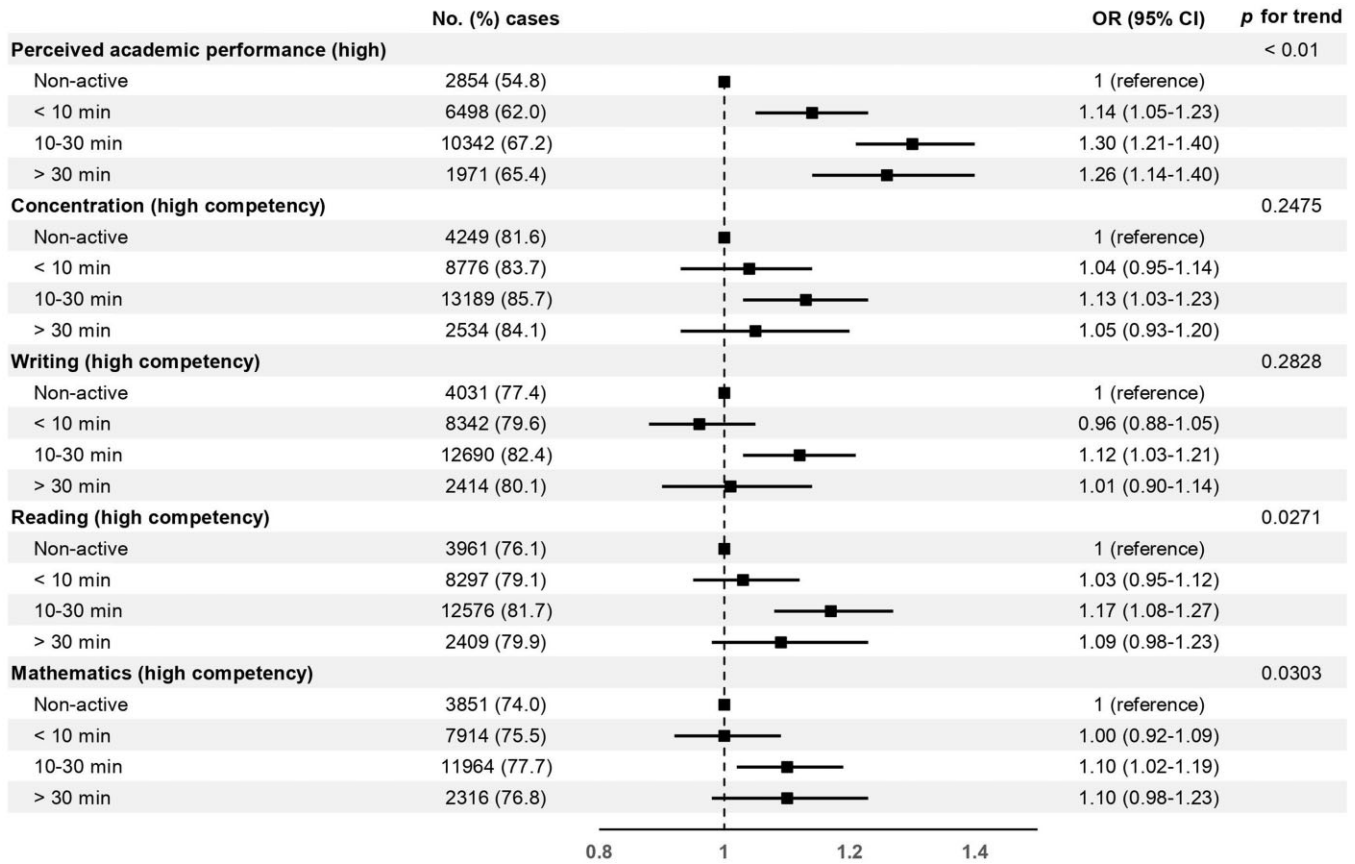


Figure 1 Adjusted odds ratios with 95% confidence intervals for educational outcomes by daily AST. Adjusted for school grade, sex, country of birth, household financial situation, parents' education level, distance to school, smoking, snus use, electric cigarette use, cannabis use, alcohol consumption, breakfast consumption and weekly leisure-time moderate-to-vigorous physical activity

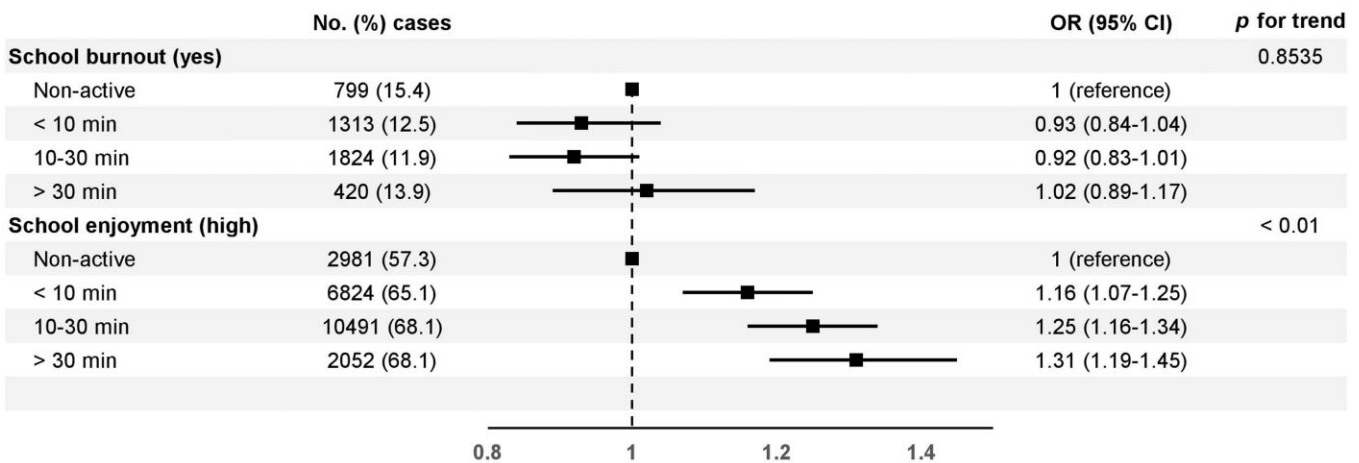


Figure 2 Adjusted odds ratios with 95% confidence intervals for school-related mental health outcomes by daily AST. Adjusted for school grade, sex, country of birth, household financial situation, parents' education level, distance to school, smoking, snus use, electric cigarette use, cannabis use, alcohol consumption, breakfast consumption and weekly leisure-time moderate-to-vigorous physical activity

Leisure-time MVPA was strongly, positively associated with all educational outcomes and with better school-related mental health.

For AST, our observations are partially consistent with earlier studies using similar academic performance outcomes and same-aged populations. For example, a Norwegian study found that regular AST was associated with 51% and 72% higher odds of high self-reported academic performance among 15- to 17-year-old girls and boys, respectively.²⁵ These findings were also supported by a Danish study of 14-year-old pupils.²⁶ However, no differences in self-reported grade scores were found between AST and non-AST

groups among 14-year-old Spanish adolescents.²⁷ That said, none of these studies controlled for leisure-time PA or other lifestyle behaviours, which are likely to confound the associations^{19,20}—as indicated by our study.

We also observed that only moderate doses of AST, 10–30 min a day, were linked with higher competency in academic skills. Again, this finding aligns, to some extent, with prior research. For example, exercise bouts longer than 11 min—optimally 20 min—may be required for the post-exercise cognitive benefits to occur.¹⁶ For longer exercise durations, such as more than 30 min of continuous

walking or cycling to school, fatigue and dehydration might hinder the benefits.¹⁶

Our results for leisure-time MVPA align with most recent findings.^{8–11} In line with our study, the evidence from intervention studies seems to be the strongest for the beneficial effects of PA on mathematical skills.¹² Minor contradictions also exist. For example, some evidence suggests that particularly overweight pupils may gain executive function benefits from PA.²⁸ However, the observed associations in our study remained virtually unchanged after adjusting for weight status, suggesting that it does not confound or mediate the relationship. Excluding participants who experienced school- or learning-related challenges also did not affect our findings.

Several contextual factors, such as PA intensity, could explain why leisure-time MVPA may be more effective in improving academic performance than AST. For example, higher exercise intensities lead to greater increases in the availability of circulating brain-derived neurotrophic factor,²⁹ vascular endothelial growth factor³⁰ and insulin-like growth factor-1.³¹ These growth factors are closely involved with human memory and learning as they enhance neurogenesis, angiogenesis and neuroplastic adaptations in the brain.³² However, we were not able to distinguish between walking and cycling, preventing comparisons between active transportation modes of different intensity.

Leisure-time MVPA, especially cognitively demanding team games, can also be more effective in improving coordination and perceptual-motor skills than simple aerobic activities, such as AST. These exercise characteristics are suggested to lead to greater improvements in executive functions,³³ and thus in academic performance.¹² Furthermore, executive function skills (e.g. working memory, inhibition and shifting) are particularly important in the development of mathematical proficiency,³⁴ which could explain why the largest effect sizes are consistently observed for math skills. These mechanisms could also explain why school-based PA interventions have shown to be effective.^{14,15} For example, classroom interventions are often designed as cognitively engaging, comprising repetition and various memorization techniques.³⁵

Compared with AST—an easy-to-do activity for able-bodied young people—leisure-time MVPA is also more likely to provide mastery experiences and successes, which can enhance self-esteem particularly among adolescents.³⁶ Therefore, the most physically active participants could have had higher self-esteem and more confidence to rate themselves as high-competency pupils, offering an additional explanation for our findings. Furthermore, walking and cycling to school may not provide similar mental health benefits to young people as leisure-time PA does.²³ As mental wellbeing is a major determinant of academic performance,²⁰ this potential explanatory pathway should also be considered.

Regarding school burnout, our observations for leisure-time MVPA are in line with the literature, which, however, is mainly focused on university-level students.²² Similar to chronic stress,²³ no associations between AST and school burnout were observed. Again, the contextual differences between the PA types could explain our observations. For example, enjoyment is one of the main motivators for engaging in leisure-time PA,³⁷ while AST is often a daily routine associated with the ‘workplace’. Therefore, the former could facilitate psychological detachment from schoolwork more efficiently than the latter.²¹ In contrast, we observed a positive dose–response association between AST and school enjoyment. Future research should explore potential explanatory mechanisms of this relationship.

The study strengths include a large, nationwide cohort and a population-based design. Compared with prior studies, we were also able to control for essential sociodemographic, environmental, lifestyle and health status covariates.

Limitations of our study include non-validated measures for PA, perceived academic performance, competency in academic skills and school enjoyment. However, the risk of measurement bias is low as all SHP study questions face extensive preliminary tests in pilot

schools before implementation.⁴ In addition, measures for AST and leisure-time MVPA were self-reported, which could lead to overestimations in PA frequency.³⁸ Nevertheless, misclassification is most likely non-differential, which would rather bias results towards the null than imply stronger associations.³⁹ Moreover, overrepresentation of healthy pupils and girls affects the generalizability of our findings.²³ Finally, the cross-sectional study design hinders us from drawing conclusions about the causality of the observed associations. Nonetheless, findings from intervention studies support our observations for potential benefits of leisure-time PA, especially on mathematical skills.¹²

In conclusion, this study suggests that AST is positively associated with perceived academic performance, competency in academic skills and school enjoyment, but not with school burnout. However, promoting cognitively engaging, enjoyable leisure-time PA opportunities is likely to have more potential in improving classroom performance and school-related mental health among adolescents. We encourage future research to investigate the acute effects of AST on executive function.

While promoting AST may not lead to substantial educational or mental health benefits, especially cycling to school can improve cardiovascular fitness among youth.⁴⁰ Hence, there is a need to increase the use of active, sustainable transportation modes for public health—as well as for climate change mitigation.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Data availability

Researchers can apply to use the School Health Promotion study resources and access the data used. Applications should be submitted to <https://findata.fi/en/>. The data will not be transferred outside the European Union.

Key points

- Active school transport was positively associated with perceived academic performance, competency in academic skills and school enjoyment, but not with school burnout.
- Leisure-time moderate-to-vigorous physical activity was strongly associated with better educational outcomes and school-related mental health.
- Promoting physical activity, both by active school transport and in leisure-time, may improve academic performance and school-related mental health among adolescents.

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