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Manuscript

Title

Cross-sectional associations between physical activity pattern, sports participation, screen time and mental health in Swedish adolescents

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ABSTRACT

Objectives: To investigate the associations between physical activity pattern, sports participation, screen time, and mental health in Swedish adolescents

Design: Cross-sectional study

Setting: Students from 34 different schools participated in the study "Physical Activity for Healthy Brain Functions in School Youth" in 2019.

Participants: 1139 Swedish adolescents (mean age 13.4)

Methods: Time spent sedentary and in moderate-to-vigorous-physical activity was measured using accelerometers (Actigraph) for seven consecutive days. Screen time and participation in organized sports were self-reported. Anxiety and health-related quality of life were assessed using a short version of the Spence Children's Anxiety Scale (SCAS-S) and Kidscreen-10. All analyzes were stratified by gender.

Results: Significant associations were found between physical activity patterns during the whole week and health-related quality of life. The moderate-to-vigorous-physical activity was positively associated whereas time spent sedentary or using screens on weekdays was inversely associated with health-related quality of life. The largest effect sizes were observed between the high/low MVPA group in boys and between the high/low screen time group in girls. With regards to anxiety, high compared to lower time spent in moderate-to-vigorous-physical activity during leisure time on weekdays was associated with lower anxiety scores. Some gender differences were observed, boys who participated in organized sports had low anxiety scores whereas girls who reported five hours or more of screen time had high anxiety scores.

Conclusions: This study showed that moderate-to-vigorous physical activity was associated with better mental health, whereas the opposite was seen for time spent sedentary or using screens. However, these associations were not consistently significant throughout all time domains, between the genders and the mental health outcomes. Our results could create a paradigm for future studies to decide which types of PA patterns and time domains to target in intervention studies with the aim improve mental health among adolescents.

Keywords: Adolescent, Physical Activity, Sedentary Behavior, Screen time, Accelerometry, Screen time, Mental health, Anxiety, Health-related quality of life, Kidscreen

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Physical activity and sedentary time were assessed using accelerometers
- The study included both a positive and negative indicator of mental health
- Due to the cross-sectional design causation or the direction of these associations cannot be studies

INTRODUCTION

The World Health Organization describes health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [1]. Thus, mental health is an important component of health and includes both positive indicators (e.g. well-being) and negative indicators (e.g. psychiatric symptoms). Poor mental health among youth is a global public health concern with major consequences for both individuals and society [2]. Mental disorders at an early age have been associated with stigma, decreased academic achievements, increased risk of physical disorders in adulthood, and premature death [3]. The age of onset for approximately half of the mental disorders occurs before or during adolescence [4], with anxiety being the most common mental disorder with a prevalence of 6.5% [5]. Therefore, it is important to investigate how modifiable lifestyle factors are associated with mental health in this population.

Physical activity (PA) has been found to be a protective factor for emotional problems [6] and high levels of PA have cross-sectionally been associated with better mental health outcomes [7-10]. Studies have also shown a lower prevalence of depressive symptoms in those engaging in organized sports compared to those being active on their own [11 12], suggesting that the context of activity could be important. However, the majority of adolescents do not meet the PA recommendations of 60 minutes of moderate-to-vigorous-physical activity (MVPA) per day [13]. A study in Swedish adolescents (11-18-year-olds) found that only 23% of girls and 43% of boys met the recommendations [14]. In addition, sedentary behaviors, especially screen time have been associated with poor mental health [15 16].

Although these associations have been studied before, most studies rely on self-reported PA [10], which has shown to have low validity in this population [17]. A more robust measure is device-measured PA that provides a more detailed estimate of PA and SED. There is also a lack of studies that include both positive and negative indicators of mental health, with a tendency to focus on mental health disorders or symptoms.

The objective of the study was therefore to examine cross-sectional associations between device-measured PA patterns (MVPA, SED), sports participation, screen time, and mental health (anxiety and health-related quality of life) in Swedish adolescents.

METHODS

Sample

This study is part of the larger cross-sectional study Physical Activity for Healthy Brain Functions in School Youth performed between September–December 2019. A sample size of 1000 students was estimated to provide a representative sample of students from schools with varying sizes, geographic locations, and parental socio-economic backgrounds. Figure 1 shows an overview of the participating schools and students. A total of 34 schools participated, the provided reasons for the schools that declined or dropped out were time constraints. From these schools, 1139 students participated (73% response rate), 49% boys and 51% girls, the recruitment process is described in more detail elsewhere [18]. The characteristics of the students are shown in Table 1. The study had ethical approval by the Swedish Ethical Review Authority (DNR: 2019-03579) and was conducted by the Declaration of Helsinki. All participants and their parents provided written informed consent.

The students participated in the measurements at the Swedish School of Sport and Health Sciences, GIH, and during the visit, they were provided with an accelerometer, which they used for the following seven days. The students received a 300 SEK (€ 30) gift card as compensation for their participation.

[Figure 1 should be inserted here]

Patient and Public Involvement

The students were not involved in the design, conduct, reporting, or dissemination plans of our research however, the participating schools, students, and their parents received a summary of the results from the study.

Measures

Mental health

Health-related quality of life (HRQoL) was assessed using Kidscreen-10. The scale includes 10 items of how often the students have felt during the last week, for example, 'sad', 'lonely' or 'fit and well'. The answers range from never/not at all to always/extremely on a five-point scale. The scores are summed up with higher values indicating greater wellbeing. To compare these values to a reference population, Rasch person-parameters can be estimated by transforming the data into a T-score with a mean of 50 and SD of 10 using the provided syntax from the Kidscreen group [19].

Anxiety was measured using a short version of the Spence Children's Anxiety Scale (SCAS-S), a tool used to assess self-reported anxiety symptoms in children and adolescents. The questionnaire includes 19 items for example "I worry about things". Each item is rated on a four-point scale ranging from 'never' to 'always'. The scores are summed up with higher values reflecting more anxiety symptoms [20]. The cut-off for elevated anxiety symptoms was set at 1 SD above the mean and the cut-off for high anxiety symptoms was set at 1.5 SD above the mean with separate cut-offs for girls and boys respectively.

These two measures have been validated towards the longer versions and provide a global score for anxiety/HRQoL rather than a subscore for each domain of HRQoL or cluster of anxiety symptoms [19] [20].

Physical activity patterns and screen time

Physical activity patterns (time spent in MVPA and SED) were measured using a hip-worn accelerometer (Actigraph GT3X). The students were told to wear the monitor at all waken times for the next seven consecutive days (not counting the distribution day), except during water-based activities. Afterward, the monitors were sent back by the teachers in pre-paid envelopes. Acceleration was measured at 30 Hz. The accelerometer data were processed in Actilife (v6.13.3) as uniaxial data using epoch time intervals of 5 seconds. To define non-wear time, 60 minutes of zero counts and no spike tolerance was used. Further, an individual time filter was created based on the participant's reported wake/sleep time (extracted from the questionnaire). A second time filter for school time was created by extracting the times from the school schedules. The criteria for a valid day were at least 500 minutes of wear time. The criteria for a valid measure were at least three valid days (including one weekend day) for analysis of the whole week, at least two valid weekdays for analysis of school-time or weekday leisure time, and at least one valid weekend day for analysis of weekends. The data were categorized into intensities using counts: SED (0-100 counts/minute) and MVPA (≥2296 counts/minute) [21]. The first day was excluded to minimize measurement bias [17].

Participation in organized sports was self-reported by the students using the following question "Are you active in any sports club/organization? (e.g., football, swimming, dancing, scouts, gym)?". Screen time was self-reported by the students using the following question for weekdays and weekends. "During a normal weekday/weekend day, approximately how much time do you spend using a screen (not included schoolwork) including a cell phone, TV, computer, iPad? (For example, to play games, watch TV, chat, watch serials, YouTube, Snapchat, and Instagram)". The answers were arranged from no time to 7 hours or more, and were later categorized into two hours and below, three to four hours, and five hours or above.

Covariates

Based on previous studies, parental education, and body mass index standard deviation score (BMIsd, i.e., BMI adjusted for age and gender) were tested as confounders.

Parental education was collected using register data from Statistics Sweden. The parent with the highest level of education was used and the variable was dichotomized into ≤12 years and >12 years. Gender was self-reported by the student. As the gender group, "other" only included one student, this observation was excluded in the models stratified by gender. Bodyweight and height were measured using standardized procedures and rounded to the closest 0.1 kilograms or millimeter. BMI status was defined according to the International Obesity Task Force [22] and BMI sds was calculated according to a Swedish reference standard [23].

Statistical analysis

Data were analyzed using STATA/SE version 17.0. Descriptive statistics are presented using mean, standard deviation, and proportions. To compare the difference between boys and girls independent t-tests were used for numerical variables and chi-square for categorical variables. To investigate the associations between PA patterns, sports participation screen time (as predictors), and mental health (as dependent variables) multi-level mixed linear regression models were used to account for the clustering of students within schools. Two levels were modeled, level 1 for school and level 2 for the individual student, and a random intercept for each school was applied. We explored both unstandardized and standardized beta-coefficients for the continuous predictors. The assumptions for mixed models were tested, and as data displayed heteroskedasticity (Breusch-Pagan test p >0.05) robust estimates were used. All models were adjusted for parental education and accelerometer wear-time. The models with sports participation were additionally adjusted for time spent in MVPA. As BMIsds were not significant in any of the models, this covariate was excluded from the final models. Only students with complete data on the mental health scales were included in the analyzes. All models were stratified by gender as the PA and mental health outcomes were significantly different between boys and girls. However, we also explored if gender moderated the associations by running the same models with all subjects and adding an interaction term. Only significant interaction results are presented in the text. Crude models are included in Tables 1-2 in the supplemental material.

To analyze the effect size in SCAS-S and Kidscreen-10, standardized mean differences (Cohen's d) were calculated between the low/high tertiles of MVPA, screen time, and participants/ non-participants in organized sports. The level of statistical significance was set at $\alpha < 0.05$, 95% confidence intervals, and p-values and beta values are bolded to indicate statistical significance.

RESULTS

In total, 1072 students (94%) completed all items on SCAS-S. Girls reported significantly higher anxiety scores compared to boys (16.6 vs. 10.6, mean difference of 6.0, $t(1070)= 13.44$ $p < 0.01$). In girls, 82 (15%) had a score >1 SD above the mean (elevated anxiety) and 50 (9%) had a score > 1.5 SD above the mean (high anxiety). In boys, the corresponding values were 75 (14%) students and 42 (8%) students. Boys to parents with low education had significantly higher anxiety symptoms (mean difference 1.6 $t(505)= 2.7$ $p<0.01$) compared to boys with high parental education. This difference was not observed in girls or for HRQoL.

A total of 1096 (96%) students completed all items on the Kidscreen-10 questionnaire where girls had significantly lower scores of HRQoL (mean difference of 2.63, $t(1094)= -8.29$ $p < 0.01$) compared to boys. The Cronbach alpha for Kidsscreen-10 was 0.78 and 0.84 for SCAS-S, indicating acceptable to good internal consistency.

For the PA measurements, 903 students (79%) had valid accelerometer readings for the whole week, 1054 students (93%) for weekdays, and 916 (80%) on weekends. There were no significant differences in mean values of SCAS-S or Kidscreen-10 between those who had a valid accelerometer reading and those who did not.

Table 1. Descriptive characteristics of the study sample by gender (mean ± SD unless otherwise specified)

	n	missing	All	n	Girls	n	Boys	Sig. p
Total			1139 (100)		580 (51.0)		558 (49.0)	
Age (year)	1139	0	13.4 ± 0.3		13.4 ± 0.3		13.4 ± 0.4	0.147
Parental education, >12 years n (%)	1102	37	730 (66.2)		371 (65.9)		358 (66.5)	0.821
Student country of birth, Sweden n (%)	1129	10	967 (85.7)		490 (84.9)		476 (86.4)	0.758
BMI status[1]	1134	5		580		554		0.203
Underweight n (%)			89 (7.8)		38 (6.6)		51 (9.2)	
Normal weight n (%)			815 (71.8)		430 (74.1)		384 (69.3)	
Overweight n (%)			179 (15.8)		89 (15.3)		90 (16.2)	
Obese n (%)			52 (4.6)		23 (4.0)		29 (5.2)	
BMI sds[2]	1134	5	0.36±1.23	580	0.45±1.11	554	0.26±1.35	**0.012**
Sedentary time (min)								
SED (average week)	903	236	602.0 ± 66.6	490	608.9 ± 62.65	413	593.7 ± 70.2	**<0.001**
SED bouts over 10 min	903	236	122.7 ± 63.6	490	132.8 ± 63.2	413	110.7 ± 62.2	**<0.001**
SED leisure time (weekdays)	1054	85	324.8 ± 69.2	548	330.0 ± 63.5	506	319.2 ± 74.7	**0.011**
SED leisure time (weekend)	916	223	539.4 ± 84.7	497	533.8 ± 80.0	419	546.1 ± 89.6	**0.029**
SED school time	1054	85	291.9 ± 37.5	548	301.7 ± 35.7	506	281.2 ± 36.5	**<0.001**
MVPA time (min)								
MVPA (average week)	903	236	52.0 ± 19.0	490	49.52 ± 17.7	413	54.86 ± 20.1	**<0.001**
MVPA leisure time (weekdays)	1054	85	31.6 ± 15.0	548	30.9 ± 13.8	506	32.3 ± 16.1	0.145
MVPA leisure time (weekend)	916	223	37.9 ± 25.3	497	36.8 ± 23.3	419	39.1 ± 27.4	0.156
MVPA school time	1054	85	26.5 ± 11.2	548	23.2 ± 9.6	506	30.1 ± 11.7	**<0.001**
Reached the MVPA recommendations n (%)	903	236	273 (30.2)	490	121 (24.7)	413	152 (36.8)	**<0.001**
Accelerometer wear time	903	236		490		413		
Wear time (average week)			792.6 ± 60.8		796.0 ± 58.1		788.5 ± 63.8	0.067
Total included valid days			6.0 ± 1.1		6.2 ± 1.0		5.8 ± 1.1	**<0.001**
Organized sports								
Participated in organized sports n (%)			787 (72.0)		396 (71.4)		391 (72.7)	0.626
Screen time (weekdays)	1125	14		575		550		0.842
≤2 hours n (%)			359 (32.0)		179 (31.1)		180 (32.7)	
3-4 hours n (%)			515 (46.0)		267 (46.4)		248 (45.1)	
≥5 hours n (%)			251 (22.3)		129 (22.4)		122 (22.2)	
Screen time (weekend)	1122	17		576		546		**<0.001**
≤2 hours n (%)			178 (15.9)		70 (12.2)		108 (19.8)	
3-4 hours n (%)			411 (36.6)		238 (41.3)		173 (31.7)	
≥5 hours n (%)			533 (47.5)		268 (46.6)		265 (48.5)	
Mental health								
SCAS-S	1072	67	13.7 ± 7.9	547	16.6 ± 8.0	525	10.6 ± 6.6	**<0.001**
Kidscreen-10	1096	43	39.6 ± 5.4	562	38.3 ± 5.2	534	41.0 ± 5.3	**<0.001**
Kidscreen-10 [T]	1096	43	49.6 ± 9.0	562	47.3± 7.5	534	51.9 ± 9.8	**<0.001**

[1]BMI status according to IOTF 2012, [2] BMI sds according to a Swedish reference standard.
MVPA moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale,
[T] international T-values based on Rasch person parameter

On an average day, boys spent significantly more in MVPA. However, when breaking down the MVPA between domains, this difference was only significant during school time (mean difference of 6.9 min, $t(1052)= -10.56$ $p<0.01$). Students who participated in organized sports had 11.3 more minutes per day in MVPA compared to those who did not participate $t(874)= -8.10$ $p<0.01$. Similarly, the group who reported low screen time (≤2 hours) on weekends spent 15 more minutes in MVPA compared to those who reported five hours or more $t(568)= 6.32$ $p<0.01$. Table 2 shows the associations between anxiety (SCAS-S) and health-related quality of life (Kidscreen-10) and predictors using multi-level mixed linear regression models.

Table 2. Associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models stratified by gender

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Girls			Boys			Girls			Boys		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	448	**-0.045 (-0.079, -0.011)**	**-0.099**	383	-0.026 (-0.058, 0.007)	-0.077	458	**0.032 (0.009, 0.054)**	**0.110**	390	**0.040 (0.015, 0.065)**	**0.157**
1.2 MVPA leisure time (weekdays)	503	**-0.091 (-0.134, -0.049)**	**-0.161**	468	**-0.038 (-0.066, -0.010)**	**-0.095**	514	**0.048 (0.023, 0.073)**	**0.130**	477	**0.036 (0.011, 0.061)**	**0.100**
1.3 MVPA leisure time (weekend)	455	-0.023 (-0.049, 0.002)	-0.067	388	-0.001 (-0.024, 0.021)	-0.005	465	**0.023 (0.033, 0.043)**	**0.105**	396	**0.034 (0.020, 0.048)**	**0.183**
1.4 MVPA school time	503	-0.027 (-0.100, 0.047)	-0.032	468	0.015 (-0.039, 0.069)	0.027	514	0.013 (-0.033, 0.059)	0.025	477	0.020 (-0.024, 0.064)	0.046
2. SED												
2.1 SED whole week	448	0.011 (-0.007, 0.028)	0.081	383	0.011 (-0.006, 0.028)	0.114	458	**-0.021 (-0.032, -0.009)**	**-0.251**	390	**-0.021 (-0.033, -0.008)**	**-0.285**
2.2 SED bouts (10 min) whole week	448	-0.001 (-0.014, 0.012)	-0.009	383	0.002 (-0.009, 0.013)	0.021	458	**-0.012 (-0.020, -0.005)**	**-0.150**	390	**-0.009 (-0.017, -0.001)**	**-0.113**
2.3 SED leisure time (weekdays)	503	**0.040 (0.017, 0.062)**	**0.315**	468	0.017 (-0.002, 0.036)	0.195	514	**-0.034 (-0.051, -0.017)**	**-0.421**	477	**-0.020 (-0.036, -0.005**	**-0.299**
2.4 SED leisure time (weekend)	455	0.007 (-0.006, 0.020)	0.064	388	0.003 (-0.009, 0.014)	0.035	465	**-0.013 (-0.022, -0.003)**	**-0.192**	396	**-0.017 (-0.025, -0.009)**	**-0.299**
2.5 SED school	503	-0.009 (-0.039, 0.021)	-0.041	468	-0.011 (-0.034, 0.012)	-0.062	514	-0.001 (-0.026, 0.001)	-0.060	477	-0.012 (-0.033, 0.001)	-0.083
3. Organized sports												
Did not participate	112	ref		97	ref		114	ref		99	ref	
Participated	321	-0.210 (-2.165, 1.745)		283	**-1.810 (-3.492, -0.129)**		329	-0.258 (-1.701, 1.185)		288	1.214 (-0.459, 2.888)	
4. Screen time weekday												
≤2 hours	162	ref		167	ref		166	ref		167	ref	
3-4 hours	253	0.628 (-0.975, 2.231)		230	0.342 (-0.782, 1.466)		256	**-1.337 (-2.175, -0.499)**		237	-0.785 (-1.758, 0.188)	
≥5 hours	116	**4.056 (1.935, 6.176)**		110	0.883 (-0.583, 2.348)		121	**-3.503 (-4.786, -2.220)**		111	**-1.539 (-2.664, -0.413)**	
5. Screen time weekend												
≤2 hours	61	ref		98	ref		65	ref		99	ref	
3-4 hours	219	1.155 (-0.582, 3.369)		164	-0.151 (-1.776, 1.473		225	-0.904 (-2.315, 0.506)		166	0.157 (-1.725, 1.411)	
≥5 hours	252	**3.340 (1.394, 5.287)**		243	1.060 (-0.207, 2.326)		254	**-2.520 (-4.014, -1.027)**		248	-0.842 (-2.320, 0.636)	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale
All models were adjusted for parental education
Model 3 were adjusted for time spent in MVPA
Models 1-3 were adjusted for accelerometer wear-time

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Associations between PA patterns, screen time, and anxiety (SCAS-S)

A significant inverse association between time spent in MVPA during leisure time on weekdays and anxiety was seen in girls and boys there was a significant interaction of gender in this association (p 0.01), such that the association was stronger in girls compared to boys. Time spent in MVPA over the whole week was only significantly associated with anxiety in girls, none of the other MVPA measured was significantly associated with anxiety among girls or boys. Boys who participated in organized sports also had a significantly lower prevalence of anxiety, compared to boys who did not participate. This association was not significant in girls.

In girls, time spent in SED during leisure time on weekdays was positively associated with anxiety. None of the other SED measures was significantly associated with anxiety in girls or boys.

With regards to screen time, significant associations were only found in the group of girls who reported ≥5 hours screen time on weekdays or weekends. These groups had significantly higher anxiety scores compared to those who reported up to 2 hours. When controlling for MVPA, this association remained significant (B=3.39, CI: 1.33, 5.46) for weekdays and (B=2.53, CI: 0.27, 4.80) for weekends. Further, there was a significant interaction of gender in the association between screen-time on weekends and anxiety with a stronger association among girls compared to boys (p<0.03) in the group who reported ≥5 hours screen time.

Associations between PA pattern, screen time, and health-related quality of life (Kidsscreen-10)

There was a positive association between time spent in MVPA during the whole week, during leisure time on weekdays, on weekends, and HRQoL in girls and boys. There was a positive association between sports participation and HRQoL in boys, however, the significance disappeared after controlling for time spent in MVPA.

Inverse associations were seen between all SED time domains and HRQoL in both boys and girls, except SED during school time. There was a significant interaction of gender in the association between time spent in SED on weekends and HRQoL (p 0.04) with a stronger association in boys compared to girls.

Girls and boys who reported ≥5 hours screen time on weekdays had significantly lower HRQoL, compared to those who reported two hours or less. The results remained significant also after adjusting for time spent in MVPA (B=-3.32, CI: -4.50, -2.14 in girls, and B= -1.65 CI: -2.70, -0.61 in boys). A significant association between screen time on weekends and HRQoL was only found in girls who reported ≥5 hours of screen time.

Figure 2 shows the unadjusted mean SCAS-S score and Kidscreen-10 scores between students reporting different levels of screen time on weekdays.

[Figure 2 should be inserted here]

To assess the clinical significance, we calculated effect sizes (Cohen's d) in mental health scores between participants/non-participants in organized sports, low/high screen time, and in low/high tertiles of MVPA. The average time (minutes) for MVPA in the lowest tertile was 32 and 34, and in the highest tertile 70 and 78 for girls and boys, respectively. Regarding SCAS-S, the effect sizes between low/high MVPA groups were 0.18 in girls (CI: -0.05, 0.40) and 0.31 in boys (0.07, 0.56). The effect sizes between participants/non-participants in organized sports were 0.13 (CI: -0.07, 0.31) in girls and 0.31 (CI: 0.12, 0.51) in boys. The effect sizes between groups with low/high screen time on weekdays were -0.47 in girls (CI: -0.70, -0.23) and -0.18 in boys (CI: -0.42, 0.05) and on weekends -0.36 in girls (CI: -0.64, -0.09) and -0.17 (CI: -0.40, 0.06) in boys.

For Kidscreen-10 the results showed that the effect sizes between low/high MVPA groups were -0.28 in girls (CI: -0.50, -0.06) and -0.51 in boys (CI: -0.75, -0.26) and between participants/non-participants in organized sports -0.01 (CI: -0.20, 0.18) in girls and -0.28 (CI: -0.47, -0.08) in boys. Between groups with high/low screen time on weekdays, the effect sizes were 0.59 in girls (CI: 0.36, 0.83) and 0.35 in boys (CI: 0.12, 0.59) and on weekends 0.50 (CI 0.23, 0.77) and 0.14 (CI: -0.9, 0.36) for girls and boys respectively (these results can be found in table 3 the supplemental material).

DISCUSSION

In this cross-sectional study, the associations between PA patterns, sports participation, screen time, and mental health (anxiety and HRQoL) were investigated in Swedish adolescents. MVPA was positively associated with HRQoL whereas time spent in SED or using screens on weekdays was inversely associated. Although the effect sizes generally were small, the largest effect sizes were observed between the high/low MVPA group in boys and between the high/low screen time group in girls. With regards to anxiety, high MVPA during leisure time on weekdays was associated with low anxiety scores. Some gender differences were observed, boys participating in organized sports had low anxiety scores whereas girls who reported five hours or more of screen time had high anxiety scores.

The mean Kidscreen-10 score in our sample was 38.3 in girls and 41.0 in boys, which corresponds to a T-score of 47.3 in girls and 51.9 in boys. A suggested threshold to classify the values as "normal" is ½ SD above or below the reference value [24]. This indicates that our sample was within this range of the Swedish reference population (12-18-year-olds) with a T-score of 49.2 for girls and 52.4 for boys [24]. The current sample also had similar PA levels (on average 52 minutes in MVPA per day) and demographic characteristics (66% had parents with ≥12 years of education, 86% were born in Sweden and 21% had overweight or obesity) compared to a nationally representative study in Swedish adolescents which reported on average 53 minutes in MVPA per day, 61% with high parental education, 88% born in Sweden, 21% with overweight or obesity [14].

The most common limitation in previous studies is the lack of detailed measures of PA. The current study used device-measured PA and could confirm many findings based on self-reported PA. One example is a review that found PA to be positively associated with HRQoL and a high proportion of SED to be associated with lower HRQoL [25]. In general, the effect sizes in the current study were small, which is not uncommon in these types of studies. A previous study by Gopinath et al. found similar mean differences in HRQoL between the high/low group of PA and screen time [26]. However, this study did not stratify the analysis by gender. In our study, we found the largest effect sizes when comparing the lowest and highest tertiles of MVPA for boys (Cohen's d= 0.51), and screen time for girls (Cohen's d= 0.50 on weekends) and (Cohen's d= 0.59 on weekdays). Our findings suggest that the strengths of the associations to HRQoL could be different for boys and girls and these gender differences should be considered when designing future intervention studies to improve HRQoL.

Regarding screen time, this study found high screen time during weekdays to be associated with lower HRQoL which confirms the findings of a review that concluded moderate evidence for the association between screen time and HRQoL. In the current study, we found a significant difference in MVPA between the low/high screen time group. Interestingly, after controlling for time spent in MVPA screen time was still significantly associated with HRQoL independently of MVPA in both genders. As previously mentioned, we found the effect size of screen time to be larger in girls. These findings are similar to a study from the UK which concluded that the association between screen time and mental health was stronger in girls. The same study also found that the dose of screen time associated with problematic mental health was lower for girls (>2 hours) compared to boys (>5 hours) [27]. This was also evident in the current study, where screen time >3 hours were associated with lower HRQoL in girls, whereas for boys this association was significant only for the group reporting ≥5 hours.

A strength of this study is the inclusion of both a positive and a negative indicator of mental health, which shows that the type of PA pattern and screen time associated with each measure differs. Fewer measures of the PA pattern and screen time were significantly associated with anxiety compared to HRQoL. MVPA during leisure time on weekdays was inversely associated with anxiety in both genders. These results are consistent with those reported previously using self-reported PA [28 29]. However, we only found sports participation to be associated with lower anxiety in boys. These findings were different from a study in 14-year-old that found sports participation to be significantly associated with lower anxiety and higher well-being in both genders [30]. Potential explanations for this could be that the study did not control for time spent in MVPA and that sports participation was lower (33%) compared to 72% in our study. Another study in older youth found that the significant association between sports participation and anxiety disappeared after controlling for time spent in

MVPA [12]. Previous studies have also suggested that the strength of the association could vary between genders. A review found a weak negative correlation between sports participation and anxiety, but in samples with a higher proportion of boys, the correlation was stronger [31]. One potential explanation for the gender differences observed in the current study could be related to the context and sports environment. Where girls have reported a higher incidence of teasing during sports participation and participation in sports common to girls (aesthetic sports such as dance or gymnastics) have been associated with body image concerns and disordered eating [32]. This indicates that depending on the sports culture the association between sports participation and mental health could differ between genders, this should be investigated further in future research.

About screen time, this study found that girls reporting ≥5 hours of screen time on weekdays and weekends had higher levels of anxiety compared to those who reported ≤2 hours. This association was not seen in boys. These findings were consistent with a study in Icelandic adolescents, that found screen time <5 hours to be associated with fewer symptoms of anxiety and depression [29]. However, the results were not stratified by gender. Although not investigated in the current study, one suggested explanation for the gender differences in the type of screen time activity. A review found social media use to be associated with anxiety, with a stronger association in girls [33], future studies should further investigate these associations.

There is a lack of studies that investigate the association between device-measured SED and mental health and many studies rely on screen time as a proxy for SED. In the current study, stronger associations were seen in the standardized beta coefficients for the SED measurements (especially during leisure time weekdays), compared to MVPA. This was seen in both genders for HRQoL and anxiety for girls. A review concluded that sedentary behaviors were associated with an increased risk of anxiety, with the strongest associations found in sitting [34]. However, it is important to note that causation or the direction of these associations cannot be studied in cross-sectional studies. Interestingly, a randomized controlled trial (RCT) showed significantly higher anxiety levels in the intervention group after a one-week intervention of increased SED and eliminated PA compared to the control group, which continued their normal PA routine [35]. These findings suggest that reducing SED could be a strategy to improve mental health among adolescents, although this should be investigated further in larger RCT studies.

A limitation of the current study was the lack of questions concerning functioning to further understand if the group with low mental health experienced impairment in their daily lives. However, including a positive and negative measure still provides a better understanding of the students' overall mental health compared to studies that only focus on symptoms of mental illness. Another limitation was the cross-sectional design, which makes it impossible to study the direction or cause of these relationships. A strength was the relatively large sample size and a high participation rate (73%), which resulted in a non-homogenous study population of adolescents with different PA levels and mental health scores. Further, PA was assessed using a detailed PA measure (accelerometer) with individual time filters, which enabled comparisons between different time domains.

CONCLUSIONS

This cross-sectional study showed that MVPA was associated with better mental health, whereas SED or screen time was associated with lower mental health. However, these associations were not significant throughout all time domains and some gender differences were observed. Our results could create a paradigm for future studies to decide which types of PA patterns and time domains to target in intervention studies with the aim improve mental health among adolescents.

LEGENDS

Figure 1. Participation of schools and students.

Figure 2. Unadjusted means SCAS-S and Kidscreen-10 score between screen time groups, mean comparisons were analyzed using an Analysis of variance ANOVA and Bonferroni post hoc test
*** p <0.001 ** p <0.01

DECLARATIONS

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Data sharing: The datasets are not available for download to protect the confidentiality of the participants. The data are held at The Swedish School of Sport and Health Sciences.

Authors' contributions: KK recruited the schools. GN, ÖE, BH, KK designed the study and participated in the data collection. BH cleaned and processed the data. JÅ contributed to the design of the statistical model and the interpretation of the results. KK drafted the manuscript. All authors read and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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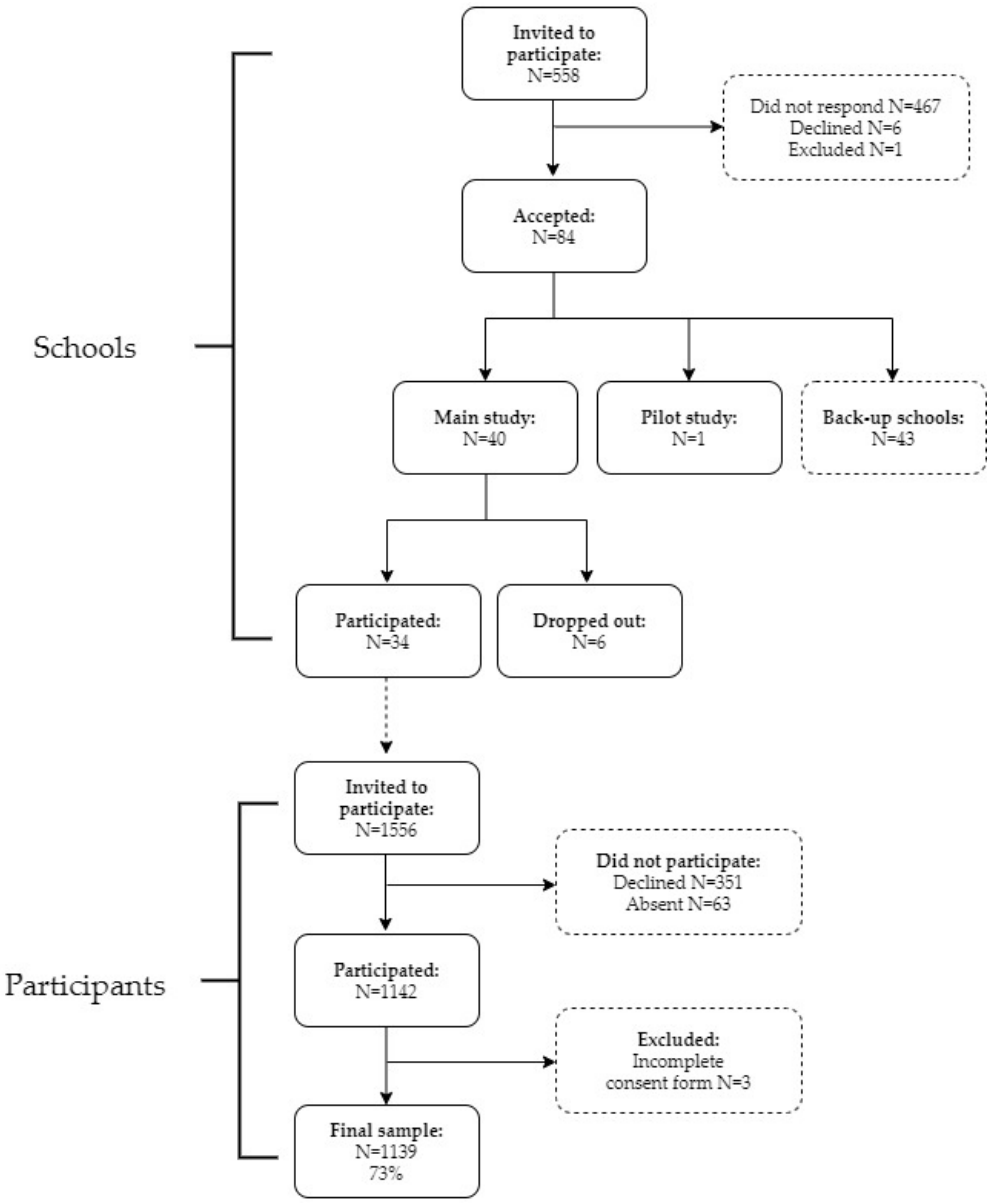

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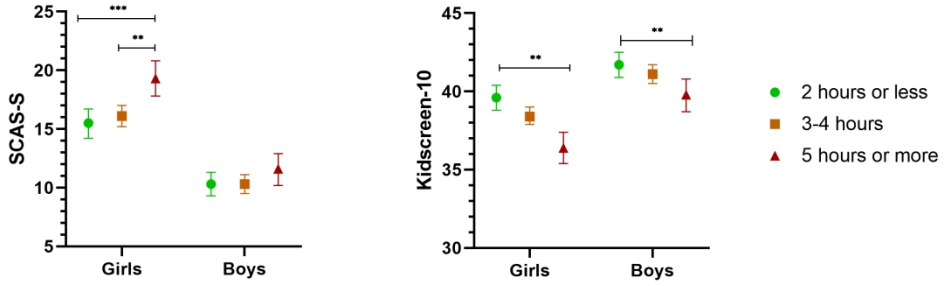

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SUPPLEMENTAL MATERIAL

Supplemental material 1. Crude and adjusted associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Crude			Adjusted			Crude			Adjusted		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	854	**-0.058 (-0.091, -0.025)**	**-0.138**	831	**-0.035 (-0.062, -0.007)**	**-0.082**	873	**0.044 (0.028, 0.060)**	**0.157**	848	**0.036 (0.021, 0.051)**	**0.130**
1.2 MVPA leisure time (weekdays)	1000	**-0.072 (-0.106, -0.038)**	-0.136	971	**-0.062 (-0.089, -0.034)**	**-0.118**	1023	**0.049 (0.029, 0.068)**	**0.137**	991	**0.043 (0.025, 0.061)**	**0.122**
1.3 MVPA leisure time (weekend)	866	-0.017 (-0.038, 0.004)	-0.053	843	-0.011 (-0.030, 0.010)	-0.033	886	**0.030 (0.019, 0.041)**	**0.144**	861	**0.028 (0.017, 0.039)**	**0.135**
1.4 MVPA school time	1000	-0.095 (-0.147, -0.043)	-0.135	971	-0.006 (-0.047, 0.036)	-0.008	1023	**0.056 (0.022, 0.090)**	**0.117**	991	0.019 (-0.013, 0.052)	0.052
2. SED												
2.1 SED whole week	854	**0.009 (0.002, 0.017)**	0.077	831	0.011 (-0.004, 0.026)	0.089	873	**-0.009 (-0.016, -0.0002)**	**-0.113**	848	**-0.021 (-0.029, -0.012)**	**-0.261**
2.2 SED bouts (10 min) whole week	854	0.008 (-0.001, 0.017)	0.064	831	0.000 (-0.010, 0.010)	0.001	873	**-0.013 (-0.018, -0.007)**	**-0.155**	848	**-0.011 (-0.016, -0.005)**	**-0.130**
2.3 SED leisure time (weekdays)	1000	**0.009 (0.004, 0.015)**	**0.081**	971	**0.026 (0.011, 0.041)**	**0.228**	1023	-0.005 (-0.009, 0.000)	-0.063	991	**-0.027 (-0.040, -0.015)**	**-0.358**
2.4 SED leisure time (weekend)	866	-0.003 (-0.009, 0.002)	-0.036	843	0.004 (-0.007, 0.015)	0.042	886	-0.004 (-0.008, 0.001)	-0.056	861	**-0.014 (-0.020, -0.008)**	**-0.230**
2.5 SED school	1000	**0.024 (0.009, 0.039)**	**0.112**	971	-0.009 (-0.030, 0.011)	-0.045	1023	**-0.013 (-0.025, -0.001)**	**-0.091**	991	-0.011 (-0.026, 0.004)	-0.079
3. Organized sports												
Did not participate	291	ref		209	ref		296	ref		213	ref	
Participated	750	**-1.589 (-2.743, -0.435)**		604	-0.963 (-2.07, 0.141)		766	**0.855 (0.036, 1.674)**		617	0.407 (-0.554, 1.367)	
4. Screen time weekday												
≤2 hours	343	ref		329	ref		348	ref		333	ref	
3-4 hours	492	0.388 (-0.599, 1.375)		483	0.407 (-0.481, 1.295)		503	**-0.827 (-1.529, -0.124)**		493	**-1.007 (-1.591, -0.423)**	
≥5 hours	235	**2.626 (1.135, 4.117)**		226	**2.409 (1.083, 3.735)**		242	**-2.521 (-1.529, -0.125)**		232	**-2.633 (-3.381, -1.885)**	
5. Screen time weekend												
≤2 hours	169	ref		159	ref		174	ref		164	ref	
3-4 hours	392	**1.302 (0.132, 2.471)**		383	0.461 (-0.609, 1.531)		402	-0.594 (-1.474, 0.286)		391	-0.261 (-1.078, 0.555)	
≥5 hours	507	**2.368 (1.236, 3.501)**		495	**1.896 (0.881, 2.912)**		515	**-1.607 (-2.582, -0.633)**		502	**-1.485 (-2.385, -0.585)**	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale
The adjusted models have been controlled for gender and parental education. Further, Model 3 were adjusted for time spent in MVPA, and Models 1-3 were adjusted for accelerometer wear-time

Supplemental material 2. Crude associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models stratified by

gender

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Girls			Boys			Girls			Boys		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	461	**-0.043 (-0.079, -0.007)**	**-0.095**	393	**-0.026 (-0.060, 0.008)**	**-0.078**	473	**0.027 (0.004, 0.05)**	**0.093**	400	**0.044 (0.020, 0.069)**	**0.171**
1.2 MVPA leisure time (weekdays)	517	**-0.096 (-0.139, -0.055)**	**-0.169**	483	**-0.037 (-0.067, -0.007)**	**-0.090**	531	**0.049 (0.023, 0.07)**	**0.132**	492	**0.042 (0.018, 0.067)**	**0.130**
1.3 MVPA leisure time (weekend)	468	-0.021 (-0.049, 0.006)	-0.063	398	-0.003 (-0.025, 0.019)	-0.011	480	0.021 (-0.001, 0.043)	0.095	406	**0.036 (0.021, 0.050)**	**0.189**
1.4 MVPA school time	517	-0.012 (-0.080, 0.056)	-0.015	483	0.004 (-0.047, 0.054)	0.007	531	0.003 (-0.042, 0.048)	0.005	492	0.028 (-0.009, 0.066)	0.0637
2. SED												
2.1 SED whole week	461	0.000 (-0.008, 0.010)	0.004	393	0.006, (-0.002, 0.014)	0.063	473	-0.004 (-0.012, 0.003)	-0.057	400	-0.009 (-0.018, 0.000)	-0.119
2.2 SED bouts (10 min) whole week	461	-0.002 (-0.014, 0.009)	-0.017	393	0.003 (-0.008, 0.014)	0.028	**473**	**-0.010 (-0.016, -0.003)**	**-0.122**	400	**-0.0100 (-0.018, -0.002)**	-0.120
2.3 SED leisure time (weekdays)	517	0.001 (-0.007, 0.010)	0.010	483	0.008 (0.001, 0.014)	0.087	531	-0.003 (-0.009, -0.004)	**-0.033**	492	-0.004 (-0.010, 0.003)	-0.052
2.4 SED leisure time (weekend)	468	-0.003 (-0.011, 0.004)	-0.033	398	-0.000 (-0.008, 0.008)	-0.002	480	0.004 (-0.005, 0.006)	0.006	406	**-0.009 (-0.014, -0.004)**	**-0.155**
2.5 SED school	517	0 .009 (-0.007, 0.025)	0.042	483	-0.010 (-0.027, 0.006)	-0.056	531	0.000 (-0.016, 0.016)	-0.000	492	-0.005 (-0.020, 0.010)	-0.034
3. Organized sports												
Did not participate	152	ref		139	ref		155	ref		141	ref	
Participated	376	-0.914 (-2.528, 0.700)		374	**-2.009 (-3.445, -0.572)**		386	0.132 (-1.110, 1.375)		380	1.358 (0.133, 2.58	
4. Screen time weekday												
≤2 hours	168	ref		175	ref		173	ref		175	ref	
3-4 hours	257	0.550 (-0.984, 2.084)		235	0.014 (-1.135, 1.162)		261	**-1.095 (-19.976, -0.213)**		242	-0.587 (-1.546, 0.372)	
≥5 hours	120	**3.856 (1.916, 5.796)**		115	1.190 (-0.143, 2.523)		126	**-3.190 (-4.292, -2.089)**		116	**-1.609 (-2.845, -0.372)**	
5. Screen time weekend	546											
≤2 hours	65	ref		104	ref		69	ref		105	ref	
3-4 hours	224	1.126 (-1.097, 3.350)		168	-0.163 (-1.719, 1.393)		232	-0.903 (-2.388, 0.582)		170	0.0449 (-1.504, 1.594)	
≥5 hours	257	**2.931 (0.924, 4.938)**		250	0.992 (-0.222, 2.206)		260	**-2.530 (-4.036, -1.025)**		255	-0.615 (-2.100, 0.870)	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale

Supplemental material 3. Unadjusted mean SCAS-S and Kidscreen-10 score and SD for students in the highest and lowest groups of MVPA and screen time

	Anxiety (SCAS-S)				Health-related quality of life (Kidsscreen-10)			
	Girls		Boys		Girls		Boys	
	n	mean ± SD	n	mean ± SD	n	mean ± SD	n	mean ± SD
Screen time								
Weekday								
≤2 hours	168	15.46 ±8.37	175	10.29±6.60	173	39.62±5.29	175	41.70±5.22
≥5 hours	120	19.33±8.24	115	11.56±7.25	126	36.40±5.60	116	39.78±5.78
Weekend								
≤2 hours	65	14.71±7.19	104	10.04±6.73	69	39.96±5.34	105	41.34±5.77
≥5 hours	257	17.69±8.43	250	11.21±6.84	260	37.35±5.19	255	40.59±5.44
Physical activity								
MVPA lowest tertile	157	17.07±8.77	128	12.06±7.48	160	37.83±5.25	135	39.65±5.94
MVPA highest tertile	152	15.65±6.98	130	9.89±6.32	157	39.20±4.58	130	42.32±4.47
Organized sports								
Did not participate	376	16.31±7.67	374	10.02±6.28	386	38.41±5.01	380	41.41±4.90
Participated	152	17.28±8.61	139	12.06±7.01	155	38.35±5.59	141	39.97±5.77

MVPA moderate-to-vigorous-physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	5-6
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	6
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	4-7
		(b) Give reasons for non-participation at each stage	4
		(c) Consider use of a flow diagram	4
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-8, and in the supplemental material (table 1 and 2)
		(*b*) Report category boundaries when continuous variables were categorized	5-6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	10-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Cross-sectional associations between physical activity pattern, sports participation, screen time and mental health in Swedish adolescents

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Manuscript

Title

Cross-sectional associations between physical activity pattern, sports participation, screen time and mental health in Swedish adolescents

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ABSTRACT

Objectives: To investigate the associations between physical activity pattern, sports participation, screen time, and mental health in Swedish adolescents

Design, setting, and participants: A total of 1139 Swedish adolescents (mean age 13.4) from 34 schools participated in the cross-sectional study "Physical Activity for Healthy Brain Functions in School Youth" in 2019.

Methods: Time spent sedentary and in moderate-to-vigorous-physical activity (MVPA) was measured using accelerometers for seven consecutive days. Screen time and sports participation were self-reported. Anxiety and health-related quality of life (HRQoL) were assessed using a short version of the Spence Children's Anxiety Scale and Kidscreen-10.

Results: MVPA was positively associated (CI: 0.01, 0.05 in girls and 0.02, 0.07 in boys) whereas screen time on weekdays was inversely associated with HRQoL (-4.79, -2.22 in girls and -2.66, -0.41 in boys). The largest effect sizes were observed between the high/low MVPA group in boys (Cohen's d= 0.51) and screen time groups in girls (Cohen's d=0.59 on weekdays). With regards to anxiety, high compared to lower time spent in MVPA during leisure time on weekdays was associated with lower anxiety scores (CI: -0.13, -0.05 in girls and -0.07, -0.01 in boys). Gender differences were observed, boys who participated in organized sports had low anxiety scores (CI: -3.49, -0.13) whereas girls who reported five hours or more of screen time had high scores (CI: 1.94, 6.18 on weekdays and 1.39, 5.29 on weekend days).

Conclusions: This study showed that MVPA was associated with better mental health, whereas the opposite was seen for screen time. These associations were not consistently significant throughout all time domains, between the genders and mental health outcomes. Our results could create a paradigm for future studies to decide which types of PA patterns and time domains to target in intervention studies with the aim improve mental health among adolescents.

Keywords: Adolescent, Physical Activity, Sedentary Behavior, Screen time, Accelerometry, Screen time, Mental health, Anxiety, Health-related quality of life, Kidscreen

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Physical activity and sedentary time were assessed using accelerometers.
- The study included both a positive and negative indicators of mental health.
- Due to the cross-sectional design causation or the direction of these associations cannot be studied.

INTRODUCTION

The World Health Organization describes health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [1]. Thus, mental health is an important component of health and includes both positive indicators (e.g. well-being) and negative indicators (e.g. psychiatric symptoms). Poor mental health among youth is a global public health concern with major consequences for both individuals and society [2]. Mental disorders at an early age have been associated with stigma, decreased academic achievements, increased risk of physical disorders in adulthood, and premature death [3]. The age of onset for approximately half of the mental disorders occurs before or during adolescence [4], with anxiety being the most common mental disorder with a prevalence of 6.5% [5]. Therefore, it is important to investigate how modifiable lifestyle factors are associated with mental health in this population.

Physical activity (PA) has been found to be a protective factor for emotional problems [6] and high levels of PA have cross-sectionally been associated with better mental health outcomes [7-10]. Studies have also shown a lower prevalence of depressive symptoms in those engaging in organized sports compared to those being active on their own [11, 12], suggesting that the context of activity could be important. However, the majority of adolescents do not meet the PA recommendations of 60 minutes of moderate-to-vigorous-physical activity (MVPA) per day [13]. A study in Swedish adolescents (11-18-year-olds) found that only 23% of girls and 43% of boys met the recommendations [14]. In addition, sedentary behaviors, especially screen time have been associated with poor mental health [15, 16].

Although these associations have been studied before, most studies rely on self-reported PA [10], which has shown to have low validity in this population [17]. A more robust measure is device-measured PA that provides a more detailed estimate of PA and SED. There is also a lack of studies that include both positive and negative indicators of mental health, with a tendency to focus on mental health disorders or symptoms. In this study, we chose health-related quality of life as a positive indicator and anxiety as a negative indicator. Anxiety (rather than depression) was selected as it is the most common psychiatric problem in this age group (13-14 years), and because anxiety tends to have an earlier mean age of onset compared to for example depression, which typically has on onset in late adolescence.

The objective of the study was therefore to examine cross-sectional associations between device-measured PA patterns (MVPA, SED), sports participation, screen time, and mental health (anxiety and health-related quality of life) in Swedish adolescents.

METHODS

Sample

This study is part of the larger cross-sectional study Physical Activity for Healthy Brain Functions in School Youth performed between September–December 2019. A sample size of 1000 students was estimated to provide a representative sample of students from schools with varying sizes, geographic locations, and parental socio-economic backgrounds. The Swedish school system is deregulated and has implemented the free choice reform which allows parents to choose which schools (independent and public) their children should attend. The schools follow a voucher system and the parents do not have to pay tuition fees [18]. In the current study, 11 (32%) were independent schools and 23 (68%) were public schools. Figure 1 shows an overview of the participating schools and students. A total of 34 schools participated, the provided reasons for the schools that declined or dropped out were time constraints. From these schools, 1139 students participated (73% response rate), 49% boys and 51% girls, the recruitment process is described in more detail elsewhere [19]. The characteristics of the students are shown in Table 1. The study had ethical approval by the Swedish Ethical Review Authority (DNR: 2019-03579) and was conducted by the Declaration of Helsinki. As the participants were minors, all participants and their parents provided written informed consent.

The students participated in the measurements at the Swedish School of Sport and Health Sciences, GIH, and during the visit, they were provided with an accelerometer, which they used for the following seven days. The students received a 300 SEK (€ 30) gift card as compensation for their participation.

[Figure 1 should be inserted here]

Patient and Public Involvement

The students were not involved in the design, conduct, reporting, or dissemination plans of our research however, the participating schools, students, and their parents received a summary of the results from the study.

Measures

Mental health

Health-related quality of life (HRQoL) was assessed using Kidscreen-10. The scale includes 10 items of how often the students have felt during the last week, for example, 'sad', 'lonely' or 'fit and well'. The answers range from never/not at all to always/extremely on a five-point scale. The scores are summed up with higher values indicating greater wellbeing. To compare these values to a reference population, Rasch person-parameters can be estimated by transforming the data into a T-score with a mean of 50 and SD of 10 using the provided syntax from the Kidscreen group [20].

Anxiety was measured using a short version of the Spence Children's Anxiety Scale (SCAS-S), a tool used to assess self-reported anxiety symptoms in children and adolescents. The questionnaire includes 19 items for example "I worry about things". Each item is rated on a four-point scale ranging from 'never' to 'always'. The scores are summed up with higher values reflecting more anxiety symptoms [21]. The cut-off for elevated anxiety symptoms was set at 1 SD above the mean and the cut-off for high anxiety symptoms was set at 1.5 SD above the mean with separate cut-offs for girls and boys respectively.

These two measures have been validated towards the longer versions and provide a global score for anxiety/HRQoL rather than a subscore for each domain of HRQoL or cluster of anxiety symptoms [20, 21].

Physical activity patterns and screen time

Physical activity patterns (time spent in MVPA and SED) were measured using a hip-worn accelerometer (Actigraph GT3X). The students were told to wear the monitor at all waken times for the next seven consecutive days (not counting the distribution day), except during water-based activities. Afterward, the monitors were sent back by the teachers in pre-paid envelopes. Acceleration was measured at 30 Hz. The accelerometer data were processed in Actilife (v6.13.3) as uniaxial data using epoch time intervals of 5 seconds. To define non-wear time, 60 minutes of zero counts and no spike tolerance was used. Further, an individual time filter was created based on the participant's reported wake/sleep time (extracted from the questionnaire). A second time filter for school time was created by extracting the times from the school schedules. The criteria for a valid day were at least 500 minutes of wear time. The criteria for a valid measure were at least three valid days (including one weekend day) for analysis of the whole week, at least two valid weekdays for analysis of school-time or weekday leisure time, and at least one valid weekend day for analysis of weekends. The data were categorized into intensities using counts: SED (0-100 counts/minute) and MVPA (≥2296 counts/minute) [22]. The first day was excluded to minimize measurement bias [17].

Participation in organized sports was self-reported by the students using the following question "Are you active in any sports club/organization? (e.g., football, swimming, dancing, scouts, gym)?".

Screen time was self-reported by the students using the following question for weekdays and weekends. “During a normal weekday/weekend day, approximately how much time do you spend using a screen (not included schoolwork) including a cell phone, TV, computer, iPad? (For example, to play games, watch TV, chat, watch serials, YouTube, Snapchat, and Instagram)”. The answers were arranged from no time to 7 hours or more, and were later categorized into two hours and below, three to four hours, and five hours or above.

Covariates

Based on previous studies, parental education, and body mass index standard deviation score (BMIsd, i.e., BMI adjusted for age and gender) were tested as confounders.

Parental education was collected using register data from Statistics Sweden. The parent with the highest level of education was used and the variable was dichotomized into ≤12 years and >12 years. Information about school type (independent or public) were collected from the National Agency for Education. Gender was self-reported by the student. As the gender group, “other” only included one student, this observation was excluded in the models stratified by gender. Bodyweight and height were measured using standardized procedures and rounded to the closest 0.1 kilograms or millimeter. BMI status was defined according to the International Obesity Task Force [23] and BMIsds was calculated according to a Swedish reference standard [24].

Statistical analysis

Data were analyzed using STATA/SE version 17.0. Descriptive statistics are presented using mean, standard deviation, and proportions. To compare the difference between boys and girls independent t-tests were used for numerical variables and chi-square for categorical variables. To investigate the associations between PA patterns, sports participation screen time (as predictors), and mental health (as dependent variables) multi-level mixed linear regression models were used to account for the clustering of students within schools. Two levels were modelled, level 1 for school and level 2 for the individual student, and a random intercept for each school was applied. We explored both unstandardized and standardized beta-coefficients for the continuous predictors. The assumptions for mixed models were tested, and as data displayed heteroskedasticity (Breusch-Pagan test p >0.05) robust estimates were used. All models were adjusted for parental education and accelerometer wear-time. The models with sports participation were additionally adjusted for time spent in MVPA. As BMIsds were not significant in any of the models, this covariate was excluded from the final models. Only students with complete data on the mental health scales were included in the analyzes. All models were stratified by gender as the PA and mental health outcomes were significantly different between boys and girls. However, we also explored if gender moderated the associations by running the same models with all subjects and adding an interaction term. Only significant interaction results are presented in the text. Crude models are included in Tables 1-2 in the supplemental material.

To analyze the effect size in SCAS-S and Kidscreen-10, standardized mean differences (Cohen’s d) were calculated between the low/high tertiles of MVPA, screen time, and participants/ non-participants in organized sports. The level of statistical significance was set at $\alpha < 0.05$, 95% confidence intervals, and p-values and beta values are bolded to indicate statistical significance.

RESULTS

In total, 1072 students (94%) completed all items on SCAS-S. Girls reported significantly higher anxiety scores compared to boys (16.6 vs. 10.6, mean difference of 6.0, $t(1070)= 13.44$ $p <0.01$). In girls, 82 (15%) had a score >1 SD above the mean (elevated anxiety) and 50 (9%) had a score > 1.5 SD above the mean (high anxiety). In boys, the corresponding values were 75 (14%) students and 42 (8%) students. Boys to parents with low education had significantly higher anxiety symptoms (mean difference 1.6 $t(505)= 2.7$ $p<0.01$) compared to boys with high parental education. This difference was not observed in girls or for HRQoL.

A total of 1096 (96%) students completed all items on the Kidscreen-10 questionnaire where girls had significantly lower scores of HRQoL (mean difference of 2.63, $t(1094)= -8.29$ $p <0.01$) compared to boys. The Cronbach alpha for Kidsscreen-10 was 0.78 and 0.84 for SCAS-S, indicating acceptable to good internal consistency.

For the PA measurements, 903 students (79%) had valid accelerometer readings for the whole week, 1054 students (93%) for weekdays, and 916 (80%) on weekends. There were no significant differences in mean values of SCAS-S or Kidscreen-10 between those who had a valid accelerometer reading and those who did not.

Table 1. Descriptive characteristics of the study sample by gender (mean ± SD unless otherwise specified)

	n	missing	All	n	Girls	n	Boys	Sig. p
Total			1139 (100)		580 (51.0)		558 (49.0)	
Age (year)	1139	0	13.4 ± 0.3		13.4 ± 0.3		13.4 ± 0.4	0.147
Parental education, >12 years n (%)	1102	37	730 (66.2)		371 (65.9)		358 (66.5)	0.821
Student country of birth, Sweden n (%)	1129	10	967 (85.7)		490 (84.9)		476 (86.4)	0.758
BMI status[1]	1134	5		580		554		0.203
Underweight n (%)			89 (7.8)		38 (6.6)		51 (9.2)	
Normal weight n (%)			815 (71.8)		430 (74.1)		384 (69.3)	
Overweight n (%)			179 (15.8)		89 (15.3)		90 (16.2)	
Obese n (%)			52 (4.6)		23 (4.0)		29 (5.2)	
BMI sds[2]	1134	5	0.36±1.23	580	0.45±1.11	554	0.26±1.35	**0.012**
Sedentary time (min)								
SED (average week)	903	236	602.0 ± 66.6	490	608.9 ± 62.65	413	593.7 ± 70.2	**<0.001**
SED bouts over 10 min	903	236	122.7 ± 63.6	490	132.8 ± 63.2	413	110.7 ± 62.2	**<0.001**
SED leisure time (weekdays)	1054	85	324.8 ± 69.2	548	330.0 ± 63.5	506	319.2 ± 74.7	**0.011**
SED leisure time (weekend)	916	223	539.4 ± 84.7	497	533.8 ± 80.0	419	546.1 ± 89.6	**0.029**
SED school time	1054	85	291.9 ± 37.5	548	301.7 ± 35.7	506	281.2 ± 36.5	**<0.001**
MVPA time (min)								
MVPA (average week)	903	236	52.0 ± 19.0	490	49.52 ± 17.7	413	54.86 ± 20.1	**<0.001**
MVPA leisure time (weekdays)	1054	85	31.6 ± 15.0	548	30.9 ± 13.8	506	32.3 ± 16.1	0.145
MVPA leisure time (weekend)	916	223	37.9 ± 25.3	497	36.8 ± 23.3	419	39.1 ± 27.4	0.156
MVPA school time	1054	85	26.5 ± 11.2	548	23.2 ± 9.6	506	30.1 ± 11.7	**<0.001**
Reached the MVPA recommendations n (%)	903	236	273 (30.2)	490	121 (24.7)	413	152 (36.8)	**<0.001**
Accelerometer wear time	903	236		490		413		
Wear time (average week)			792.6 ± 60.8		796.0 ± 58.1		788.5 ± 63.8	0.067
Total included valid days			6.0 ± 1.1		6.2 ± 1.0		5.8 ± 1.1	**<0.001**
Organized sports								
Participated in organized sports n (%)			787 (72.0)		396 (71.4)		391 (72.7)	0.626
Screen time (weekdays)	1125	14		575		550		0.842
≤2 hours n (%)			359 (32.0)		179 (31.1)		180 (32.7)	
3-4 hours n (%)			515 (46.0)		267 (46.4)		248 (45.1)	
≥5 hours n (%)			251 (22.3)		129 (22.4)		122 (22.2)	
Screen time (weekend)	1122	17		576		546		**<0.001**
≤2 hours n (%)			178 (15.9)		70 (12.2)		108 (19.8)	
3-4 hours n (%)			411 (36.6)		238 (41.3)		173 (31.7)	
≥5 hours n (%)			533 (47.5)		268 (46.6)		265 (48.5)	
Mental health								
SCAS-S	1072	67	13.7 ± 7.9	547	16.6 ± 8.0	525	10.6 ± 6.6	**<0.001**
Kidscreen-10	1096	43	39.6 ± 5.4	562	38.3 ± 5.2	534	41.0 ± 5.3	**<0.001**
Kidscreen-10 [T]	1096	43	49.6 ± 9.0	562	47.3± 7.5	534	51.9 ± 9.8	**<0.001**

[1]BMI status according to IOTF 2012, [2] BMI sds according to a Swedish reference standard.
MVPA moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale,
[T] international T-values based on Rasch person parameter

On an average day, boys spent significantly more in MVPA. However, when breaking down the MVPA between domains, this difference was only significant during school time (mean difference of 6.9 min, $t(1052)= -10.56$ $p<0.01$). Students who participated in organized sports had 11.3 more minutes per day in MVPA compared to those who did not participate $t(874)= -8.10$ $p<0.01$. Similarly, the group who reported low screen time (≤2 hours) on weekends spent 15 more minutes in MVPA compared to those who reported five hours or more $t(568)= 6.32$ $p<0.01$. Table 2 shows the associations between anxiety (SCAS-S) and health-related quality of life (Kidscreen-10) and predictors using multi-level mixed linear regression models.

Table 2. Associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models stratified by gender

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Girls			Boys			Girls			Boys		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	448	**-0.045 (-0.079, -0.011)**	**-0.099**	383	-0.026 (-0.058, 0.007)	-0.077	458	**0.032 (0.009, 0.054)**	**0.110**	390	**0.040 (0.015, 0.065)**	**0.157**
1.2 MVPA leisure time (weekdays)	503	**-0.091 (-0.134, -0.049)**	**-0.161**	468	**-0.038 (-0.066, -0.010)**	**-0.095**	514	**0.048 (0.023, 0.073)**	**0.130**	477	**0.036 (0.011, 0.061)**	**0.100**
1.3 MVPA leisure time (weekend)	455	-0.023 (-0.049, 0.002)	-0.067	388	-0.001 (-0.024, 0.021)	-0.005	465	**0.023 (0.033, 0.043)**	**0.105**	396	**0.034 (0.020, 0.048)**	**0.183**
1.4 MVPA school time	503	-0.027 (-0.100, 0.047)	-0.032	468	0.015 (-0.039, 0.069)	0.027	514	0.013 (-0.033, 0.059)	0.025	477	0.020 (-0.024, 0.064)	0.046
2. SED												
2.1 SED whole week	448	0.011 (-0.007, 0.028)	0.081	383	0.011 (-0.006, 0.028)	0.114	458	**-0.021 (-0.032, -0.009)**	**-0.251**	390	**-0.021 (-0.033, -0.008)**	**-0.285**
2.2 SED bouts (10 min) whole week	448	-0.001 (-0.014, 0.012)	-0.009	383	0.002 (-0.009, 0.013)	0.021	458	**-0.012 (-0.020, -0.005)**	**-0.150**	390	**-0.009 (-0.017, -0.001)**	**-0.113**
2.3 SED leisure time (weekdays)	503	**0.040 (0.017, 0.062)**	**0.315**	468	0.017 (-0.002, 0.036)	0.195	514	**-0.034 (-0.051, -0.017)**	**-0.421**	477	**-0.020 (-0.036, -0.005**	**-0.299**
2.4 SED leisure time (weekend)	455	0.007 (-0.006, 0.020)	0.064	388	0.003 (-0.009, 0.014)	0.035	465	**-0.013 (-0.022, -0.003)**	**-0.192**	396	**-0.017 (-0.025, -0.009)**	**-0.299**
2.5 SED school	503	-0.009 (-0.039, 0.021)	-0.041	468	-0.011 (-0.034, 0.012)	-0.062	514	-0.001 (-0.026, 0.001)	-0.060	477	-0.012 (-0.033, 0.001)	-0.083
3. Organized sports												
Did not participate	112	ref		97	ref		114	ref		99	ref	
Participated	321	-0.210 (-2.165, 1.745)		283	**-1.810 (-3.492, -0.129)**		329	-0.258 (-1.701, 1.185)		288	1.214 (-0.459, 2.888)	
4. Screen time weekday												
≤2 hours	162	ref		167	ref		166	ref		167	ref	
3-4 hours	253	0.628 (-0.975, 2.231)		230	0.342 (-0.782, 1.466)		256	**-1.337 (-2.175, -0.499)**		237	-0.785 (-1.758, 0.188)	
≥5 hours	116	**4.056 (1.935, 6.176)**		110	0.883 (-0.583, 2.348)		121	**-3.503 (-4.786, -2.220)**		111	**-1.539 (-2.664, -0.413)**	
5. Screen time weekend												
≤2 hours	61	ref		98	ref		65	ref		99	ref	
3-4 hours	219	1.155 (-0.582, 3.369)		164	-0.151 (-1.776, 1.473		225	-0.904 (-2.315, 0.506)		166	0.157 (-1.725, 1.411)	
≥5 hours	252	**3.340 (1.394, 5.287)**		243	1.060 (-0.207, 2.326)		254	**-2.520 (-4.014, -1.027)**		248	-0.842 (-2.320, 0.636)	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale
All models were adjusted for parental education
Model 3 were adjusted for time spent in MVPA
Models 1-3 were adjusted for accelerometer wear-time

1

Associations between PA patterns, screen time, and anxiety (SCAS-S)

A significant inverse association between time spent in MVPA during leisure time on weekdays and anxiety was seen in girls and boys. There was a significant interaction of gender in this association (p 0.01), such that the association was stronger in girls compared to boys. Time spent in MVPA over the whole week was only significantly associated with anxiety in girls, none of the other MVPA measured was significantly associated with anxiety among girls or boys. Boys who participated in organized sports also had a significantly lower prevalence of anxiety, compared to boys who did not participate. This association was not significant in girls.

In girls, time spent in SED during leisure time on weekdays was positively associated with anxiety. None of the other SED measures was significantly associated with anxiety in girls or boys.

With regards to screen time, significant associations were only found in the group of girls who reported ≥5 hours screen time on weekdays or weekends. These groups had significantly higher anxiety scores compared to those who reported up to 2 hours. When controlling for MVPA, this association remained significant (B=3.39, CI: 1.33, 5.46) for weekdays and (B=2.53, CI: 0.27, 4.80) for weekends. Further, there was a significant interaction of gender in the association between screen-time on weekends and anxiety with a stronger association among girls compared to boys (p<0.03) in the group who reported ≥5 hours screen time.

Associations between PA pattern, screen time, and health-related quality of life (Kidsscreen-10)

There was a positive association between time spent in MVPA during the whole week, during leisure time on weekdays, on weekends, and HRQoL in girls and boys. There was a positive association between sports participation and HRQoL in boys, however, the significance disappeared after controlling for time spent in MVPA.

Inverse associations were seen between all SED time domains and HRQoL in both boys and girls, except SED during school time. There was a significant interaction of gender in the association between time spent in SED on weekends and HRQoL (p 0.04) with a stronger association in boys compared to girls.

Girls and boys who reported ≥5 hours screen time on weekdays had significantly lower HRQoL, compared to those who reported two hours or less. The results remained significant also after adjusting for time spent in MVPA (B=-3.32, CI: -4.50, -2.14 in girls, and B= -1.65 CI: -2.70, -0.61 in boys). A significant association between screen time on weekends and HRQoL was only found in girls who reported ≥5 hours of screen time.

Figure 2 shows the unadjusted mean SCAS-S score and Kidscreen-10 scores between students reporting different levels of screen time on weekdays.

[Figure 2 should be inserted here]

To assess the clinical significance, we calculated effect sizes (Cohen's d) in mental health scores between participants/non-participants in organized sports, low/high screen time, and in low/high tertiles of MVPA. The average time (minutes) for MVPA in the lowest tertile was 32 and 34, and in the highest tertile 70 and 78 for girls and boys, respectively. Regarding SCAS-S, the effect sizes between low/high MVPA groups were 0.18 in girls (CI: -0.05, 0.40) and 0.31 in boys (0.07, 0.56). The effect sizes between participants/non-participants in organized sports were 0.13 (CI: -0.07, 0.31) in girls and 0.31 (CI: 0.12, 0.51) in boys. The effect sizes between groups with low/high screen time on weekdays were -0.47 in girls (CI: -0.70, -0.23) and -0.18 in boys (CI: -0.42, 0.05) and on weekends -0.36 in girls (CI: -0.64, -0.09) and -0.17 (CI: -0.40, 0.06) in boys.

For Kidscreen-10 the results showed that the effect sizes between low/high MVPA groups were -0.28 in girls (CI: -0.50, -0.06) and -0.51 in boys (CI: -0.75, -0.26) and between participants/non-participants in organized sports -0.01 (CI: -0.20, 0.18) in girls and -0.28 (CI: -0.47, -0.08) in boys. Between groups with high/low screen time on weekdays, the effect sizes were 0.59 in girls (CI: 0.36, 0.83) and 0.35 in boys (CI: 0.12, 0.59) and on weekends 0.50 (CI 0.23, 0.77) and 0.14 (CI: -0.9, 0.36) for girls and boys respectively (these results can be found in table 3 the supplemental material).

DISCUSSION

In this cross-sectional study, the associations between PA patterns, sports participation, screen time, and mental health (anxiety and HRQoL) were investigated in Swedish adolescents. MVPA was positively associated with HRQoL whereas time spent in SED or using screens on weekdays was inversely associated. Although the effect sizes generally were small, the largest effect sizes were observed between the high/low MVPA group in boys and between the high/low screen time group in girls. With regards to anxiety, high MVPA during leisure time on weekdays was associated with low anxiety scores. Some gender differences were observed, boys participating in organized sports had low anxiety scores whereas girls who reported five hours or more of screen time had high anxiety scores.

The mean Kidscreen-10 score in our sample was 38.3 in girls and 41.0 in boys, which corresponds to a T-score of 47.3 in girls and 51.9 in boys. A suggested threshold to classify the values as "normal" is ½ SD above or below the reference value [25]. This indicates that our sample was within this range of the Swedish reference population (12-18-year-olds) with a T-score of 49.2 for girls and 52.4 for boys, as well as the overall European T-score based on 11 countries (48.6 for girls and 49.5 for boys) [25]. The current sample also had similar PA levels (on average 52 minutes in MVPA per day) and demographic characteristics (66% had parents with ≥12 years of education, 86% were born in Sweden and 21% had overweight or obesity) compared to a nationally representative study in Swedish adolescents which reported on average 53 minutes in MVPA per day, 61% with high parental education, 88% born in Sweden, 21% with overweight or obesity [14].

The most common limitation in previous studies is the lack of detailed measures of PA. The current study used device-measured PA and could confirm many findings based on self-reported PA. One example is a review that found PA to be positively associated with HRQoL and a high proportion of SED to be associated with lower HRQoL [26]. In general, the effect sizes in the current study were small, which is not uncommon in these types of studies. A previous study by Gopinath et al. found similar mean differences in HRQoL between the high/low group of PA and screen time [27]. However, this study did not stratify the analysis by gender. In our study, we found the largest effect sizes when comparing the lowest and highest tertiles of MVPA for boys (Cohen's d= 0.51), and screen time for girls (Cohen's d= 0.50 on weekends) and (Cohen's d= 0.59 on weekdays). Our findings suggest that the strengths of the associations to HRQoL could be different for boys and girls and these gender differences should be considered when designing future intervention studies to improve HRQoL.

Regarding screen time, this study found high screen time during weekdays to be associated with lower HRQoL which confirms the findings of a review that concluded moderate evidence for the association between screen time and HRQoL. In the current study, we found a significant difference in MVPA between the low/high screen time group. Interestingly, after controlling for time spent in MVPA screen time was still significantly associated with HRQoL independently of MVPA in both genders. As previously mentioned, we found the effect size of screen time to be larger in girls. These findings are similar to a study from the UK which concluded that the association between screen time and mental health was stronger in girls. The same study also found that the dose of screen time associated with problematic mental health was lower for girls (>2 hours) compared to boys (>5 hours) [28]. This was also evident in the current study, where screen time >3 hours were associated with lower HRQoL in girls, whereas for boys this association was significant only for the group reporting ≥5 hours.

A strength of this study is the inclusion of both a positive and a negative indicator of mental health, which shows that the type of PA pattern and screen time associated with each measure differs. Fewer measures of the PA pattern and screen time were significantly associated with anxiety compared to HRQoL. MVPA during leisure time on weekdays was inversely associated with anxiety in both genders. These results are consistent with those reported previously using self-reported PA [29, 30]. However, we only found sports participation to be associated with lower anxiety in boys. These

findings were different from a study in 14-year-old that found sports participation to be significantly associated with lower anxiety and higher well-being in both genders [31]. Potential explanations for this could be that the study did not control for time spent in MVPA and that sports participation was lower (33%) compared to 72% in our study. Another study in older youth found that the significant association between sports participation and anxiety disappeared after controlling for time spent in MVPA [12]. Previous studies have also suggested that the strength of the association could vary between genders. A review found a weak negative correlation between sports participation and anxiety, but in samples with a higher proportion of boys, the correlation was stronger [32]. One potential explanation for the gender differences observed in the current study could be related to the context and sports environment. Where girls have reported a higher incidence of teasing during sports participation and participation in sports common to girls (aesthetic sports such as dance or gymnastics) have been associated with body image concerns and disordered eating [33]. This indicates that depending on the sports culture the association between sports participation and mental health could differ between genders, this should be investigated further in future research.

About screen time, this study found that girls reporting ≥5 hours of screen time on weekdays and weekends had higher levels of anxiety compared to those who reported ≤2 hours. This association was not seen in boys. These findings were consistent with a study in Icelandic adolescents, that found screen time <5 hours to be associated with fewer symptoms of anxiety and depression [30]. However, the results were not stratified by gender. Although not investigated in the current study, one suggested explanation for the gender differences in the type of screen time activity. A review found social media use to be associated with anxiety, with a stronger association in girls [34]future studies should further investigate these associations. With regards to screen time, it is important to acknowledge the methodological challenges of measuring screen time, and that there is no consensus of how to best capture these behaviors. In this study self-reported screen time was used with broad questions that included all types of screen devices and activities, except schoolwork. When comparing self-reported screen time to more objective measures (using an app for example) some underreporting is evident, although total daily duration was more accurately reported compared to number of phone use [35]. In the current study self-report was used to decrease participant burden and privacy invasion, but it is worth noting that the screen time duration acquired in this study should not be considered an exact dose but rather interpreted as a proxy for high/low screen users.

There is a lack of studies that investigate the association between device-measured SED and mental health and many studies rely on screen time as a proxy for SED. In the current study, stronger associations were seen in the standardized beta coefficients for the SED measurements (especially during leisure time weekdays), compared to MVPA. This was seen in both genders for HRQoL and anxiety for girls. A review concluded that sedentary behaviors were associated with an increased risk of anxiety, with the strongest associations found in sitting [36]. However, it is important to note that causation or the direction of these associations cannot be studied in cross-sectional studies. Interestingly, a randomized controlled trial (RCT) showed significantly higher anxiety levels in the intervention group after a one-week intervention of increased SED and eliminated PA compared to the control group, which continued their normal PA routine [37]. These findings suggest that reducing SED could be a strategy to improve mental health among adolescents, although this should be investigated further in larger RCT studies.

A limitation of the current study was the lack of questions concerning functioning to further understand if the group with low mental health experienced impairment in their daily lives. However, including a positive and negative measure still provides a better understanding of the students' overall mental health compared to studies that only focus on symptoms of mental illness. Moreover, other measures not included in this article such as academic attainment and cognition could be important in this association. Another limitation was the cross-sectional design, which makes it impossible to study the direction or cause of these relationships. A strength was the detailed PA measure (accelerometer) with individual time filters, which enabled comparisons between different time domains. Furthermore,

the relatively large sample size and a high participation rate (73%), which resulted in a non-homogenous study population of adolescents with different PA levels and mental health scores. As our population were within the range of the European norm values for HRQoL it is plausible that our findings could be generalized to other European adolescent populations. However, as our questionnaires were in Swedish, immigrant adolescents with a low proficiency in Swedish could not participate, neither did we have a representation of adolescents with physical impairments. Therefore, future studies should ensure that these groups are represented as well to enhance the generalizability of the findings.

CONCLUSIONS

This cross-sectional study showed that MVPA was associated with better mental health, whereas SED or screen time was associated with lower mental health. However, these associations were not significant throughout all time domains and some gender differences were observed. Although this cross-sectional study cannot conclude causation or direction the relationship, our results suggests that adolescents with worse mental health scores also spend less time being physically active and more time being sedentary or using screens. Therefore, it is important in future research and school efforts to consider how to reach this group, as they might be the ones most in need of an intervention. Our results could create a paradigm for future studies to decide which types of PA patterns and time domains to target in intervention studies with the aim improve mental health among adolescents.

LEGENDS

Figure 1. Participation of schools and students.

Figure 2. Unadjusted means SCAS-S and Kidscreen-10 score between screen time groups, mean comparisons were analyzed using an Analysis of variance ANOVA and Bonferroni post hoc test
*** p <0.001 ** p <0.01

DECLARATIONS

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Data sharing: The datasets are not available for download to protect the confidentiality of the participants. The data are held at The Swedish School of Sport and Health Sciences.

Authors' contributions: KK recruited the schools. GN, ÖE, BH, KK designed the study and participated in the data collection. BH cleaned and processed the data. JÅ contributed to the design of the statistical model and the interpretation of the results. KK drafted the manuscript. All authors read and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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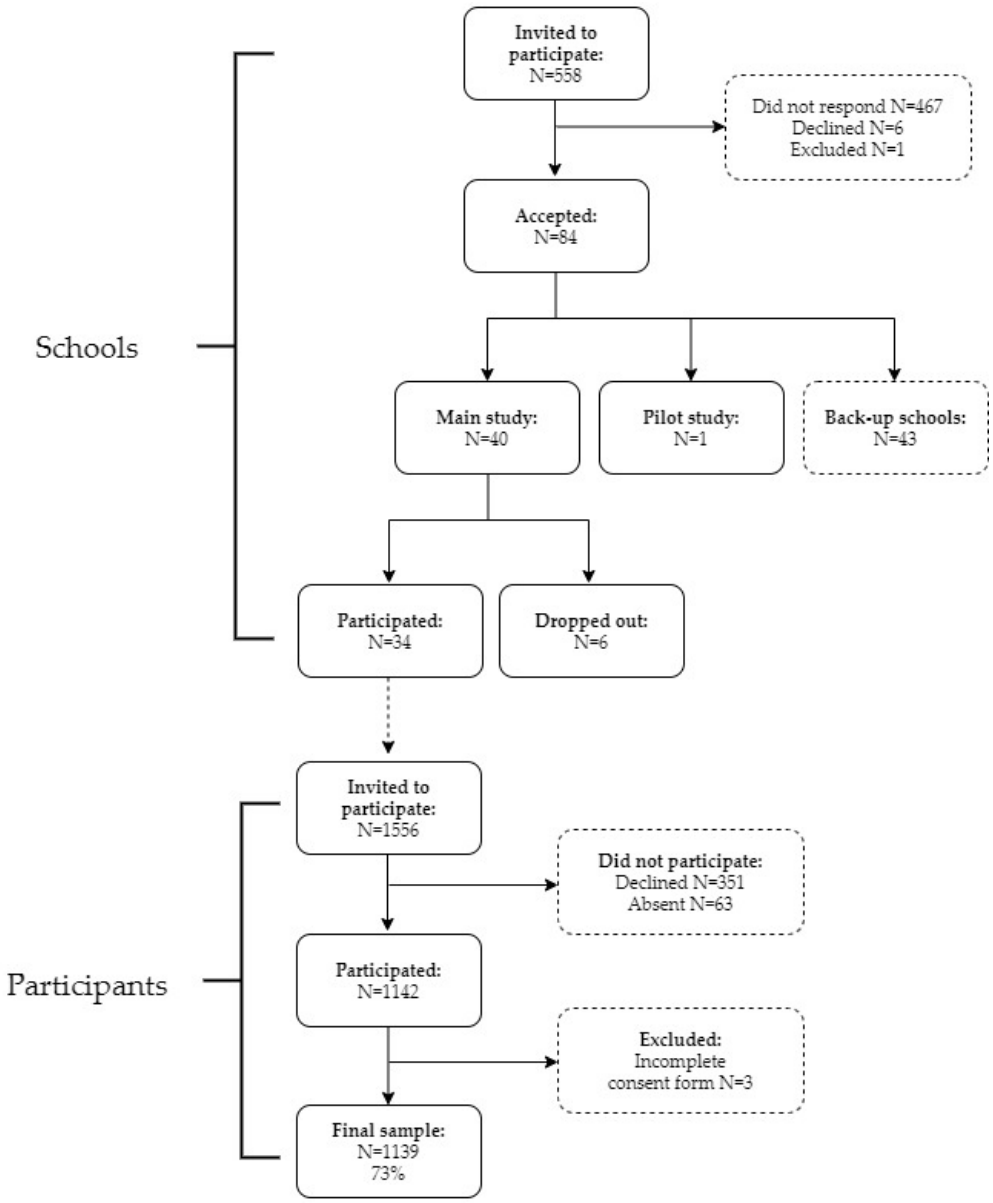

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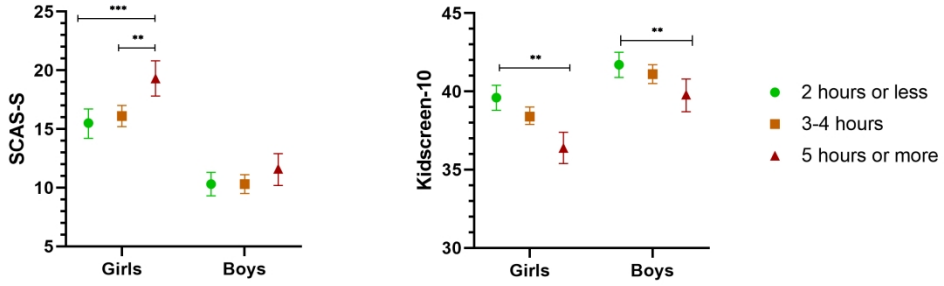

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SUPPLEMENTAL MATERIAL

Supplemental material 1. Crude and adjusted associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Crude			Adjusted			Crude			Adjusted		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	854	**-0.058 (-0.091, -0.025)**	**-0.138**	831	**-0.035 (-0.062, -0.007)**	**-0.082**	873	**0.044 (0.028, 0.060)**	**0.157**	848	**0.036 (0.021, 0.051)**	**0.130**
1.2 MVPA leisure time (weekdays)	1000	**-0.072 (-0.106, -0.038)**	-0.136	971	**-0.062 (-0.089, -0.034)**	**-0.118**	1023	**0.049 (0.029, 0.068)**	**0.137**	991	**0.043 (0.025, 0.061)**	**0.122**
1.3 MVPA leisure time (weekend)	866	-0.017 (-0.038, 0.004)	-0.053	843	-0.011 (-0.030, 0.010)	-0.033	886	**0.030 (0.019, 0.041)**	**0.144**	861	**0.028 (0.017, 0.039)**	**0.135**
1.4 MVPA school time	1000	-0.095 (-0.147, -0.043)	-0.135	971	-0.006 (-0.047, 0.036)	-0.008	1023	**0.056 (0.022, 0.090)**	**0.117**	991	0.019 (-0.013, 0.052)	0.052
2. SED												
2.1 SED whole week	854	**0.009 (0.002, 0.017)**	0.077	831	0.011 (-0.004, 0.026)	0.089	873	**-0.009 (-0.016, -0.0002)**	**-0.113**	848	**-0.021 (-0.029, -0.012)**	**-0.261**
2.2 SED bouts (10 min) whole week	854	0.008 (-0.001, 0.017)	0.064	831	0.000 (-0.010, 0.010)	0.001	873	**-0.013 (-0.018, -0.007)**	**-0.155**	848	**-0.011 (-0.016, -0.005)**	**-0.130**
2.3 SED leisure time (weekdays)	1000	**0.009 (0.004, 0.015)**	**0.081**	971	**0.026 (0.011, 0.041)**	**0.228**	1023	-0.005 (-0.009, 0.000)	-0.063	991	**-0.027 (-0.040, -0.015)**	**-0.358**
2.4 SED leisure time (weekend)	866	-0.003 (-0.009, 0.002)	-0.036	843	0.004 (-0.007, 0.015)	0.042	886	-0.004 (-0.008, 0.001)	-0.056	861	**-0.014 (-0.020, -0.008)**	**-0.230**
2.5 SED school	1000	**0.024 (0.009, 0.039)**	**0.112**	971	-0.009 (-0.030, 0.011)	-0.045	1023	**-0.013 (-0.025, -0.001)**	**-0.091**	991	-0.011 (-0.026, 0.004)	-0.079
3. Organized sports												
Did not participate	291	ref		209	ref		296	ref		213	ref	
Participated	750	**-1.589 (-2.743, -0.435)**		604	-0.963 (-2.07, 0.141)		766	**0.855 (0.036, 1.674)**		617	0.407 (-0.554, 1.367)	
4. Screen time weekday												
≤2 hours	343	ref		329	ref		348	ref		333	ref	
3-4 hours	492	0.388 (-0.599, 1.375)		483	0.407 (-0.481, 1.295)		503	**-0.827 (-1.529, -0.124)**		493	**-1.007 (-1.591, -0.423)**	
≥5 hours	235	**2.626 (1.135, 4.117)**		226	**2.409 (1.083, 3.735)**		242	**-2.521 (-1.529, -0.125)**		232	**-2.633 (-3.381, -1.885)**	
5. Screen time weekend												
≤2 hours	169	ref		159	ref		174	ref		164	ref	
3-4 hours	392	**1.302 (0.132, 2.471)**		383	0.461 (-0.609, 1.531)		402	-0.594 (-1.474, 0.286)		391	-0.261 (-1.078, 0.555)	
≥5 hours	507	**2.368 (1.236, 3.501)**		495	**1.896 (0.881, 2.912)**		515	**-1.607 (-2.582, -0.633)**		502	**-1.485 (-2.385, -0.585)**	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale
The adjusted models have been controlled for gender and parental education. Further, Model 3 were adjusted for time spent in MVPA, and Models 1-3 were adjusted for accelerometer wear-time

Supplemental material 2. Crude associations between predictors and anxiety (SCAS-S) and health-related quality of life (Kidsscreen-10) were analyzed with multi-level mixed linear regression models stratified by gender

Model	Anxiety (SCAS-S)						Health-related quality of life (Kidsscreen-10)					
	Girls			Boys			Girls			Boys		
	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta	n	Unstandardized B (95% CI)	Standardized beta
1. MVPA												
1.1 MVPA whole week	461	**-0.043 (-0.079, -0.007)**	**-0.095**	393	**-0.026 (-0.060, 0.008)**	**-0.078**	473	**0.027 (0.004, 0.05)**	**0.093**	400	**0.044 (0.020, 0.069)**	**0.171**
1.2 MVPA leisure time (weekdays)	517	**-0.096 (-0.139, -0.055)**	**-0.169**	483	**-0.037 (-0.067, -0.007)**	**-0.090**	531	**0.049 (0.023, 0.07)**	**0.132**	492	**0.042 (0.018, 0.067)**	**0.130**
1.3 MVPA leisure time (weekend)	468	-0.021 (-0.049, 0.006)	-0.063	398	-0.003 (-0.025, 0.019)	-0.011	480	0.021 (-0.001, 0.043)	0.095	406	**0.036 (0.021, 0.050)**	**0.189**
1.4 MVPA school time	517	-0.012 (-0.080, 0.056)	-0.015	483	0.004 (-0.047, 0.054)	0.007	531	0.003 (-0.042, 0.048)	0.005	492	0.028 (-0.009, 0.066)	0.0637
2. SED												
2.1 SED whole week	461	0.000 (-0.008, 0.010)	0.004	393	0.006, (-0.002, 0.014)	0.063	473	-0.004 (-0.012, 0.003)	-0.057	400	-0.009 (-0.018, 0.000)	-0.119
2.2 SED bouts (10 min) whole week	461	-0.002 (-0.014, 0.009)	-0.017	393	0.003 (-0.008, 0.014)	0.028	**473**	**-0.010 (-0.016, -0.003)**	**-0.122**	400	**-0.0100 (-0.018, -0.002)**	-0.120
2.3 SED leisure time (weekdays)	517	0.001 (-0.007, 0.010)	0.010	483	0.008 (0.001, 0.014)	0.087	531	-0.003 (-0.009, -0.004)	**-0.033**	492	-0.004 (-0.010, 0.003)	-0.052
2.4 SED leisure time (weekend)	468	-0.003 (-0.011, 0.004)	-0.033	398	-0.000 (-0.008, 0.008)	-0.002	480	0.004 (-0.005, 0.006)	0.006	406	**-0.009 (-0.014, -0.004)**	**-0.155**
2.5 SED school	517	0 .009 (-0.007, 0.025)	0.042	483	-0.010 (-0.027, 0.006)	-0.056	531	0.000 (-0.016, 0.016)	-0.000	492	-0.005 (-0.020, 0.010)	-0.034
3. Organized sports												
Did not participate	152	ref		139	ref		155	ref		141	ref	
Participated	376	-0.914 (-2.528, 0.700)		374	**-2.009 (-3.445, -0.572)**		386	0.132 (-1.110, 1.375)		380	1.358 (0.133, 2.58	
4. Screen time weekday												
≤2 hours	168	ref		175	ref		173	ref		175	ref	
3-4 hours	257	0.550 (-0.984, 2.084)		235	0.014 (-1.135, 1.162)		261	**-1.095 (-19.976, -0.213)**		242	-0.587 (-1.546, 0.372)	
≥5 hours	120	**3.856 (1.916, 5.796)**		115	1.190 (-0.143, 2.523)		126	**-3.190 (-4.292, -2.089)**		116	**-1.609 (-2.845, -0.372)**	
5. Screen time weekend	546											
≤2 hours	65	ref		104	ref		69	ref		105	ref	
3-4 hours	224	1.126 (-1.097, 3.350)		168	-0.163 (-1.719, 1.393)		232	-0.903 (-2.388, 0.582)		170	0.0449 (-1.504, 1.594)	
≥5 hours	257	**2.931 (0.924, 4.938)**		250	0.992 (-0.222, 2.206)		260	**-2.530 (-4.036, -1.025)**		255	-0.615 (-2.100, 0.870)	

B unstandardized coefficients, beta standardized coefficients, CI confidence interval
MVPA Moderate-to-vigorous physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale

Supplemental material 3. Unadjusted mean SCAS-S and Kidscreen-10 score and SD for students in the highest and lowest groups of MVPA and screen time

	Anxiety (SCAS-S)				Health-related quality of life (Kidsscreen-10)			
	Girls		Boys		Girls		Boys	
	n	mean ± SD	n	mean ± SD	n	mean ± SD	n	mean ± SD
Screen time								
Weekday								
≤2 hours	168	15.46 ±8.37	175	10.29±6.60	173	39.62±5.29	175	41.70±5.22
≥5 hours	120	19.33±8.24	115	11.56±7.25	126	36.40±5.60	116	39.78±5.78
Weekend								
≤2 hours	65	14.71±7.19	104	10.04±6.73	69	39.96±5.34	105	41.34±5.77
≥5 hours	257	17.69±8.43	250	11.21±6.84	260	37.35±5.19	255	40.59±5.44
Physical activity								
MVPA lowest tertile	157	17.07±8.77	128	12.06±7.48	160	37.83±5.25	135	39.65±5.94
MVPA highest tertile	152	15.65±6.98	130	9.89±6.32	157	39.20±4.58	130	42.32±4.47
Organized sports								
Did not participate	376	16.31±7.67	374	10.02±6.28	386	38.41±5.01	380	41.41±4.90
Participated	152	17.28±8.61	139	12.06±7.01	155	38.35±5.59	141	39.97±5.77

MVPA moderate-to-vigorous-physical activity, SED sedentary time, SCAS-S Short version of the Spence Children's Anxiety Scale

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	2
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	2-3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	2
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	3-4
Bias	9	Describe any efforts to address potential sources of bias	3-4
Study size	10	Explain how the study size was arrived at	2
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	3-4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4
		(*b*) Describe any methods used to examine subgroups and interactions	4
		(*c*) Explain how missing data were addressed	4
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	4
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	3-7
		(b) Give reasons for non-participation at each stage	3, 5
		(c) Consider use of a flow diagram	3
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	6
Outcome data	15*	Report numbers of outcome events or summary measures	6-7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-8, and in the supplemental material (table 1 and 2)
		(*b*) Report category boundaries when continuous variables were categorized	3-4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	4
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	9-11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.