



## Reciprocal associations between screen time and emotional disorder symptoms during adolescence

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### ABSTRACT

Screen-based sedentary behaviors and emotional disorders are associated with one another in youth. Yet, the direction of the association is unclear, as is whether specific types of screen-based sedentary behaviors and emotional disorder symptoms are more closely linked. This study estimated the bi-directional associations between two types of screen-based sedentary behaviors and four types of self-reported emotional disorder symptoms, and tested whether physical activity buffered these associations in a Los Angeles high school student cohort ( $N = 2525$ , baseline  $Mage = 14.6$  years). Participants completed baseline (9th Grade, 2013) and 12-month follow-up (10th grade, 2014) surveys reporting on: television viewing and computer/videogame use ( $\geq 4$  h/day; yes/no), physical activity ( $\geq 60$  min/day for  $\geq 5$  days/week), and Major Depressive Disorder (MDD), Generalized Anxiety Disorder (GAD), Panic Disorder (PD), and Social Phobia (SP) symptoms (meet/exceed [sub] clinical symptom threshold; yes/no). After adjusting for baseline screen-based sedentary behavior and covariates, students with (sub)clinical baseline MDD and GAD were at increased odds of high computer/videogame use one year later (OR = 1.36[95%CI, 1.07–1.73]; OR = 1.36[95%CI, 1.09–1.71], respectively). Baseline SP was marginally related to increased computer/videogame use at follow-up (OR = 1.33[95%CI, 1.04–1.69]). Greater baseline computer/videogame use was associated with increased odds of (sub)clinical GAD (OR = 1.54[95%CI, 1.23–1.94]) and (sub)clinical SP (OR = 1.64[95%CI 1.27–2.12]) at follow-up; these associations were suppressed among baseline physically active students. Television viewing was unrelated to emotional disorder symptoms and PD was not associated with screen-based sedentary behaviors. Thus, only reciprocal associations between computer/videogame use, SP, and GAD during a one-year period of adolescence were observed. Interventions reducing computer/videogame use and increasing physical activity may improve adolescent emotional health.

### 1. Introduction

Leisure-time screen-based sedentary behaviors (e.g., television, computer, videogames) can increase risk for a host of adverse cardiometabolic, social, and health outcomes throughout youth and adulthood (Pate et al., 2011; Sisson et al., 2009; Utter et al., 2003; Sardinha et al., 2008; Lou, 2014; Biswas et al., 2015; Chassiakos et al., 2016). It is estimated that adolescents spend approximately 4 h daily engaged in leisure-time screen-based sedentary behaviors (Twenge and Campbell, 2018; Olds et al., 2006; Suchert et al., 2015). However, the accumulation of as little as 2 h of screen-time per day can be associated with depressive or anxiety (emotional) disorder symptoms in youth (Kremer

et al., 2014; Hoare et al., 2016; Katon et al., 2010); with the prevalence of emotional disorders being highest among adolescents compared to all other age groups (Kessler et al., 2005a; Kessler et al., 2012; Merikangas et al., 2010; Kessler et al., 2005b), a greater understanding of the association between screen-based sedentary behaviors and depressive and anxiety disorder symptoms is needed.

While positive associations between screen-based sedentary behaviors and emotional disorder symptoms have been previously identified, much of the work to date is cross-sectional (Hoare et al., 2016; Teychenne et al., 2015), and thus it is plausible that the associations are reciprocal (Gunnell et al., 2016; Houghton et al., 2018). For example, youth who engage in certain forms of screen-based sedentary behaviors

*Abbreviations:* BMI, body mass index; CDC, Centers for Disease Control and Prevention; GAD, Generalized Anxiety Disorder; H&H, Happiness and Health; MDD, Major Depressive Disorder; PD, Panic Disorder; SES, socioeconomic status; SP, social phobia; YRBSS, Youth Risk Behavior Surveillance System

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(e.g., passive social media use) may become socially isolated or may engage in upward social comparison, whereby feelings of inferiority and envy reduce emotional well-being (Frison and Eggermont, 2016; Verduyn et al., 2015; Verduyn et al., 2017; Nesi and Prinstein, 2015). On the other hand, adolescents with anxiety or mood problems may have difficulty drawing the necessary motivation, energy, and social skills to seek out opportunities for physical or social activities, instead selecting low-energy screen-based sedentary behaviors such as television viewing as a main source of enjoyment. A better understanding of the potential reciprocal associations between screen-based sedentary behaviors and emotional disorders could inform risk identification models and help to determine if reducing screen time may have collateral mental health benefits, or if improving mental health may prevent excessive engagement in screen-based sedentary behaviors.

It is also unclear whether specific types of screen-based sedentary behaviors (computer/videogame use vs. television viewing) and certain forms of emotional disorder symptoms (depression vs. panic vs. social phobia vs. generalized anxiety) are more closely linked with one another. Given that the use of computers and modern social media in current milieu is tied to interpersonal functioning, and different forms of emotional problems have distinct manifestations (e.g., social phobia is linked with interpersonal deficits) (Ranta et al., 2016), the association between screen time and emotional disorders may not be monotonic across different types of screen-based sedentary behaviors and emotional disorders. If certain screen-based sedentary behaviors and specific forms of emotional problems are more tightly linked, a greater understanding of the mechanisms linking these factors may emerge.

Therefore, the aim of this study was to estimate the reciprocal (bi-directional) associations between self-reported time spent in television viewing or computer/videogame use and significant symptomatology of four emotional disorders (Major Depressive Disorder [MDD], Generalized Anxiety Disorder [GAD], Panic Disorder [PD], and social phobia [SP]) over a 12-month follow-up period among a cohort of high school students in Los Angeles in 9th grade at baseline. Previous cross-sectional studies have demonstrated weaker associations between screen-based sedentary behaviors and emotional disorder symptoms in youth who also engage in higher (vs. lower) levels of physical activity (Cao et al., 2011; Griffiths et al., 2010) and in boys (vs. girls) (Suchert et al., 2015; Brodersen et al., 2005; Desai et al., 2010; Godinho et al., 2014). Thus, a secondary aim was to test whether the associations were moderated by baseline physical activity or sex, in order to increase our understanding of vulnerable populations and to inform preventive intervention strategies.

## 2. Methods

Data were drawn from participants enrolled in the Happiness and Health (H&H) study; an observational longitudinal cohort survey of health behavior and mental health in Southern California high school students (Leventhal et al., 2015). Forty schools in the Los Angeles area with diverse demographic characteristics near the study site were recruited for the H&H study, and of these, 10 schools agreed to participate.

All 9th grade students enrolled in a standard educational program in one of the participating schools in fall of 2013 were eligible for the study. Students and their parents were required to provide written or verbal assent and consent, respectively. Data in this report involved two assessment waves—baseline (fall during 9th grade) and 12-month follow-up (fall during 10th grade). Data were collected via paper-and-pencil surveys on-site in the students' classrooms. If students were not on-site to complete the full survey during the in-person data collection, an abbreviated version of survey (which omitted screen-based sedentary behavior) was administered. All study procedures were approved by the University of Southern California institutional review board.

### 2.1. Measures

Screen-based sedentary behaviors were measured using two items from the Youth Risk Behavior Surveillance System (YRBSS) survey (Eaton et al., 2010). Television viewing was measured with the YRBSS item, "On an average school day, how many hours do you watch TV?" Computer/videogame use was measured with the YRBSS item, "On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Count time spent on things such as Xbox, PlayStation, an iPod, an iPad or other tablet, a smartphone, YouTube, Facebook or other social networking tools, and the Internet)." Response options for both items included: none, < 1 h, 1 h, 2 h, 3 h, 4 h, and 5 or more hours per day. To be consistent with prior research (Carson and Janssen, 2011), and to reflect the recently estimated average amount of self-reported screen-based sedentary behavior in a population-based study of United States youth (Twenge and Campbell, 2018), responses were dichotomized as  $\geq 4$  h of television viewing per day vs. < 4 h per day, and  $> 4$  h of computer/videogame use per day vs.  $\geq 4$  h per day. YRBSS items assessing screen-based sedentary behaviors have previously demonstrated adequate psychometric properties (Brener et al., 2013; Brener et al., 2002).

Emotional disorder symptoms were measured utilizing the Revised Children's Anxiety and Depression Scale (RCADS). The RCADS is a self-report instrument designed to assess symptoms of anxiety and depressive disorders according to the DSM-IV diagnostic criteria and includes subscales for MDD (10 items), GAD (six items), PD (nine items), and SP (eight items) (Chorpita et al., 2000). The RCADS has shown adequate factorial reliability and convergent validity in prior work among youth (Chorpita et al., 2005; Kesters et al., 2015). Following the published standardized metrics, students reporting scores that met the subclinical or clinical ([sub]clinical) age- and sex- normed thresholds for each subscale were classified as meeting diagnostic criteria for that emotional health condition (Chorpita et al., 2005). Cronbach's alpha for each subscale ranged from 0.89 to 0.92 in our sample.

Physical activity was measured using one item from the YRBSS, "During the past 7 days, how many days were you physically active for a total of at least 60 minutes per day? (Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time)" with response options of 0 to 7 days. This item was dichotomized as meeting the Centers for Disease Control and Prevention (CDC) recommendation of 60 min per day, five days per week of aerobic physical activity versus not meeting these recommendations (McGuire S. U.S. Department of Agriculture and U.S. Department of Health and Human Services, Dietary Guidelines for Americans, 2010). YRBSS items assessing physical activity have previously demonstrated adequate psychometric properties (Brener et al., 2013; Brener et al., 2002).

Baseline covariates were selected a priori based on past work showing associations with screen-based sedentary behaviors and emotional disorders (Gunnell et al., 2016; Maras et al., 2015). In addition the physical activity measure described above, we included the demographic characteristics of sex, age, race, ethnicity, and highest parental education, which served as a proxy for socioeconomic status (SES), and body mass index (BMI) percentile based on self-reported height and weight using the age- and sex-normed CDC standardized guideline (Kuczmarski et al., 2000).

### 2.2. Statistical analysis

Descriptive analyses of the sample were performed. Logistic regression models were used to assess if any participant characteristics predicted missing data at follow-up (yes vs. no). The prevalence of each emotional health disorder and each type of screen-based sedentary behavior at baseline and follow-up were calculated, and differences were tested using McNemar's test for paired data. Reciprocal associations between emotional health and screen-based sedentary behavior

**Table 1**  
Prevalence of physical activity, screen-based sedentary behaviors, and emotional disorders at baseline and 12-month follow-up ( $N = 2525$ ).

	Baseline $N(\%)$	Follow-up $N(\%)$	$P$ value for change in prevalence <sup>e</sup>
Physical activity <sup>a</sup>	1638 (64.9%)	1528 (60.5%)	< 0.001
Television viewing <sup>b</sup>	324 (12.8%)	255 (10.1%)	< 0.001
Computer/videogame use <sup>c</sup>	647 (25.6%)	626 (24.8%)	0.39
Major depressive disorder <sup>d</sup>	521 (20.6%)	576 (22.8%)	0.01
Generalized anxiety disorder <sup>d</sup>	583 (23.1%)	533 (21.2%)	0.04
Panic disorder <sup>d</sup>	423 (16.8%)	540 (21.4%)	< 0.001
Social phobia <sup>d</sup>	476 (18.9%)	407 (16.1%)	0.001

<sup>a</sup> Physical activity for 60 min daily, at least 5 days per week vs. not.

<sup>b</sup> Television viewing for 4 or more hours daily vs. not.

<sup>c</sup> Computer/videogame use for 4 or more hours daily vs. not.

<sup>d</sup> Meeting the (sub)clinical threshold of symptoms vs. not.

<sup>e</sup> Calculated using McNemar's Test.

were examined in logistic regression models.

To test the associations between baseline screen-based sedentary behavior and emotional health one year later, both screen-based sedentary behavior variables (television and computer/videogames) at baseline were entered as simultaneous predictors of each emotional disorder variable (MDD, GAD, PD, and SP) 12-months later in a separate model for each outcome. This was done to assess the unique contributions of each type of baseline screen-based sedentary behavior to emotional disorder symptoms at follow-up. Next, the screen-based sedentary behavior by physical activity interaction term and the screen-based sedentary behavior by sex interaction term were then added in separate models to test these variables as moderators of the association of interest, as previous studies suggest (Cao et al., 2011; Griffiths et al., 2010; Ohannessian, 2009).

To test the opposite direction, each baseline emotional disorder variable was entered as predictor of each screen-based sedentary behavior variable 12-months later, with separate models for each combination of emotional disorder-screen-based sedentary behavior pair. The emotional disorder by physical activity interaction term and the emotional disorder by sex interaction term were then added in separate models to assess moderation. If any of the interaction terms were significant, then stratified analyses were conducted.

All models controlled for the respective baseline emotional disorder or screen-based sedentary behavior variable that was being tested as the outcome. Additionally, models were run both unadjusted and adjusted for categorical (sex, race/ethnicity and physical activity) and continuous (age, socioeconomic status, and BMI percentile) covariates. Interclass correlations for school effects on baseline MDD, GAD, PD, SP, television viewing, and computer/videogame use ranged from 0.0005 to 0.015, indicating minimal impact of nesting of data by school and permitting the modeling of school as a fixed effect in all logistic regression models. Participants with missing data for any of the outcome variables were excluded, while respondents with missing data on any of the covariates (other than sex and physical activity) were included and addressed using multiple imputation (note the available  $N$  for each covariate in Supplemental Table 1) (Toutenburg, 1990). For the primary analysis of reciprocal associations between screen-based sedentary behavior and emotional disorder symptoms, raw (two-tailed)  $p$ -values are presented. Additionally, a Benjamini-Hochberg correction was applied, yielding a corrected significance level of  $P < 0.016$ . A significance level of  $P < 0.05$  was used for secondary aim tests of moderators. All statistics were completed using SASv9.4.

### 3. Results

#### 3.1. Study sample and characteristics

Of the 4100 9th grade students in the student body of the participating schools, 3874 (94.5%) assented, of whom 3396 (87.7%) parents

provided consent. Baseline data were collected from 3383 (99.6%) of these students and follow-up data were collected from 3282 (96.6%) participants. Students who were not in class and were administered the abbreviated survey that omitted screen-based sedentary behaviors questions at either wave ( $N = 142$ ), were excluded. Of the remaining 3140 who completed the full survey at both waves, 615 (19.6%) students did not provide complete data for all emotional health, screen-based sedentary behavior, physical activity, or sex variables, leaving an analytic sample of ( $N = 2525$ ) for this report. See the **supplemental text** provided for a comparison of the cohort enrollees to the analytic sample.

Fifty-six percent of the participants in the sample were female, and ranged in age from 13 to 16 years old at baseline. Forty-seven percent of the participants were of Hispanic ethnicity and about 28% of the sample had at least one college graduate parent. The  $M(SD)$  baseline BMI percentile was 58.9 (29.4); the  $M(SD)$  participant-reported screen-based sedentary behavior (the sum of the television viewing and computer/videogame use items) was 3.9 (2.5) hours per day at baseline (data not shown). **Supplemental Table 1** provides additional baseline demographic characteristics.

**Table 1** presents the prevalence of physical activity, screen-based sedentary behaviors, and emotional disorders at baseline and follow-up. Two-thirds (64.9%) of the sample reported meeting activity recommendations at baseline; this prevalence decreased by follow-up (60.5%) ( $p < 0.001$ ). Similarly, the prevalence of high television viewing decreased from baseline (12.8%) to follow-up (10.1%) ( $p < 0.001$ ), while high computer/videogame use was relatively stable. The prevalence of surpassing (sub)clinical symptom levels for each emotional disorder differed significantly over one year; MDD and PD increased, while GAD and SP decreased.

#### 3.2. The relation between baseline screen-based sedentary behaviors and subsequent emotional disorder symptoms at follow-up

##### 3.2.1. Television viewing

Baseline daily television viewing for 4-hours or more (vs. less) was only associated with subsequent (sub)clinical PD (Odds Ratio [OR] 1.38, 95%CI 1.03–1.85,  $p = 0.03$ ) in the adjusted model. This association did not persist after applying corrections for multiple testing (**Table 2**).

##### 3.2.2. Computer/videogame use

The unadjusted positive associations between baseline daily computer/videogame use for 4-hours or more (vs. less) and subsequent (sub)clinical emotional disorder symptoms at follow-up were significant for all disorders, with ORs ranging from 1.32 to 1.85 (**Table 3**). After adjusting for covariates, the association between baseline high computer/videogame use and follow-up (sub)clinical GAD (OR 1.54, 95%CI 1.23–1.94,  $p < 0.001$ ) and (sub)clinical SP (OR 1.64, 95%CI

**Table 2**  
Associations between baseline screen-based sedentary behaviors and emotional disorder symptom status at 12-month follow-up (N = 2525).

	Symptom prevalence of respective emotional disorder at follow-up, by baseline $\geq 4$ h respective screen-based sedentary behavior		Association of $\geq 4$ h of respective baseline screen-based sedentary behavior with symptom-positive status for respective emotional disorder at follow-up		
	< 4 h of screen time N(%)	$\geq 4$ h of screen time N(%)	UOR (95%CI)	AOR (95%CI) <sup>g</sup>	P value
Regressor: baseline television viewing <sup>i</sup>					
Outcome: major depressive disorder symptoms at follow-up <sup>a,e,h</sup>	487 (22.1%)	89 (27.5%)	1.33 (1.02, 1.74)	1.09 (0.80, 1.48)	0.60
Outcome: generalized anxiety disorder symptoms at follow-up <sup>b,e,h</sup>	455 (20.7%)	79 (24.5%)	1.24 (0.94, 1.63)	1.03 (0.76, 1.39)	0.85
Outcome: panic disorder symptoms at follow-up <sup>c,e,h</sup>	452 (20.5%)	89 (27.5%)	1.47 (1.13, 1.91)	1.38 (1.03, 1.85)	0.03
Outcome: social phobia symptoms at follow-up <sup>d,e,h</sup>	359 (16.3%)	47 (14.5%)	0.87 (0.63, 1.21)	0.69 (0.48, 1.00)	0.05
Regressor: baseline computer/video game use <sup>i</sup>					
Outcome: major depressive disorder symptoms at follow-up <sup>a,f,h</sup>	394 (20.9%)	182 (28.1%)	1.47 (1.20, 1.81)	1.23 (0.96, 1.57)	0.10
Outcome: generalized anxiety disorder symptoms at follow-up <sup>b,f,h</sup>	344 (18.3%)	190 (29.4%)	1.85 (1.51, 2.28)	1.54 (1.23, 1.94)	< 0.001*
Outcome: panic disorder symptoms at follow-up <sup>c,f,h</sup>	379 (20.2%)	162 (25.0%)	1.32 (1.07, 1.63)	1.12 (0.89, 1.42)	0.32
Outcome: social phobia symptoms at follow-up <sup>d,f,h</sup>	262 (14.0%)	144 (22.3%)	1.77 (1.41, 2.22)	1.64 (1.27, 2.12)	< 0.001*

UOR = unadjusted odds ratio.

AOR = adjusted odds ratio.

<sup>a</sup> Adjusted for baseline Major Depressive Disorder.

<sup>b</sup> Adjusted for baseline Generalized Anxiety Disorder.

<sup>c</sup> Adjusted for baseline Panic Disorder.

<sup>d</sup> Adjusted for baseline Social Phobia.

<sup>e</sup> Adjusted for baseline computer/video game use.

<sup>f</sup> Adjusted for baseline television viewing.

<sup>g</sup> Additionally adjusted for age, sex, race/ethnicity, SES, school, physical activity, and BMI percentile.

<sup>h</sup> Meeting the (sub)clinical threshold of symptoms vs. not.

<sup>i</sup> Television viewing for 4 or more hours daily vs. not.

<sup>j</sup> Computer/video game use for 4 or more hours daily vs. not.

\* Significant after Benjamini-Hochberg correction to control study-wise false discovery rate to 0.05.

**Table 3**  
Associations between emotional disorder symptoms at baseline and television viewing or computer/videogame use at 12-month follow-up (N = 2525).

	Prevalence of ≥ 4 h respective screen-based sedentary behavior at follow-up, by baseline emotional symptom status for respective disorder		Association of respective baseline emotional disorder symptoms with ≥ 4 h of respective screen-based sedentary behavior at follow-up	
	Negative Status N(%)	Positive Status N(%)	UOR (95%CI)	P value
<b>Outcome: television viewing at follow-up<sup>d</sup></b>				
Regressor: baseline major depressive disorder symptoms <sup>a, c</sup>	192 (9.6%)	63 (12.1%)	1.30 (0.96, 1.76)	0.09
Regressor: baseline generalized anxiety disorder symptoms <sup>a, c</sup>	191 (9.8%)	64 (11.0%)	1.13 (0.84, 1.53)	0.42
Regressor: baseline panic disorder symptoms <sup>a, c</sup>	216 (10.3%)	39 (9.2%)	0.89 (0.62, 1.27)	0.51
Regressor: baseline social phobia symptoms <sup>a, c</sup>	214 (10.4%)	41 (8.6%)	0.81 (0.57, 1.15)	0.23
<b>Outcome: computer/videogame use at follow-up<sup>d</sup></b>				
Regressor: baseline major depressive disorder symptoms <sup>a, c</sup>	459 (22.9%)	167 (32.1%)	1.59 (1.27, 1.96)	< 0.001*
Regressor: baseline generalized anxiety disorder symptoms <sup>a, c</sup>	438 (22.6%)	188 (32.3%)	1.64 (1.33, 2.00)	< 0.001*
Regressor: baseline panic disorder symptoms <sup>a, c</sup>	509 (24.2%)	117 (27.7%)	1.20 (0.95, 1.51)	0.13
Regressor: baseline social phobia symptoms <sup>a, c</sup>	474 (23.1%)	152 (31.9%)	1.60 (1.25, 1.94)	< 0.001*

UOR = unadjusted odds ratio.

AOR = adjusted odds ratio.

<sup>a</sup> Adjusted for baseline television viewing and computer/videogame use.

<sup>b</sup> Additionally adjusted for age, sex, race/ethnicity, SES, school, physical activity, and BMI percentile.

<sup>c</sup> Meeting the (sub)clinical threshold of symptoms vs. not.

<sup>d</sup> Television viewing for 4 or more hours daily vs. not.

<sup>e</sup> Computer/videogame use for 4 or more hours daily vs. not.

\* Significant after Benjamini-Hochberg correction to control study-wise false discovery rate to 0.05.



1.27–2.12,  $p < 0.001$ ) persisted, but the associations with subsequent (sub)clinical MDD (OR 1.23, 95% CI 0.96–1.57,  $p = 0.10$ ) and PD (OR 1.12, 95% CI 0.89–1.42,  $p = 0.32$ ) were no longer significant (Table 2).

### 3.3. The relation between baseline emotional health and screen-based sedentary behaviors at follow-up

#### 3.3.1. Television viewing

After adjustment for covariates, (sub)clinical SP was protective against high television viewing at follow-up (OR 0.67, 95%CI 0.46–0.99,  $p = 0.04$ ). This association did not persist after correction for multiple testing. No other significant associations between baseline (sub)clinical emotional disorder symptoms and high television viewing at follow-up were observed (Table 3).

#### 3.3.2. Computer/videogame use

The unadjusted associations between all baseline emotional disorders, except for PD, and high computer/videogame use one year later were significant. After adjusting for covariates, the associations between baseline (sub)clinical MDD (OR 1.36, 95% CI 1.07–1.73,  $p = 0.01$ ) and baseline (sub)clinical GAD (OR 1.36, 95% CI 1.09–1.71,  $p = 0.01$ ) and high computer/videogame use persisted. The association between (sub)clinical SP (OR 1.33, 95% CI 1.04–1.69) symptom status and high daily computer/videogame use at follow-up was not significant beyond the corrected threshold of 0.016, (test  $p$ -value = 0.022). The adjusted association of baseline (sub)clinical PD with computer/videogame use at follow-up was not significant (OR 1.01, 95% CI 0.78–1.32,  $p = 0.91$ ) (Table 3).

### 3.4. Moderation by physical activity or sex

Physical activity moderated the relationship between high baseline computer/videogame use and subsequent (sub)clinical GAD (interaction  $p = 0.046$ ). In those not meeting physical activity recommendations at baseline ( $n = 887$ ), high computer/videogame use was associated with a greater likelihood of subsequent (sub)clinical GAD (OR 1.98, 95% CI 1.39–2.82,  $p < 0.001$ ). High computer/videogame use was unrelated to subsequent (sub)clinical GAD in those who reported meeting physical activity guidelines at baseline ( $n = 1638$ ) (OR 1.28, 95% CI 0.95–1.73,  $p = 0.11$ ). Physical activity similarly moderated the relationship between high computer/videogame use and (sub)clinical SP (interaction  $p = 0.01$ ). High computer/videogame use was associated with an increased likelihood of subsequent (sub)clinical SP in those not meeting physical activity guidelines ( $n = 887$ ) (OR 2.40, 95% CI 1.61–3.57,  $p < 0.001$ ), while high computer/videogame use was unrelated to subsequent (sub)clinical SP in those meeting physical activity guidelines ( $n = 1638$ ) (OR 1.21, 95% CI 0.86–1.71,  $p = 0.27$ ). No other interaction tests of moderation were significant.

### 3.5. Sensitivity analyses

Sensitivity analyses using alternative cutoffs for screen time ( $\geq 2$  h per day vs. not and  $\geq 3$  h per day vs. not) yielded comparable results (Supplemental tables 2–5). Additionally, we conducted sensitivity analyses using continuous RCADS subscale scores as well as dichotomized RCADS subscale scores based on the clinical cutoffs (vs. not), which yielded comparable results (Supplemental tables 6–9). Therefore, our findings may be applicable across additional screen time and emotional disorder symptom thresholds to those presented above.

## 4. Discussion

The present study found that the associations between different types of screen-based sedentary behaviors (computer/videogame use and television viewing) and emotional disorder symptoms (MDD, GAD, SP, and PD) were non-monotonic and in some cases reciprocal. Previous

longitudinal studies have found bi-directional associations between screen-based sedentary behaviors, anxiety, and depression in adolescents (Gunnell et al., 2016; Houghton et al., 2018; Raudsepp, 2016). However, most of these studies failed to distinguish between subtypes of screen-based sedentary behavior and did not assess specific types of anxiety disorder symptoms that are common among youth, such as SP, PD, and GAD. This study addresses these gaps, and indicates that symptoms of GAD, specifically, were reciprocally associated with computer/videogame playing. Findings are additionally suggestive that SP is bi-directionally related to computer/videogame use. This study extends previous evidence of longitudinal associations between depression and screen-based sedentary behavior (Sund et al., 2011; Primack et al., 2009; Selfhout et al., 2009) and provides novel findings that associations were more consistent for anxiety disorder symptoms and computer/videogame use, regardless of concurrently-reported television viewing.

The type of screen-based sedentary behavior may matter for comorbid emotional health problems by way of one's environmental surroundings. Given that television viewing was not consistently associated with emotional disorder symptoms in the current study, we draw from the social withdrawal theory, which postulates that screen-based sedentary behavior may relate to poorer emotional health by promoting social isolation (Rubin and Burgess, 2001). However recent evidence indicates that television viewing often occurs in the presence of peers and family members (Busschaert et al., 2016; Salvy et al., 2017). Thus, it is plausible that television viewing may only lead to emotional health consequences when one typically engages in this behavior alone.

Extreme levels of computer/videogame use may indicate pathological, addictive behavior. Excessive computer/videogame users may experience feelings of tension, dysphoria, or anxiety when not engaged in computer use, akin to a withdrawal state (Weinstein and Lejocuey, 2010). Additionally, SP can be both a risk factor for and consequence of excessive computer use (Selfhout et al., 2009; Caplan, 2006). Those who fear in-person social interactions may gravitate toward computer use as means of communicating with peers; however, online communication may not increase social skills and comfort with in-person communication (Campbell et al., 2006; Hoge et al., 2017), which could increase risk of SP symptoms. An additional aspect that is unique to computer/videogame use and may partially explain this finding is the avenue for cyber-bullies and their victims to intersect, leading to emotional health disturbances for both the bully and the victim (Hoge et al., 2017; Wang et al., 2011). Thus, outcome expectancies and the content of computer/videogames may influence screen-time emotional disorder symptom associations.

Computer and videogames can also be linked to sleep problems in adolescents (Hale and Guan, 2015), which is an established risk factor for poorer emotional health (Medic et al., 2017). One study among a similar sample of adolescents found that sleep problems predicted lower distress tolerance skills and were more likely to be absorbed by, or ruminate on, negative emotions one year later (Kechter and Leventhal, 2018), which is a prominent symptom of GAD. Altogether, our study highlights that computer/videogame use, but not television viewing, relates to symptoms of anxiety disorders in youth.

Findings also indicated that physical activity may mitigate associations between high computer/videogame use and subsequent GAD and SP symptoms. Physical activity has been a longstanding behavior recommended to minimize anxiety because of its anxiolytic properties (Ströhle, 2009). Adolescents often accumulate a majority of their physical activity in the form of organized sports (Payne et al., 2013). Peer socialization and support experienced during participation in organized sports promotes psychosocial well-being and healthy youth development (Kiluk et al., 2009; Solomon, 1980), and could prevent any social anxiety resulting from isolation on computers/videogames. Physical activity also alters activity in neuropharmacological pathways (i.e., serotonin, brain derived neurotrophic factor, and endorphins) implicated in anxiety, which may underlie subjective feelings of post-exercise

relaxation (De Moor et al., 2006; Carek et al., 2011).

This study had some limitations. Consistent with the YRBSS, single-item questions were used to assess the quantity of time spent in television viewing or computer/videogame use, which does not allow us to examine how the content or the context of screen-based sedentary behaviors may impact emotional health. The YRBSS items also did not differentiate weekday from weekend day screen-based sedentary behaviors, which may overlook variations in youth's screen time accumulation across the week (Ortega et al., 2013). Computer and videogame use were combined in our survey, despite literature suggesting these two types of screen-based sedentary behaviors might influence emotional health in different ways (Maras et al., 2015; Casiano et al., 2012). Additionally, we did not assess active versus passive screen-based sedentary behaviors, however evidence in a similar sample of youth indicates that both forms of screen-based sedentary behaviors influence mental health outcomes similarly (Ra et al., 2018). Future research using more descriptive self-reported measures or objective measures (e.g., a combination of inspection of billing records of digital device use and accelerometer-measured activity levels) of sedentary time may be useful for addressing the limitations of the present study. We also did not assess factors such as clinician-based diagnoses of emotional disorders/emotional disorder symptoms, participant use of medication, parental diagnoses of similar emotional disorders, and parental levels of screen time and physical activity; future research should aim to understand the roles of these factors in screen time-emotional disorder symptom associations. Lastly, due to the observational study design, it is unclear whether there are unknown and unmeasured confounding variables that may explain the associations found.

## 5. Conclusions

In this study of Los Angeles high school students, an association between screen-based sedentary behavior and emotional disorder symptoms over a one-year period of follow-up was observed, with some evidence of bi-directionality, specificity between computer/videogame use and certain emotional conditions, and generalizability across boys and girls. Future studies should focus on a more rigorous examination of causal associations and the potential for reciprocal associations, which may be useful for informing interventions aimed at alleviating emotional disorder symptomatology and reducing problematic levels of screen time. Such research could also provide evidence to determine whether interventions that reduce exposure to computer/videogames or increase physical activity levels may prevent GAD and SP in youth.

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## Conflict of interest

The authors report no conflicts of interest.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2019.01.014>.

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