Journal of Physical Activity and Health, 2025, 22, 1168-1177
https://doi.org/10.1123/jpah.2024-0788

Human Kinetics
ORIGINAL RESEARCH

Screen-Based Behaviors as Moderators of the Link Between Physical Activity and Internalizing and Externalizing Symptoms in Adolescents: A Population-Based Cohort Study

Ruimin Ma,[1] Eugenia Romano,[1] Dara Aldisi,[2] Nasser M. Al-Daghri,[3] Shaun Sabico,[3] Arnold Baca,[4] Guillermo Felipe López Sánchez,[5] Lee Smith,[6] Liye Zou,[7] José Francisco López-Gil,[8,9] Brendon Stubbs,[1,4] and André O. Werneck[10]

[1]Psychological Medicine, Institute of Psychiatry, Psychology and Neuroscience (IoPPN), King's College London, London, United Kingdom; [2]Department of Community Health Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia; [3]Biochemistry Department, College of Science, King Saud University, Riyadh, Saudi Arabia; [4]Center for Sport Science and University Sports, University of Vienna, Wien, Austria; [5]Division of Preventive Medicine and Public Health, Department of Public Health Sciences, School of Medicine, University of Murcia, Murcia, Spain; [6]Center for Health, Performance and Wellbeing, Anglia Ruskin University, Cambridge, United Kingdom; [7]Body-Brain-Mind Laboratory, School of Psychology, Shenzhen University, Shenzhen, GD, China; [8]School of Medicine, Universidad Espíritu Santo, Samborondón, Ecuador; [9]Vicerrectoría de Investigación y Postgrado, Universidad de los Lagos, Osorno, Chile; [10]Center for Epidemiological Research in Nutrition and Health, Department of Nutrition, School of Public Health, Universidade de São Paulo (USP), São Paulo, SP, Brazil

Background: Increased engagement in screen-based behaviors may contribute to decreased physical activity (PA) participation and is associated with mental health among adolescents. Yet, there remain knowledge gaps in how types and duration of screen-based behaviors may moderate the associations between PA, psychological distress, internalizing, and externalizing symptoms. This population-based study aimed to examine this relationship. ***Methods:*** Longitudinal data were obtained from the Millennium Cohort Study and adolescents were followed up from the 14-year to 17-year waves. Data on device-based moderate to vigorous PA (MVPA), screen-based behaviors (watching videos and playing videogames), internalizing (emotional and peer problems) and externalizing symptoms (hyperactivity and conduct problem), and psychological distress were analyzed using negative binomial regression (stratified by gender) with interaction terms of continuous device-based PA and categorical screen-based behaviors being applied. ***Results:*** The final sample included 3397 adolescents (mean age = 13.8, 54% girls). Device-based MVPA was associated with a lower incidence of emotional problems (boys [incidence rate ratio (IRR) = 0.97], and girls [IRR = 0.98]), peer problems (IRR = 0.97), and psychological distress (girls only, IRR = 0.98). Video watching for ≥2 hours per day was associated with a higher incidence of conduct problem in boys (IRR = 1.20) and videogames playing ≥2 hours per day was associated with all internalizing and externalizing symptoms in girls (IRR range 1.10–1.21). A buffering effect of MVPA on various symptoms among those spent <2 hours per day on screen-based behaviors was observed. ***Conclusions:*** Reducing screen-based behaviors may help maximize the benefits of MVPA on mental health outcomes in adolescents therefore implementing interventions targeting screen-based behaviors reduction should be recognized as first-line priority.

Keywords: internalizing problems, externalizing problems, mental health, screen time, exercise, sedentary time

Key Points

- Moderate-to-vigorous physical activity is linked to fewer emotional, peer, and psychological distress symptoms, especially in girls.
- Screen time over 2 hours daily is associated with increased internalizing and externalizing problems, particularly among girls who play videogames.
- Moderate-to-vigorous physical activity appears most beneficial for mental health when screen-based behaviors are kept under 2 hours per day.

There are growing concerns around the mental health of young people including adolescents.[1] Recent reports indicate how adolescents' mental distress has increased sharply in the last decades which has been expedited by the coronavirus disease 2019 (COVID-19) pandemic.[2,3] Given that at least 50% of mental health conditions first develop in adolescence and early intervention at this critical period is key, there is an urgent need to identify modifiable factors (typically referring to risk and/or

Romano https://orcid.org/0000-0003-4112-2787
Aldisi https://orcid.org/0000-0001-5202-4432
Al-Daghri https://orcid.org/0000-0001-5472-1725
Sabico https://orcid.org/0000-0002-5248-2350
Baca https://orcid.org/0000-0002-1704-0290
López Sánchez https://orcid.org/0000-0002-9897-5273
Smith https://orcid.org/0000-0002-5340-9833
Zou https://orcid.org/0000-0001-6411-5710
López-Gil https://orcid.org/0000-0002-7412-7624
Stubbs https://orcid.org/0000-0001-7387-3791
Werneck https://orcid.org/0000-0002-9166-4376
Ma (ruimin.1.ma@kcl.ac.uk) is corresponding author, https://orcid.org/0000-0002-6051-8093

protective factors) which could help develop effective preventive measures.

Among the protective factors for better mental health and a reduced risk of mental illness, regular engagement in physical activity (PA) has been increasingly recommended by researchers and health professionals.[4–6] Specifically, PA is widely recognized for its benefits, both for physical health and for mental well-being.[7,8] For example, previous studies indicated that engagement in PA is associated with less stress, pain, and sleep complaints, as well as with lower depressive symptoms in people with or without mental illness.[5,9] Among adolescents with subthreshold mood disorders, exercise can improve mental health, possibly through changes in the gut microbiome and key structural changes in the brain.[10,11] However, maintaining a high PA level is becoming increasingly challenging for adolescents, with social barriers reported, such as feeling self-conscious, a lack of time to dedicate to PA, lack of availability of interesting sports in their area, or preference for other types of leisure activities.[12,13]

Simultaneously to such barriers, a dramatic increase in screen-based behaviors or activities has been documented over the last years[14] and potentially acts as a potential risk factor for low PA among adolescents. Although screen-based behaviors can be performed while sedentary or physically active, most of screen-based behaviors are predominantly sedentary.[15] Consistent with the Displacement Theory,[16] current evidence supports the idea that the increased amount of time spent on sedentary behaviors or activities may displace time spent on PA. For example, a study on the association between screen-based activities and PA among adolescents found that participants who spent less time on TV/movie streaming and playing electronic games had significantly higher odds of participating in PA,[17] and a study on US youth found a trend in increased screen time, while adherence to PA guidelines seemed to decrease,[18,19] highlighting a need for public health efforts to reduce screen time and promote PA among adolescents.

Furthermore, hours of screen time were observed to negatively link to lower well-being, higher anxiety and depression in adolescents.[20] Total screen use has shown a longitudinal association with a higher risk of self-harm and suicidal behavior in young people,[21] although relationship seems to be complex and influenced by variables, such as type of device[22] and specific characteristics of sedentary behavior such as cognitively active versus passive sedentary behaviors.[23] For example, there is evidence of moderation for screen-type on the association between screen-based sedentary behaviors, symptoms of depression and anxiety in adolescents.[24] Overall, this suggests that while the relationship between device-based PA and mental health is well-established, the moderating role of screen-based behaviors in this relationship needs to be further investigated. Therefore, this study aims to analyze the moderating role of screen-based behaviors on the prospective association between device-based moderate to vigorous PA (MVPA) and internalizing and externalizing symptoms in adolescents.

Methods

Design and Sample

The present research used data from the Millennium Cohort Study, which is a prospective cohort including a nationally representative sample of children born between September/2000 and January/2002 in the United Kingdom.[25] Considering potential higher sample losses, children from lower socioeconomic backgrounds and ethnic minority areas were oversampled. Considering that device-based PA was assessed at the 14-year wave for the first time during adolescence among participants of the Millennium Cohort Study, we included data from the 14-year (2015), and 17-year (2018) waves. Our study initially included 18,818 participants in the cohort. However, 11,276 families took part in the 14-year wave. Considering that there were not enough accelerometers for all the cohort members, a random subsample including 81% of the eligible cohort members in England was created, while all the eligible participants living in Wales, Scotland, and Northern Ireland were invited to take part in the accelerometer study. From the 11,276 families included in the 14-year wave, 10,337 cohort members were eligible for using the accelerometers. However, devices were worn by in 1153 participants (the main reason was due to refusal), 2448 devices were not returned, and 503 devices were broken or returned with no data. Considering the 6233 cohort members that have returned the devices, data were not processed in 1122 (most cases because data were not collected for the specified days), 307 participants did not present one valid day with at least 10 valid hours, and 645 presented only one valid day. Therefore, 4159 participants presented valid data on device-based PA. Of those, 3397 also presented valid data on mental health-related outcomes at 17 years of age. Ethical approval for all procedures was obtained from the Northern and Yorkshire Multi-Center Research Ethics Committee of the National Health Service, and informed consent was secured from all participating families.

Internalizing and Externalizing Symptoms at 17 Years

Internalizing and externalizing symptoms were estimated using the Strengths and Difficulties Questionnaire (SDQ),[26] self-reported by the cohort member. The SDQ, includes 2 subscales related to internalizing symptoms (ie, emotional and peer problems) and 2 related to externalizing symptoms (ie, hyperactivity and conduct problems), comprising five 3-point Likert scale items each. Clinical cut-off scores for total score and each subscale have been proposed: total score ≥ 17, emotional ≥ 5, peer problems ≥ 4, hyperactivity ≥ 7, and conduct problems ≥ 4.[27] The 6-item Kessler Psychological Distress Scale was used to estimate psychological distress.[28] The scale asks the frequency of which the respondent experience different feelings (ie, nervousness, hopelessness, lack of energy, depressive mood, restlessness, and worthlessness), in a 5-item Likert scale. Total scores ranged from 0 to 24, with higher scores indicating worse symptoms.

MVPA and Screen-Based Behaviors at 14 Years

MVPA was estimated using the triaxial GENEActiv accelerometer (ActivInsights Ltd). The device was used on the nondominant wrist for 2 days, including a weekday, and one weekend day. Previous validation study found that the GENEActiv monitor was able to predict more than 70% of the measured oxygen consumption in different activities and there was agreement with an ActiGraph device.[29] Data were downloaded using the GENEActiv software and raw data was treated using the DDIR package in R. An epoch of 5 seconds was adopted and the analysis included all days with at least 10 hours of valid data, and we included participants with 2 valid days. PA was estimated using the Euclidean Norm Minus One. The cutoff point of Euclidean Norm Minus One ≥100 mg was adopted in each epoch for MVPA.[30]

We assessed time watching videos and playing videogames as screen-based behaviors. Watching videos was estimated through the question: "On a normal week day during term time, how many hours do you spend watching television programs or films? Please remember to include time spent watching programs or films on a computer, or mobile device, as well as on a TV, DVD, etc. Please also include time spent before school as well as time after school" Videogame use was assessed through the following question: "On a normal week day during term time, how many hours do you spend playing electronic games on a computer or games systems, such as Wii, Nintendo D-S, X-Box or PlayStation? Please remember to include time before school as well as time after school." Possible answers for each question were: "None," "Less than half an hour," "Half an hour to less than 1 hour," "1 hour to less than 2 hours," "2 hours to less than 3 hours," "3 hours to less than 5 hours," "5 hours to less than 7 hours," or "7 hours or more." Although these specific questions were not previously validated, they are widely used and previous studies using similar questionnaires found good reproducibility.[31] We categorized watching videos and playing videogames using the cut-off point of 2 hours based on the Canadian 24-Hour Movement Guidelines,[32] by considering the computing of each category.

Potential Confounders

We selected potential confounders based on existing evidence.[33,34] Maternal education, ethnicity, maternal psychological distress, age, season of accelerometer use (for MVPA analysis), accelerometer wear time (for MVPA analysis), and strength and difficulties questionnaire (total difficulties) at 14 years were adopted as potential confounders. Age was used as a continuous variable. Ethnicity was self-reported by the main caregiver, and classified as White, Mixed (ie, multiple ethnic backgrounds), Indian, Pakistani or Bangladeshi, Black or Black British, or other. Parent's education was assessed considering the highest academic achievement. Parent's psychological distress was assessed using the Kessler psychological distress scale.[28] Total accelerometer wear time was derived from the mean time of the valid accelerometer days. The season of accelerometer use was computed based on the first valid day of accelerometer use. Total difficulties derived from the SDQ questionnaire were estimated using the main caregiver report of the SDQ at 14 years.

Statistical Analysis

We used values of mean or relative frequency, along with their respective 95% CIs, to describe the characteristics of the sample. Considering the nature of the outcomes, which presented overdispersion (ie, variance-to-mean ratio > 1), we used negative binomial regression for the main associations. Initially, we tested the individual associations of device-based MVPA, watching videos, and playing videogames at 14 years old with internalizing and externalizing symptoms at 17 years old, stratified by gender. To test the potential moderation of screen-based behaviors in the association of MVPA with internalizing and externalizing symptoms, we included interaction terms of continuous MVPA, and categorical time spent watching videos and playing videogames in the models. We also conducted analyses of the association between device-based MVPA at 14 years old and internalizing and externalizing symptoms at 17 years old, stratified by screen-based behaviors. The analyses were adjusted for maternal education, ethnicity, maternal psychological distress, age, season of accelerometer use (for MVPA analysis), accelerometer wear time (for MVPA analysis), and SDQ (total difficulties) score at 14 years old. For ease of interpretation, MVPA was standardized in units of 30 minutes. Incidence rate ratio (IRR) and 95% CI were reported. We considered the cluster sampling design structure in all the analyses by using appropriate sample weights.[35] All analyses were conducted using Stata 18 software.

Results

The current study, included a total of 3397 adolescents (mean age = 13.8; 95% CI, 13.7–13.8), including 1828 girls and 1569 boys, with a majority from a White ethnic background. MVPA time of our sample was 129 minutes per day with a slightly longer mean MVPA time among boys (mean = 136 min/d) than girls (mean = 124 min/d). Our sample on average scored 7 on the SDQ at age 14, but the total difficulties score increased to 11 at age 17. Table 1 presents detailed characteristics of our sample.

Association Between Device-Based MVPA, Screen-Based Activities at Age 14 and Internalizing and Externalizing Problems at Age 17

Among boys, after adjusting for confounders, higher device-based MVPA was associated with a lower incidence of emotional problems (IRR = 0.97; 95% CI, 0.95–0.99), but a higher incidence of hyperactivity (IRR = 1.02; 95% CI, 1.01–1.04). Watching videos more than 2 hours per day was associated with a higher incidence of conduct problems (IRR = 1.20; 95% CI, 1.06–1.35), compared with watching videos for less than 2 hours per day (Table 2).

Among girls, in the adjusted model, higher device-based MVPA was associated with a lower incidence of peer problems (IRR = 0.97; 95% CI, 0.96–0.99), emotional problems (IRR = 0.98; 95% CI, 0.97–0.99), and psychological distress (IRR = 0.98; 95% CI, 0.97–0.99), but a higher incidence of hyperactivity (IRR = 1.01; 95% CI, 1.01–1.02). Playing videogames for more than 2 hours per day, on the other hand, was associated with a higher incidence of all internalizing and externalizing problems (peer problem: IRR = 1.14, 95% CI, 1.03–1.27; emotional problems: IRR = 1.12, 95% CI, 1.05–1.21; hyperactivity: IRR = 1.10, 95% CI, 1.03–1.18; conduct problems: IRR = 1.21, 95% CI, 1.07–1.37; psychological distress: IRR = 1.10, 95% CI, 1.02–1.19), as well as total difficulties (IRR = 1.13; 95% CI, 1.07–1.19), compared with playing videogames for less than 2 hours per day (Table 3).

Moderation of Screen-Based Behaviors in the Association of Device-Based MVPA and Internalizing and Externalizing Problems

Table 4 presents the association between device-based MVPA at age 14, and internalizing and externalizing problems at age 17, moderated by 2 screen-based behaviors at age 14 (ie, watching videos and playing videogames). Among boys, there was an interaction between watching videos and MVPA at 14 years, with MVPA promoting a higher protection against total difficulties at 17 years (IRR = 0.96, 95% CI, 0.94–0.99) in the group with lower screen-based behaviors, without significant associations in the stratified analyses. In the stratified analyses, MVPA at 14 years was associated with lower peer and emotional problems at 17 years in the group with lower time watching videos, but was associated with higher hyperactivity and conduct problems among those with

Table 1 Baseline Characteristics of the Sample

Variable	Category or measure	Whole sample (N = 3397)	Girls (n = 1828)	Boys (n = 1569)
Mother's psychological distress	Score	3.78 (3.58 to 3.96)	3.97 (3.76 to 4.17)	3.55 (3.26 to 3.85)
Mother's education	NVQ Level 1, %	5.0 (4.1 to 6.1)	4.1 (3.1 to 5.4)	6.0 (4.5 to 7.8)
	NVQ Level 2, %	25.7 (23.3 to 28.3)	26.6 (23.4 to 30.0)	24.7 (21.5 to 28.2)
	NVQ Level 3, %	13.2 (11.8 to 14.9)	13.7 (11.9 to 15.9)	12.7 (10.6 to 15.1)
	NVQ Level 4, %	35.8 (33.3 to 38.4)	33.2 (30.2 to 36.3)	38.8 (35.2 to 42.5)
	NVQ Level 5, %	12.9 (10.9 to 15.1)	13.9 (11.7 to 16.4)	11.7 (8.4 to 16.1)
	Overseas qualification only, %	2.2 (1.6 to 2.9)	2.6 (1.8 to 3.7)	1.7 (1.1 to 2.8)
	None of these, %	5.2 (4.3 to 6.4)	5.9 (4.7 to 7.5)	4.4 (3.3 to 5.9)
Ethnicity	White, %	88.2 (85.6 to 90.4)	88.4 (85.6 to 90.8)	87.9 (85.0 to 90.3)
	Mixed, %	3.7 (2.9 to 4.5)	3.3 (2.4 to 4.4)	4.1 (3.1 to 5.4)
	Indian, %	1.7 (1.2 to 2.5)	1.5 (0.9 to 4.4)	2.0 (1.3 to 5.4)
	Pakistani, %	2.3 (1.5 to 3.6)	2.5 (1.6 to 3.9)	2.1 (1.3 to 3.4)
	Bangladeshi, %	0.8 (0.4 to 1.5)	0.8 (0.4 to 1.4)	0.9 (0.4 to 2.1)
	Black Caribbean, %	0.4 (0.2 to 0.7)	0.6 (0.3 to 1.2)	0.2 (0.1 to 0.4)
	Black African, %	1.2 (0.7 to 2.1)	1.1 (0.6 to 2.0)	1.3 (0.6 to 2.7)
	Other, %	1.7 (1.1 to 2.5)	1.8 (1.1 to 2.8)	1.6 (0.9 to 2.7)
MVPA	min/d	129.2 (126.2 to 132.1)	**123.6 (119.3 to 128.0)**	**135.5 (131.9 to 139.0)**
Accelerometer wear time	h/d	22.2 (22.1 to 22.3)	22.4 (22.2 to 22.5)	22.0 (21.9 to 22.2)
Watching videos	<2 h/d, %	34.5 (32.3 to 36.8)	32.5 (29.8 to 35.4)	36.8 (33.2 to 40.5)
	≥2 h/d, %	65.5 (63.2 to 67.7)	67.5 (64.6 to 70.2)	63.2 (59.5 to 66.8)
Playing videogame	<2 h/d, %	62.3 (59.9 to 64.7)	83.0 (80.9 to 84.9)	40.6 (36.4 to 45.0)
	≥2 h/d, %	37.7 (35.3 to 40.1)	17.0 (15.1 to 19.1)	59.4 (55.0 to 63.6)
Season of assessment	Spring, %	34.3 (31.5 to 37.1)	33.4 (30.3 to 36.6)	35.2 (31.2 to 39.5)
	Summer, %	33.5 (30.8 to 36.3)	34.4 (31.2 to 37.8)	32.5 (29.0 to 36.2)
	Autumn, %	17.0 (15.1 to 19.0)	17.1 (14.9 to 19.7)	16.8 (14.5 to 19.4)
	Winter, %	15.3 (13.2 to 17.6)	15.1 (12.5 to 18.0)	15.5 (13.0 to 18.3)
Total difficulties at age 14 (SDQ)	Score	7.12 (6.86 to 7.39)	6.95 (6.64 to 7.25)	7.32 (6.92 to 7.72)
Internalizing and externalizing symptoms at 17 y				
Peer problem	Score	2.10 (2.02 to 2.18)	2.13 (2.03 to 2.24)	2.06 (1.95 to 2.18)
Emotion	Score	3.58 (3.47 to 3.68)	**4.33 (4.18 to 4.48)**	**2.73 (2.60 to 2.87)**
Hyperactivity	Score	3.90 (3.78 to 4.01)	3.77 (3.63 to 3.90)	4.04 (3.87 to 4.22)
Conduct	Score	1.55 (1.48 to 1.63)	1.38 (1.30 to 1.45)	1.75 (1.62 to 1.88)
Total difficulties	Score	11.12 (10.86 to 11.39)	**11.60 (11.27 to 11.94)**	**10.59 (10.20 to 11.00)**
Psychological distress[a]	Score	7.30 (7.06 to 7.52)	**8.23 (7.93 to 8.53)**	**6.23 (5.95 to 6.51)**

Abbreviations: MVPA, moderate to vigorous Physical activity; NVQ, National Vocational Qualifications; SDQ, the Strengths and Difficulties Questionnaire. Note: Values are presented as mean or relative frequency as well as their corresponding 95% CI. *P* values < .05 are marked in bold.
[a]Measured by the 6-item Kessler psychological distress scale.

higher time watching videos. Regarding time playing videogame, there was a significant interaction with MVPA at 14 years in the associations with emotional problem (IRR = 0.93, 95% CI, 0.88–0.98), conduct problems (IRR = 0.93, 95% CI, 0.87–0.99), total difficulties (IRR = 0.96, 95% CI, 0.93–0.99), and psychological distress (IRR = 0.94, 95% CI, 0.91–0.98) at 17 years, with all of them indicating a lower risk for each outcome, related with MVPA among the group with lower time playing videogame. Stratified analyses found that MVPA at 14 years was associated with lower emotional problem and psychological distress in the group with lower time playing videogame, but a higher risk for hyperactivity and conduct problems in those with greater time playing videogame. In the stratified analysis, MVPA at 14 years was associated with lower emotional problems and psychological distress at 17 years in the group with lower time playing videogames, while MVPA was associated with higher hyperactivity and conduct problems in the group with higher time playing videogame.

Among girls, there was an interaction between watching videos and device-based MVPA, with a higher protection against emotional problems (IRR = 0.95, 95% CI, 0.91–0.99) and psychological distress (IRR = 0.95, 95% CI, 0.91–0.99) at 17 years, with a higher protection in the group with < 2 hours per day. In the stratified analysis, higher MVPA was associated with lower peer problems, emotional problems, total difficulties, and psychological distress in the group spent <2 hours per day watching videos, as well as associated with lower peer problems in those who spent more time watching videos. Among those with higher time playing videogames, although there were no significant interactions,

Table 2 Individual Associations of MVPA, Watching Videos, and Playing Videogame at 14 Years With Internalizing and Externalizing Symptoms at 17 Years Among Boys

	Peer problem IRR (95% CI)	Emotional problems IRR (95% CI)	Hyperactivity IRR (95% CI)	Conduct problems IRR (95% CI)	Total difficulties IRR (95% CI)	Psychological distress IRR (95% CI)
Crude						
MVPA, 30 min[a]	0.97 (0.94–1.00)	**0.96 (0.94–0.99)**	**1.02 (1.01–1.03)**	1.02 (0.99–1.05)	1.00 (0.98–1.01)	**0.98 (0.96–0.99)**
Watching videos						
≥2 h/d (ref : <2 h/d)	1.10 (0.98–1.24)	0.94 (0.85–1.04)	**1.09 (1.01–1.18)**	**1.23 (1.07–1.40)**	1.07 (1.00–1.15)	1.02 (0.93–1.11)
Playing videogame						
≥2 h/d (ref : <2 h/d)	**1.17 (1.05–1.31)**	**1.12 (1.02–1.23)**	1.03 (0.93–1.13)	1.05 (0.89–1.24)	1.08 (1.00–1.18)	1.06 (0.98–1.15)
Adjusted						
MVPA, 30 min	0.98 (0.95–1.01)	**0.97 (0.95–0.99)**	**1.02 (1.01–1.04)**	1.02 (1.00–1.05)	1.00 (0.98–1.01)	0.98 (0.96–1.00)
Watching videos						
≥2 h/d (ref : <2 h/d)	1.07 (0.96–1.19)	0.94 (0.85–1.03)	1.08 (1.00–1.16)	**1.20 (1.06–1.35)**	1.05 (0.99–1.13)	1.01 (0.93–1.10)
Playing videogame						
≥2 h/d (ref : <2 h/d)	1.11 (1.00–1.21)	1.09 (0.99–1.19)	1.00 (0.91–1.09)	1.01 (0.87–1.16)	1.04 (0.97–1.13)	1.03 (0.95–1.11)

Abbreviations: IRR, incidence rate ratios; MVPA, moderate to vigorous physical activity. Note. Adjusted for maternal education, ethnicity, maternal psychological distress, age, season of accelerometer use (for MVPA analysis), accelerometer wear time (for MVPA analysis), and strength and difficulties questionnaire (total difficulties) at 14 years. *P* values < .05 are marked in bold.
[a]Standardized in units of 30 minutes.

Table 3 Individual Associations of MVPA, Watching Videos, and Playing Videogame at 14 Years With Internalizing and Externalizing Symptoms at 17 Years Among Girls

	Peer problem IRR (95% CI)	Emotional problem IRR (95% CI)	Hyperactivity IRR (95% CI)	Conduct problems IRR (95% CI)	Total difficulties IRR (95% CI)	Psychological distress IRR (95% CI)
Crude						
MVPA, 30 min[a]	**0.97 (0.95–0.99)**	**0.98 (0.97–0.99)**	**1.02 (1.01–1.02)**	0.99 (0.97–1.01)	0.99 (0.98–1.00)	**0.98 (0.97–0.99)**
Watching videos						
≥2 h/d (ref : <2 h/d)	1.10 (0.99–1.22)	1.08 (0.99–1.17)	1.06 (0.98–1.16)	1.10 (0.99–1.22)	1.08 (1.00–1.16)	1.09 (1.00–1.18)
Playing videogame						
≥2 h/d (ref : <2 h/d)	**1.25 (1.11–1.39)**	**1.18 (1.10–1.27)**	**1.16 (1.08–1.25)**	**1.32 (1.17–1.48)**	**1.20 (1.14–1.27)**	**1.18 (1.09–1.27)**
Adjusted						
MVPA, 30 min	**0.97 (0.96–0.99)**	**0.98 (0.97–0.99)**	**1.01 (1.01–1.02)**	0.99 (0.98–1.01)	0.99 (0.99–1.00)	**0.98 (0.97–0.99)**
Watching videos						
≥2 h/d (ref : <2 h/d)	1.05 (0.95–1.16)	1.05 (0.97–1.14)	1.04 (0.95–1.13)	1.05 (0.94–1.17)	1.05 (0.98–1.12)	1.05 (0.98–1.14)
Playing videogame						
≥2 h/d (ref : <2 h/d)	**1.14 (1.03–1.27)**	**1.12 (1.05–1.21)**	**1.10 (1.03–1.18)**	**1.21 (1.07–1.37)**	**1.13 (1.07–1.19)**	**1.10 (1.02–1.19)**

Abbreviations: IRR, incidence rate ratios; MVPA, moderate to vigorous physical activity. Note: Adjusted for maternal education, ethnicity, maternal psychological distress, age, season of accelerometer use (for MVPA analysis), accelerometer wear time (for MVPA analysis), and strength and difficulties questionnaire (total difficulties) at 14 years. *P* values < .05 are marked in bold.
[a]Standardized in units of 30 minutes.

stratified analyses indicate a significant association between higher MVPA and lower peer problems, emotional problems, and psychological distress among those spent less time playing videogames, and lower peer problems in those with greater time playing videogames.

Discussion

Adolescence is a critical phase marked by an increased susceptibility to both internalizing and externalizing problems,[36] with increased level of screen-based sedentary behaviors but dramatically decreased PA level following COVID-19 being particularly evident.[37,38] The current study observed a longitudinal impact of device-based MVPA level at 14 years on internalizing and externalizing problems, such as emotional problems, and hyperactivity among adolescents at 17 years. Spending more time watching videos at 14 years was associated with an increased risk for conducted problems at 17 years among boys, playing videogame for more than 2 hours per day was longitudinally associated with increased risk for all internalizing and externalizing

Table 4 Association Between MVPA at 14 Years and Internalizing/Externalizing Symptoms, Stratified by Watching Videos and Playing Videogame as Well as Their Corresponding Interaction

	Peer problem IRR (95% CI)	Emotional problem IRR (95% CI)	Hyperactivity IRR (95% CI)	Conduct problems IRR (95% CI)	Total difficulties IRR (95% CI)	Psychological distress IRR (95% CI)
Boys						
Watching videos						
<2 h/d	**0.95 (0.90–0.99)**	**0.95 (0.91–0.99)**	1.02 (1.00–1.05)	0.98 (0.93–1.04)	0.98 (0.96–1.01)	0.97 (0.94–1.01)
≥2 h/d	0.99 (0.95–1.02)	0.98 (0.95–1.01)	**1.02 (1.01–1.04)**	**1.04 (1.01–1.06)**	1.01 (0.99–1.02)	0.99 (0.96–1.01)
Multiplicative interaction	0.96 (0.90–1.02)	0.95 (0.90–1.01)	0.99 (0.96–1.02)	0.94 (0.89–1.00)	**0.96 (0.94–0.99)**	0.98 (0.93–1.02)
Playing videogame						
<2 h/d	0.97 (0.94–1.02)	**0.93 (0.90–0.97)**	1.01 (0.98–1.04)	0.97 (0.92–1.03)	0.98 (0.95–1.00)	**0.95 (0.92–0.98)**
≥2 h/d	0.98 (0.94–1.02)	0.99 (0.96–1.03)	**1.03 (1.01–1.05)**	**1.05 (1.02–1.08)**	1.02 (1.00–1.03)	1.00 (0.98–1.03)
Multiplicative interaction	0.98 (0.93–1.04)	**0.93 (0.88–0.98)**	0.98 (0.95–1.01)	**0.93 (0.87–0.99)**	**0.96 (0.93–0.99)**	**0.94 (0.91–0.98)**
Girls						
Watching videos						
<2 h/d	**0.94 (0.89–0.99)**	**0.93 (0.89–0.97)**	0.99 (0.94–1.03)	1.00 (0.94–1.06)	**0.96 (0.92–0.99)**	**0.94 (0.90–0.98)**
≥2 h/d	**0.98 (0.96–0.99)**	0.99 (0.98–1.00)	1.02 (1.01–1.03)	0.99 (0.98–1.01)	1.00 (0.99–1.01)	0.99 (0.96–1.00)
Multiplicative interaction	0.96 (0.91–1.02)	**0.95 (0.91–0.99)**	0.98 (0.94–1.02)	1.01 (0.95–1.07)	0.96 (0.93–1.00)	**0.95 (0.91–0.99)**
Playing videogame						
<2 h/d	**0.97 (0.96–0.99)**	**0.98 (0.97–0.99)**	1.02 (1.01–1.03)	0.99 (0.98–1.01)	0.99 (0.99–1.00)	**0.98 (0.97–0.99)**
≥2 h/d	0.97 (0.92–1.02)	0.98 (0.95–1.01)	1.00 (0.96–1.05)	1.01 (0.94–1.08)	0.99 (0.97–1.01)	**0.95 (0.92–0.99)**
Multiplicative interaction	1.00 (0.95–1.05)	1.00 (0.97–1.04)	1.01 (0.97–1.06)	0.97 (0.91–1.04)	1.00 (0.98–1.03)	1.03 (0.99–1.07)

Abbreviations: IRR, incidence rate ratios; MVPA, moderate to vigorous physical activity. Note: Adjusted for maternal education, ethnicity, maternal psychological distress, age, season of accelerometer use (for MVPA analysis), accelerometer wear time (for MVPA analysis), and strength and difficulties questionnaire (total difficulties) at 14 years. *P* values <.05 are marked in bold.

problems among girls at 17 years. Additionally, there was an interaction between watching videos and device-based MVPA at 14 years, amplifying the association of MVPA with total difficulties and emotional problems at 17 years for boys and girls spending less time on watching videos, respectively.

Our findings on the impact of device-based MVPA and screen-based behaviors on internalizing and externalizing problems are consistent with existing literature. Another longitudinal research[4,39,40] reported higher incidences of internalizing and externalizing problems among adolescents who had lower PA but spent more time on computers and videogames during their childhood. The positive impact of PA on mental health among adolescents is widely acknowledged[41,42]; therefore, it is not surprising that engaging in higher device-based MVPA was beneficial for reducing emotional problems for both sexes in this study. It is important to note that, in our study, adolescents on average scored below the clinical cut-offs for all internalizing and externalizing subscales, as well as total difficulties. Therefore, our findings may be more reflective of subclinical variations in psychological difficulties rather than clinically diagnosed conditions. Previous studies linked low level of PA but high screen-based sedentary behaviors to increased psychosocial difficulties,[43] and the impact of high device-based MVPA on peer problems was particularly evident among girls in this study. PA not only provides social opportunities for establishing peer relationships and collaboration,[44] previous evidence also suggests a positive effect of PA on prosocial behaviors[45] and social competences.[46] Although adolescent girls engage in lower PA than boys in general,[47] which we also confirmed in this study, they benefit more from social aspects of PA.[48] This may therefore explain our finding that engaging in regular device-based MVPA had a more pronounced impact on peer problems for girls than boys.

In this study, spending more time playing videogames was associated with all internalizing and externalizing problems for girls. Evidence suggests a higher vulnerability for internalizing problems in adolescent girls engaging in screen-based sedentary behaviors than boys,[24] and girls tend to spend more time on social media, general computer use, and watching TV rather than videogaming.[49] It has been suggested previously that online environment could be more hostile for girls than boys,[50] negative contents from videogames, for example, violence and sexual themes therefore may had a greater impact on girls who engaged in more frequent gaming than boys.

Different types of TV programs, or films, and videogames may affect the risk of internalizing and externalizing problems in adolescents. Certain forms could be more detrimental and exhibit different relationships with internalizing and externalizing symptoms, respectively. For example, violent TV programs and videogames may include stress- and anxiety-provoking content[51] therefore have a more negative impact on one's emotional well-being[52] and contribute to aggression and behaviors such as self-harm.[53] On the other hand, more recreational screen-based behaviors with a socially interactive format, for example multiplayer games, could instead promote mood and encourage social participation and therefore bring social health benefits.[54] Preferred types of screen-based behaviors between boys and girls may also play a part in the varying association between screen-based behaviors and internalizing and externalizing problems. Compared with boys, young girls may prefer unhealthy screen-based behaviors characterized by components of screen entertainment and social interactions, for example, watching TV,

texting, social media use,[55,56] rather than videogame playing. This may further explain why playing videogames was significantly associated with all internalizing and externalizing symptoms among girls who spent a large amount of time on videogames, and this trend was not observed among boys. Future studies may want to further explore potential gender differences in the relationship of various screen-based behaviors forms with distinct contents (eg, violent vs casual) and internalizing and externalizing problems, which may further help identify the unique vulnerabilities of young boys and girls who engage in regular screen-based behaviors.

Previous studies support a relationship between lower PA, greater engagement in screen-based behaviors and higher incidence of internalizing and externalizing problems.[39] The current study extends beyond current understanding and discovers a protective effect of device-based MVPA on a range of internalizing and externalizing symptoms at 17-year-old boys and girls, especially among those engaged in less video watching and videogame playing at 14 years, suggesting that the association of regular device-based MVPA engagement with mental health may be amplified by screen-based behaviors. Previous meta-analysis[24] illustrates that PA may impact the magnitude of the associations between screen-based behaviors and internalizing symptoms, particularly depression, although the evidence was inconsistent. Our study may otherwise suggest a moderating role played by the amount of time adolescents engage in screen-based behaviors. Replacing screen-based behaviors with adequate MVPA, for example aerobic training like running and muscle strengthening training, could have a positive impact on children and adolescents' mental health,[41] but our results suggest that simply encouraging adolescents who engage a significant number of screen-based behaviors to participate MVPA may not be sufficient. Children and adolescents tend to prefer screen-based behaviors, for example TV viewing, even when a wide range of PA are available.[57] A more targeted approach to screen-based behaviors, such as interventions involving family, and behavioral intervention could therefore be first implemented before encouraging MVPA participation.[58,59]

Our findings suggest a potential path of additive interaction, where the benefits of increased PA combine with those of reduced screen-based behaviors time to prevent/reduce internalizing and externalizing symptoms. Both factors may share mechanisms, as higher PA and reduced sedentary behavior are associated with lower inflammation levels.[60] Both excessive screen exposure and low PA are also linked to poorer sleep quality.[61,62] Additionally, lower PA and higher sedentary behavior might reduce opportunities for social interactions, increasing feelings of isolation.[63,64]

The current study demonstrated benefits from including a large nationally representative sample in the United Kingdom and controlling for a wide range of confounding factors. Its longitudinal nature allowed us to investigate the direction of the relationship from screen-based behaviors and device-based MVPA to internalizing and externalizing symptoms. Previous studies indicate a bidirectional relationship between screen-based behaviors, depression, and anxiety over time among adolescents[65]; therefore, we also speculate a reciprocal relationship between these factors. High internalizing and externalizing symptoms may facilitate a higher level of screen-based behaviors and concurrently lower PA level, which may lead to further exacerbation of both symptoms among adolescents. The findings should be interpreted with the consideration of its limitations. First, the majority of our sample were White therefore limiting the generalizability of our findings to children and adolescents with an ethnic minority background. Second, psychological distress was not assessed at the 14-year wave. Although we adjusted our analysis for the SDQ, which may indicate emotional and behavioral disturbances, residual confounding may still exist in the analysis. Third, screen-based behaviors were measured using self-reported questionnaires, hence could introduce recall and reporting bias. Given the current study only investigated 2 types of screen-based behaviors, the impacts of other types (eg, social media use and website browsing) and overall screen-based behaviors on MVPA, internalizing and externalizing symptoms warrant further investigation. In particular future research should consider not only the duration of other screen-based behaviors, but also the ways in which they are used, including the type of content engaged with. Despite that this study utilized a device-based indicator for PA, the accelerometer wear-time was only 2 days and a minimal 4 days of valid data were recommended by a previous systematic review to ensure data reliability.[66] Additionally, specific types of MVPA were not explored in detail. The interplay between MVPA types, gender, and internalizing and externalizing symptoms could be complex, with differential relationship between MVPA types and internalizing and externalizing problems being moderated by gender. For example, previous literature suggests a lower risk of internalizing problems among boys who engaged in PA that was facilitated by a coach, on the other hand, this was only observed among girls who participated PA without a coach.[39] This further suggests a need to tailor available MVPA programs to meet specific needs of adolescents.

This study provides evidence supporting a protective effect of device-based MVPA participation on preventing internalizing and externalizing problems for adolescents who spend less time on screen-based behaviors. This finding highlights the importance of implementing interventions targeting screen-based behaviors reduction as first-line priority in order to maximize the effectiveness of MVPA in modifying mental health and behavioral problems at a later stage.

Acknowledgments

Acquired data and conducted data analysis: Werneck. *Drafted the manuscript with support from Stubbs*: Ma and Romano. All authors provided critical revisions and approved the final version. The authors extend their appreciation to the Researchers Supporting Project number (RSPD2024R716), King Saud University, Riyadh, Saudi Arabia, for supporting this project. **Funding:** The authors would like to extend their appreciation to the Deanship of Scientific Research at King Saud University for funding this work through the ISPP Program (ISPP25-23). Stubbs is funded by a National Institute for Health and Care Research Advanced Fellowship. Werneck is supported by the São Paulo Research Foundation with a PhD scholarship (FAPESP process: 2019/24124-7). The views expressed in this publication are those of the authors and not necessarily those of the acknowledged institutions. **Conflicts of Interest:** Stubbs is on the Editorial Board of the Journal of Physical Activity and Health, Aging Research Reviews, Mental Health and Physical Activity, The Journal of Evidence Based Medicine, and The Brazilian Journal of Psychiatry. Brendon has received honorarium from a co-edited book on exercise and mental illness (Elsevier), and unrelated advisory work from ASICS, in addition to honorarium and stock options at FitXR LTD.

References

1. McGorry PD, Mei C, Dalal N, et al. The Lancet Psychiatry commission on youth mental health. *Lancet Psychiatry*. 2024;11(9):731–774. doi:10.1016/S2215-0366(24)00163-9

2. Solmi M, Estradé A, Thompson T, et al. Physical and mental health impact of COVID-19 on children, adolescents, and their families: the Collaborative Outcomes Study on Health and Functioning during Infection Times—Children and Adolescents (COH-FIT-C&A). *J Affect Disord*. 2024; 299:367–376. doi:10.1016/j.jad.2021.09.090
3. Solmi M, Thompson T, Estradé A, et al. Global and risk-group stratified well-being and mental health during the COVID-19 pandemic in adults: results from the international COH-FIT Study. *Psychiatry Res*. 2024; 342:115972. doi:10.1016/j.psychres.2024.115972
4. Kandola A, Lewis G, Osborn DPJ, Stubbs B, Hayes JF. Depressive symptoms and objectively measured physical activity and sedentary behaviour throughout adolescence: a prospective cohort study. *Lancet Psychiatry*. 2020; 7(3):262–271. doi:10.1016/S2215-0366(20)30034-1
5. Stubbs B, Vancampfort D, Hallgren M, et al. EPA guidance on physical activity as a treatment for severe mental illness: a meta-review of the evidence and position statement from the European Psychiatric Association (EPA), supported by the International Organization of Physical Therapists in Mental Health (IOPTMH). *Eur Psychiatry*. 2018;54:124–144. doi:10.1016/j.eurpsy.2018.07.004
6. Schuch FB, Vancampfort D, Firth J, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry*. 2018;175(7):631–648. doi:10.1176/appi.ajp.2018.17111194
7. Pascoe MC, Bailey AP, Craike M, et al. Exercise interventions for mental disorders in young people: a scoping review. *BMJ Open Sport Exerc Med*. 2020;6:678. doi:10.1136/bmjsem-2019-000678
8. Ashdown-Franks G, Firth J, Carney R, et al. Exercise as medicine for mental and substance use disorders: a meta-review of the benefits for neuropsychiatric and cognitive outcomes. *Sports Med*. 2020; 50(1): 151–170. doi:10.1007/s40279-019-01187-6
9. Gerber M, Brand S, Herrmann C, Colledge F, Holsboer-Trachsler E, Pühse U. Increased objectively assessed vigorous-intensity exercise is associated with reduced stress, increased mental health, and good objective and subjective sleep in young adults. *Physiol Behav*. 2014; 135:17–24. doi:10.1016/j.physbeh.2014.05.047
10. Wang R, Cai Y, Lu W, et al. Exercise effect on the gut microbiota in young adolescents with subthreshold depression: a randomized psychoeducation-controlled trial. *Psychiatry Res*. 2023;319:115005. doi:10.1016/j.psychres.2022.115005
11. Lin K, Stubbs B, Zou W, et al. Aerobic exercise impacts the anterior cingulate cortex in adolescents with subthreshold mood syndromes: a randomized controlled trial study. *Transl Psychiatry*. 2020;10(1):155. doi:10.1038/s41398-020-0840-8
12. Koski P, Hirvensalo M, Villberg J, Kokko S. Young people in the social world of physical activities: meanings and barriers. *Int J Environ Res Public Health*. 2022;19(9):5466. doi:10.3390/ijerph19095466
13. Mulvihill C, Rivers K, Aggleton P. Views of young people towards physical activity: determinants and barriers to involvement. *Health Educ*. 2000;100(5):190–199. doi:10.1108/09654280010343555
14. Harvey DL, Milton K, Jones AP, Atkin AJ. International trends in screen-based behaviours from 2012 to 2019. *Prev Med*. 2022;154: 106909. doi:10.1016/j.ypmed.2021.106909
15. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behaviour Research Network (SBRN)—terminology consensus project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75. doi:10.1186/s12966-017-0525-8
16. Bryant J, Fondren W. Displacement effects. In: Nabi RL, Oliver MB, eds. *The Sage Handbook of Media Processes and Effects*. Sage; 2009:505–516.
17. Chortatos A, Henjum S, Torheim LE, Terragni L, Gebremariam MK. Comparing three screen-based sedentary behaviours' effect upon adolescents' participation in physical activity: The ESSENS study. *PLoS One*. 2020;15(11):1887. doi:10.1371/journal.pone.0241887
18. Garcia-Hermoso A, López-Gil J, Ramírez-Vélez R, Alonso-Martínez AM, Izquierdo M, Ezzatvar Y. Adherence to aerobic and muscle-strengthening activities guidelines: a systematic review and meta-analysis of 3.3 million participants across 32 countries. *Br J Sports Med*. 2023;57(4):225–229. doi:10.1136/bjsports-2022-106189
19. Hou M, Herold F, Cheval B, et al. Recent trends and disparities in 24-hour movement behaviours among US youth with mental, behavioural, and neurodevelopmental conditions. *J Affect Disord*. 2024; 367:58–66. doi:10.1016/j.jad.2024.08.209
20. Twenge JM, Campbell WK. Associations between screen time and lower psychological well-being among children and adolescents: evidence from a population-based study. *Prev Med Rep*. 2018;12: 271–283. doi:10.1016/j.pmedr.2018.10.003
21. Chen Z, Liao X, Yang J, et al. Association of screen-based activities and risk of self-harm and suicidal behaviors among young people: a systematic review and meta-analysis of longitudinal studies. *Psychiatry Res*. 2024;338:115991. doi:10.1016/j.psychres.2024.115991
22. Tang S, Werner-Seidler A, Torok M, Mackinnon AJ, Christensen H. The relationship between screen time and mental health in young people: a systematic review of longitudinal studies. *Clin Psychol Rev*. 2021;86:102021. doi:10.1016/j.cpr.2021.102021
23. Zou L, Herold F, Cheval B, et al. Sedentary behaviour and lifespan brain health. *Trends Cogn Sci*. 2024;28(4):369–382. doi:10.1016/j.tics.2024.02.003
24. Zink J, Belcher BR, Imm K, Leventhal AM. The relationship between screen-based sedentary behaviour and symptoms of depression and anxiety in youth: a systematic review of moderating variables. *BMC Public Health*. 2020; 20(1):472. doi:10.1186/s12889-020-08572-1
25. Connelly R, Platt L. Cohort profile: UK Millennium Cohort Study (MCS). *Int J Epidemiol*. 2014;43(6):1719–1725. doi:10.1093/ije/dyu001
26. Goodman R. The strengths and difficulties questionnaire: a research note. *J Child Psychol Psychiatry*. 1997;38(5):581–586. doi:10.1111/j.1469-7610.1997.tb01545.x
27. Bryant A, Guy J,The CALM Team, & Holmes J. The strengths and difficulties questionnaire predicts concurrent mental health difficulties in a transdiagnostic sample of struggling learners. *Front Psychol*. 2020;11:587821. doi:10.3389/fpsyg.2020.587821
28. Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med*. 2002;32(6):959–976. doi:10.1017/S0033291702006074
29. Hildebrand M, Van Hees VT, Hansen BH, Ekelund U. Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. *Med Sci Sports Exerc*. 2014;46(9):1816–1824. doi:10.1249/MSS.0000000000000289
30. Da Silva IC, Van Hees VT, Ramires VV, et al. Physical activity levels in three Brazilian birth cohorts as assessed with raw triaxial wrist accelerometery. *Int J Epidemiol*. 2014;43(6):1959–1968. doi:10.1093/ije/dyu203
31. Hidding LM, Altenburg TM, Mokkink LB, Terwee CB, Chinapaw MJM. Systematic review of childhood sedentary behavior questionnaires: what do we know and what is next? *Sports Med*. 2017;47(4): 677–699. doi:10.1007/s40279-016-0610-1
32. Tremblay MS, Carson V, Chaput JP., et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical

activity, sedentary behaviour and sleep. *Appl Phyisol Nutr Metab*. 2016;41(6 [Suppl. 3]):S311–S327. doi:10.1139/apnm-2016-0151
33. Ahn JV, Sera F, Cummins S, & Flouri E. Associations between objectively measured physical activity and later mental health outcomes in children: findings from the UK millennium cohort study. *J Epidemiol Community Health*. 2018; 72(2):94–100. doi:10.1136/jech-2017-209455
34. Kandola A, Owen N, Dunstan DW, Hallgren M. Prospective relationships of adolescents' screen-based sedentary behaviour with depressive symptoms: the millennium cohort study. *Psychol Med*. 2021; 52(15):3531–3539. doi:10.1017/S0033291721000258
35. Ketende SC, Jones EM. User guide to analysing MCS data using STATA. 2011. https://cls.ucl.ac.uk/wp-content/uploads/2017/07/User-Guide-to-Analysing-MCS-Data-using-Stata.pdf
36. Fusar-Poli P, Solmi M, Brondino N, et al. Transdiagnostic psychiatric: a systematic review. *World Psychiatry*. 2019;18(2): 192–207.
37. Chen Q, Dai W, Li G, Li G, Ma N. The impact of screen time changes on anxiety during the COVID-19 pandemic: sleep and physical activity as mediators. *Sleep Biol Rhythms*. 2022;20(4):521–531. doi:10.1007/s41105-022-00398-1
38. Stockwell S, Trott M, Tully M, et al. Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. *BMJ Open Sport Exerc Med*. 2021;7: 960. doi:10.1136/bmjsem-2020-000960
39. Wu X, Bastian K, Ohinmaa A, Veugelers P. Influence of physical activity, sedentary behaviour and diet quality in childhood on the incidence of internalising and externalising disorders during adolescence: a population-based cohort study. *Ann Epidemiol*. 2018;28(2): 86–94. doi:10.1016/j.annepidem.2017.12.002
40. Eirich R, McArthur BA, Anhorn C, McGuinness C, Christakis DA, Madigan S. Association of screen time with internalising and externalising behaviour problems in children 12 years or younger: a systematic review and meta-analysis. *JAMA Psychiatry*. 2022;79(5): 393–405. doi:10.1001/jamapsychiatry.2022.0155
41. Kandola A, Del Pozo Cruz B, Hayes JF, Owen N, Dunstan DW, Hallgren M. Impact on adolescent mental health of replacing screen-use with exercise: a prospective cohort study. *J Affect Disord*. 2022; 301:240–247. doi:10.1016/j.jad.2021.12.064
42. Isaksson J, Selinus EN, Åslund C, Nilsson KW. Physical activity in early adolescence predicts depressive symptoms 2 years later: a community-based study. *J Affect Disord*. 2020;277:825–830. doi:10.1016/j.jad.2020.09.008
43. Khan A, Uddin R, Burton NW. Insufficient physical activity in combination with high screen time is associated with adolescents' psychosocial difficulties. *Int Health*. 2018;10(4):246–251. doi:10.1093/inthealth/ihy019
44. Smith AL. Peer relationships in physical activity contexts: a road less travelled in youth sport and exercise psychology research. *Psychol Sport Exerc*. 2003;4(1):25–39. doi:10.1016/S1469-0292(02)00015-8
45. Di Bartolomeo G, Papa S. The effects of physical activity on social interactions: the case of trust and trustworthiness. *J Sports Econ*. 2019;20(1):50–71. doi:10.1177/1527002517717299
46. Spruit A, Assink M, van Vugt E, van der Put C, Stams GJ. The effects of physical activity interventions on psychosocial outcomes in adolescents: a meta-analytic review. *Clin Psychol Rev*. 2016;45:56–71. doi:10.1016/j.cpr.2016.03.006
47. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1.6 million participants. *Lancet Child Adolesc Health*. 2020;4(1):23–35. doi:10.1016/S2352-4642(19)30323-2
48. Mammen G, Faulkner G. Physical activity and the prevention of depression: a systematic review of prospective studies. *Am J Prev Med*. 2013;45(5):649–657. doi:10.1016/j.amepre.2013.08.001
49. Twenge M, Martin GN. Gender differences in associations between digital media use and psychological wellbeing: evidence from three large datasets. *J Adolesc*. 2020;79(1):91–102. doi:10.1016/j.adolescence.2019.12.018
50. Park S. Concentration of internet usage and its relation to exposure to negative content: does the gender gap differ among adults and adolescents? *Womens Stud Int Forum*. 2009;32(2):98–107. doi:10.1016/j.wsif.2009.03.009
51. Kowalski RM, Limber SP. Psychological, physical and academic correlates of cyberbullying and traditional bullying. *J Adolesc Health*. 2013;53:13–20. doi:10.1016/j.jadohealth.2012.09.018
52. Akel M, Fahs I, Haddad C, Kheir N, Obeid S, Hallit S. Association of violent video gaming with mental health among male teenagers in Lebanon. *Vulner Children Youth Stud*. 2022;18(1):76–86. doi:10.1080/17450128.2022.2160884
53. Cosquer M, Finck C, Jousselme C, Lefebvre A. Violent video gaming among French adolescents: impact on mental health by gender. *L'Encephale*. In press.
54. Costigan SA, Barnett L, Plotnikoff RC, Lubans DR. The health indicators associated with screen-based sedentary behaviour among adolescent girls: a systematic review. *J Adolesc Health*. 2013;52(4): 382–392. doi:10.1016/j.jadohealth.2012.07.018
55. Houghton S, Hunter SC, Rosenberg M, et al. Virtually impossible: limiting Australian children and adolescents' daily screen-based media use. *BMC Public Health*. 2015;15(1):5. doi:10.1186/1471-2458-15-5
56. Taverno Ross SE, Byun W, Dowda M, McIver KL, Saunders RP, Pate RR. Sedentary behaviours in fifth-grade boys and girls: where, with whom and why? *Child Obes*. 2013;9(6):532–539. doi:10.1089/chi.2013.0021
57. Epstein LH, Roemmich JN. Reducing sedentary behaviour: role in modifying physical activity. *Exerc Sport Sci Rev*. 2001;29(3):103–108. doi:10.1097/00003677-200107000-00003
58. Biddle SJH, Petrolini I, Pearson N. Interventions designed to reduce sedentary behaviours in young people: a review of reviews. *Br J Sports Med*. 2014;48(3):182–186. doi:10.1136/bjsports-2013-093078
59. Nguyen P, Le LK, Nguyen D, Gao L, Dunstan DW, Moodie M. The effectiveness of sedentary behaviour interventions on sitting time and screen time in children and adults: an umbrella review of systematic reviews. *Int J Behav Nutr Phys Act*. 2020;17(1):117. doi:10.1186/s12966-020-01009-3
60. Agbaje AO. Longitudinal mediating effect of fat mass and lipids on sedentary time, light PA, and MVPA with inflammation in youth. *J Clin Endocrinol Metab*. 2023;108(12):3250–3259. doi:10.1210/clinem/dgad354
61. Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Med Rev*. 2015; 21:50–58. doi:10.1016/j.smrv.2014.07.007
62. Lang C, Brand S, Feldmeth AK, et al. Increased self-reported and objectively assessed physical activity predict sleep quality among adolescents. *Physiol Behav*. 2013;120:46–53. doi:10.1016/j.physbeh.2013.07.001
63. Arundell L, Salmon J, Veitch J, Timperio A. The relationship between objectively measured and self-reported sedentary behaviours and social connectedness among adolescents. *Int J Environ Res Public Health*. 2019;16(2):277. doi:10.3390/ijerph16020277
64. Werneck AO, Araujo RHO, Oyeyemi AL, Silva DR. Social isolation is associated with higher leisure-time sedentary behavior and lower

physical activity practice: a multi-country analysis of data from 79 countries from the global school-based student health survey. *Prev Med*. 2023;175:107677. doi:10.1016/j.ypmed.2023.107677

65. Gunnell KE, Flament MF, Buchholz A, et al. Examining the bidirectional relationship between physical activity, screen time, and symptoms of anxiety and depression over time during adolescence. *Prev Med*. 2016;88:147–152. doi:10.1016/j.ypmed.2016.04.002
66. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc*. 2005;37(11):S531–S543. doi:10.1249/01.mss.0000185657.86065.98