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Examining the bidirectional relationship between physical activity, screen time, and symptoms of anxiety and depression over time during adolescence

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ABSTRACT

More physical activity (PA) and less screen time (ST) are positively associated with mental health in adolescents; however, research is limited by short-term designs and the exclusion of ST when examining PA. We examined: (a) changes in PA, ST, symptoms of depression, and symptoms of anxiety over four assessments spanning 11 years, and (b) bidirectional relationships between initial PA, ST, and symptoms of depression and anxiety as predictors of change in each other during adolescence. Between 2006 and 2010, participants from Ottawa Canada (Time1; $N = 1160$, Mean age = 13.54 years) completed questionnaires at four points covering the ages from 10 to 21 years. Latent growth modeling was used. PA decreased over time whereas ST and symptoms of depression and anxiety increased over time. Controlling for sex, ethnicity, school location, zBMI, birth year, and parents' education, initially higher anxiety was associated with initially higher ST (covariance = .88, $p < .05$) and initially lower PA (covariance = −6.84, $p = .07$) independent of initial symptoms of depression. Higher initial depression was associated with higher initial ST (covariance = 2.55, $p < .05$). Increases in anxiety were associated with increases in ST (covariance = .07, $p = .06$) and increases in depression (covariance = .41, $p < .05$). Examining bidirectional relationships, higher initial symptoms of depression predicted greater decreases in PA (b = −.28, $p < .05$). No other significant findings between initial PA, ST, anxiety, or depression were found as predictors of change in each other. Interventions targeting depression around age 13 may be useful to prevent further declines in PA. Similarly, interventions to reduce ST may be beneficial for concurrent reductions in symptoms of depression and anxiety, irrespective of PA.

1. Introduction

Mental health disorders are a leading cause of disability (Merikangas et al., 2009) and typically develop in childhood or adolescence (Kessler et al., 2007). Anxiety and depression are among the most common mental disorders in youth (Merikangas et al., 2009) with increasing incidence during adolescence (Leadbeater et al., 2012). With prevalence rates of symptoms of depression in childhood ranging from 21 to 50% (Merikangas, 2002) and similar rates for anxiety disorders (Merikangas, 2002) more research is needed to understand the trajectory of psychopathology and factors that predict changes in symptoms of depression and anxiety such that targeted interventions can be developed to aid prevention and treatment.

Two factors that have links with mental health are physical activity (PA) and screen time (ST) (Maras et al., 2015; Goldfield et al., in press). However, the relationship between PA, ST, and mental disorders and their symptoms is complex. On the one hand, increasing PA and reducing ST can alleviate or prevent symptoms of mental health disorders such as anxiety and depression (Maras et al., 2015; Goldfield et al., in press; Herman et al., 2015; Biddle and Asare, 2011). On the other hand, mental disorders can lead to disengagement in PA and increased engagement in ST (Jerstad et al., 2010; Lindwall et al., 2011; Azevedo Da Silva et al., 2012; Roshanaei-Moghaddam et al., 2009). Longitudinal research examining ST, PA, and symptoms of depression and anxiety in adolescents is sparse and preliminary findings are contradictory. Investigators have demonstrated that changes in PA and ST over time

Abbreviations: ST, screen time; PA, physical activity.

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are predictive of depression (Motl et al., 2004; Primack et al., 2009; Sund et al., 2010) whereas others have found no association (Hume et al., 2011; Brunet et al., 2013). Moreover, researchers have not always controlled for ST (Motl et al., 2004) when examining the relationships between PA and symptoms of depression and/or anxiety, or for PA when examining the relationships with ST (Primack et al., 2009). This is an important methodological limitation given the evidence that sedentary behaviors and PA have distinct relationships with physical and mental health outcomes (Tremblay et al., 2010). Given these independent relationships, the psychological benefits of focusing on one lifestyle behavior (i.e., PA) may be offset by ignoring the other (i.e., ST). Finally, although there is emerging evidence that the relationship between PA and mental disorders may be bidirectional, much of the research examining directionality has been conducted among adults (Lindwall et al., 2011; Azevedo Da Silva et al., 2012; Steinmo et al., 2014; Ku et al., 2012) and did not include ST despite its independent relationship with mental health (Maras et al., 2015; Herman et al., 2015; Goldfield et al., 2015).

Therefore, the objectives of this study in a community-based sample of adolescents were to examine (1) if and how PA, ST, symptoms of depression, and symptoms of anxiety changed over time during adolescence, and (2) if initial PA and ST predicted change in symptoms of depression and symptoms of anxiety and/or if initial symptoms of depression and initial symptoms of anxiety predicted changes in PA and ST. We hypothesized that PA would decrease whereas ST, symptoms of depression, and symptoms of anxiety would increase over time. Second, we hypothesized that higher initial PA and lower initial ST would predict reductions in symptoms of depression and symptoms of anxiety over time whereas higher initial symptoms of depression and anxiety would predict decreases in PA and increases in ST over time.

2. Methods

2.1. Participants and procedure

These data are part of a larger study entitled the Research on Eating and Adolescent Lifestyles (REAL) study (see (Flament et al., 2015) and online supplement). The study was approved through two hospital research ethics boards and relevant school board authorities. Briefly, beginning between 2006 and 2010 students ($N = 1208$) from grades 7 and 9 consented to participate in a longitudinal component of the REAL study, which involved repeated assessments at 1 to 2 year intervals up to 7 years (average interval in years: $M_{T1-T2} = 1.28$, $SD = 0.72$; $M_{T2-T3} = 1.58$, $SD = 0.92$; $M_{T3-T4} = 1.55$, $SD = 0.79$). The data from assessments beyond the fourth time point were not used due to low participation rates (Blozis and Cho, 2008). At each time point, participants completed pen-and-paper questionnaires under supervision of research staff in their school or in the research lab, except for the last (or last two) assessment(s) that was (were) done online for 170 participants.

The number of participants across each measurement point varied ($N_{time1} = 1160$, $N_{time2} = 706$, $N_{time3} = 382$, $N_{time4} = 236$; see attrition analysis in supplemental file). The analytic sample was comprised of adolescents ($N = 1160$; $n_{females} = 711$; see supplemental file for differences between analytic sample and those who consented but were excluded due to missing data on covariates), who on average were 13.54 (SD = 1.12), 14.65 (SD = 1.36), 16.11 (SD = 1.45), and 17.21 (SD = 1.40), years old at waves 1 through 4, respectively. Demographic characteristics of the participants at Time 1 are presented in Table 1.

3. Measures

3.1. Demographic and anthropometric characteristics

These included school, grade, and self-reported sex, birthdate, parents' education level, and ethnic background. Exact age at each time point was calculated. Objective measures of height and weight were collected with a Portable Stadiometre (Quick Medical Equipment and Supplies, U. S. A.) and a UC-321 Digital Weighing scale (Quick Medical Equipment and Supplied, U. S. A.). Body mass index (BMI) at Time 1 was calculated (kg/m^2). Sex and age standardized BMI (zBMI) was calculated (World Health Organization, 2016). Except for age, each demographic and anthropometric variable plus birth year obtained from Time 1 was entered as a confounding variable in the bidirectional model (described below).

Table 1
Demographic information at Time 1 and descriptive statistics for each main variable across time points.

Variable	*N*	*Mean*	*SD*
Age	1160	13.54	1.12
BMI	1160	20.65	3.66
*z*BMI	1160	.41	1.09
Variable	***N***	**%**	
Sex			
Male	458	39.5	
Female	702	60.5	
Ethnicity			
Caucasian	859	74.1	
Other	301	25.9	
School geographic location			
Urban	313	27	
Suburban	651	56.1	
Rural	196	16.9	
Parent's education			
Both parents college	637	54.9	
One parent college	233	20.1	
Neither parent college	103	8.9	
Unknown	187	16.1	
Variable	***N***	***M***	***SD***
PA_Time1	1072	49.20	28.14
PA_Time2	668	47.78	27.72
PA_Time3	362	42.59	26.07
PA_Time4	231	39.41	25.85
ST_Time1	1132	4.96	2.02
ST_Time2	698	5.17	1.90
ST_Time3	377	5.16	1.87
ST_Time4	236	4.99	1.95
Depression_Time1	1098	7.30	6.76
Depression_Time2	699	7.58	6.82
Depression_Time3	380	7.95	6.54
Depression_Time4	234	8.33	6.48
Anxiety_Time1	1092	10.30	5.14
Anxiety_Time2	697	10.36	5.22
Anxiety_Time3	380	10.76	5.16
Anxiety_Time4	235	10.98	5.23

Note. Participants were recruited between 2006 and 2010 from Ottawa Canada. Demographic information is presented for Time 1 only. PA = physical activity, ST = screen time, SD = standard deviation.

3.2. Physical activity

Self-reported PA was assessed with the 3-item Leisure Time Exercise Questionnaire (LTEQ) (Godin and Shephard, 1985) Respondents were asked to think about their activity over the past seven days and record the number of bouts of mild, moderate, and strenuous activity that were engaged in for over 15 min. Following recommendations, (Godin, 2011) a total continuous PA score was calculated using the formula [(strenuous*9) + (moderate*5)]. Scores from this questionnaire have demonstrated reliability and validity in adolescents including good test–retest reliability (Sallis et al., 1993; Eisenmann et al., 2002) Higher scores represent higher PA.

3.3. Screen time

A self-report questionnaire was developed for the current study. Participants were asked to respond to 6-items querying how many hours per day they typically engaged in TV viewing, video game playing, and computer use. Response options were 0 (*not at all*), 1 (*less than 1 h*), 2 (*1 to 3 h*), 3 (*3 to 5 h*), 4 (*5 to 8 h*), and 5 (*more than 8 h*). The three first items inquired about time spent in ST pursuits during weekdays whereas the last three inquired about weekend days. Total ST was calculated by adding Likert category responses (i.e., 0–5) to total time spent on TV, video games, and computers, and weighting by time of the week: [(weekday*5) + (weekend*2)] / 7. Higher scores reflect higher ST. A study using the Time 1 data from the REAL study found evidence of convergent validity with scores from the ST measure positively correlated with BMI and negatively correlated with symptoms of depression and anxiety (Maras et al., 2015).

3.4. Depression

Self-reported symptoms of depression were assessed with the 27-item Children's Depression Inventory (CDI). Items reflect cognitive, affective, and behavioral indicators of depression and are scored from 0 (*absence of symptom*) to 2 (*definite symptom*) (Kovacs, 1978). Total scores range from 0 to 54 and researchers have found evidence for score validity and reliability (Kovacs, 1978). In the REAL cross-sectional study (Maras et al., 2015), internal consistency scores (α) were >.88 and in the current study $\alpha > .86$ (see Table 1). Higher total scores reflect higher depressive symptoms.

3.5. Anxiety

Self-reported symptoms of anxiety were assessed using the 10-item Multidimensional Anxiety Scale for Children-10 (MASC-10) (March et al., 1997). The MASC-10 is used to assess global symptoms of anxiety with responses provided on a scale of 0 (*never true about me*) to 3 (*often true about me*). Researchers have supported the total score validity and reliability (March and Sullivan, 1999; Osman et al., 2008). In the REAL cross-sectional study (Maras et al., 2015), internal consistency scores (α) were >.75 and in the current study, internal consistency scores were >.74 (see Table 1). Higher scores reflect higher symptoms of anxiety.

4. Statistical analyses

Latent growth modeling (LGM) was conducted using Mplus 7.3 with robust full information maximum likelihood estimation to account for possible non-normality and missing data. For each variable (PA, ST, symptoms of depression, and symptoms of anxiety), LGM was used to create two random latent variables that represent an intercept (baseline) and slope (change), and each individual was allowed to vary from the mean intercept and slope. Because the data were not collected at equal intervals, the data were analyzed based on participants' exact age (Bollen and Curran, 2006; Mehta and West, 2000). Therefore, even though one participant only provided data at a maximum of 4 age points (with the total sample covering an approximately 11-year interval), LGM allowed for the creation of a complete trajectory over 11 years based on each individual's age simultaneously (Orth et al., 2010). Age was centered around the average age at Time 1 ($M_{age.T1}$ = 13.54 years). Therefore, interpretation of intercept values reflected the individuals expected response when age was 13.54 years old (Blozis and Cho, 2008).

To answer the first research question, univariate models wherein ST, PA, symptoms of depression, and symptoms of anxiety were examined independently to determine if the variables were changing over time and what the form of change was (linear or quadratic). Next, a combined LGM was estimated wherein the intercepts and slopes of PA, ST, symptoms of depression, and symptoms of anxiety were analyzed concurrently to determine their associations. Means, variances, and covariances from this model were interpreted. To answer the second research question eight regression paths were added to the model: (a) four regressions from the slopes of PA and ST on the intercepts of symptoms of depression and symptoms of anxiety (i.e., to examine if initial symptoms of depression and initial symptoms of anxiety predicted change in PA and ST), and (b) four regressions from the slopes of symptoms of depression and symptoms of anxiety on the intercepts of PA and ST (i.e., to examine if initial PA and ST predicted change in symptoms of depression and symptoms of anxiety). In this model, we controlled for sex, birth year (to ensure varying birth years did not impact the results), parents' education, ethnicity, school location, and *z*BMI given their hypothesized influence on our variables of interest (Maras et al., 2015)

5. Results

5.1. Patterns of change

Descriptive statistics for the main variables are reported in Table 1. Independent analyses of each variable indicated that PA, ST, symptoms of depression, and symptoms of anxiety were changing steadily (i.e., linearly) over time. There were no significant accelerations or decelerations in the rates of change (i.e., quadratic trend) in any variables. Means, variances, and covariances from the LGM with all variables analyzed simultaneously are presented in Table 2. Examining the mean slope values, symptoms of depression, symptoms of anxiety, and ST increased significantly ($p < .05$) over time, and PA decreased significantly ($p < .05$) over time. Slope variances were statistically significant ($p < .06$) for all variables indicating that there was significant individual variability in the rates of change in each variable.

5.2. Bidirectional relationships between initial status and change

Controlling for sex, birth year, parents' education, ethnicity, school location, and zBMI, we found that higher initial symptoms of anxiety were independently associated with higher initial symptoms of depression (covariance = 7.02, $p < .05$), higher ST (covariance = .88, $p < .05$), and lower initial PA (covariance = −6.88, $p = .07$). Higher initial symptoms of depression were associated with higher initial ST (covariance = 2.55 $p < .05$) and increases in symptoms of depression (covariance = 1.13, $p < .05$) over time. Finally, examining how the variables 'move together' in time, we found that increases in symptoms of anxiety were associated with increases in symptoms of depression (covariance = .41, $p < .05$) and increases in ST (covariance = .07, $p = .06$) over time. When examining the bidirectional relationships, we found that after accounting for covariates, higher initial depression scores at age 13.54 years were associated with a greater decrease in PA over time ($b = -.28$, $p < .05$; see Fig. 1). Initial symptoms of anxiety did not predict change in PA or ST and initial symptoms of depression did not predict changes in ST (see Fig. 1). Similarly, initial ST or PA did not predict changes in symptoms of depression or anxiety (see Fig. 1).

6. Discussion

Over a developmental period during adolescence, we examined the independent roles of initial PA, ST, symptoms of depression, and symptoms of anxiety as bidirectional predictors of change in symptoms of depression, symptoms of anxiety, PA, and ST, respectively. Results were based on 4 measurement points spanning 11 years in a large sample of 1160 adolescents from ages 10 to 21 years. To the best of our knowledge, this is the first longitudinal investigation that has examined directionality and the independent relationships of PA and ST in relation to symptoms of depression and anxiety.

When each variable was examined in univariate models, results were in line with our hypotheses and previous research indicating

Table 2
Means, variances, and bivariate covariances of latent growth model.

	Mean	Variance	Intercept depression	Intercept anxiety	Intercept PA	Intercept ST	Slope depression	Slope anxiety	Slope PA	Slope ST
Intercept depression	7.091*	18.916*	–							
Intercept anxiety	10.179*	14.369*	8.478*	–						
Intercept PA	49.274*	300.143*	−9.363†	−16.933*	–					
Intercept ST	5.011*	2.280*	2.581*	0.730*	−2.466	–				
Slope depression	0.513*	0.559†	0.887	−0.354	0.394	−0.166	–			
Slope anxiety	0.184*	0.603*	0.057	−0.288	−0.369	−0.228*	0.439*	–		
Slope PA	−2.158*	5.207*	−3.555*	−2.027	−17.603	−.731	−0.504	−0.275	–	
Slope ST	0.077*	0.054*	−0.232†	−0.219*	−1.091*	−0.094	0.018	0.074*	0.172	–

Note. Participants were recruited between 2006 and 2010 from Ottawa Canada. PA = physical activity, ST = screen time.
* $p < .05$.
† $p < .061$.

that PA decreased over time (Sund et al., 2010) whereas ST (Sund et al., 2010), symptoms of depression, and symptoms of anxiety (Leadbeater et al., 2012) increased over time. The naturally occurring changes in behaviors and symptoms of mental health disorders indicate that strategies are needed to prevent the decline in PA and the increase in ST and symptoms of depression and anxiety during adolescence.

When examining the final combined model and accounting for covariates, interpretation of the covariances between the intercept variables (i.e., at age 13.54 years) indicated our results were comparable to previous cross-sectional findings. For example, consistent with past research, we found that higher symptoms of anxiety at baseline were independently (i.e., irrespective of any other variable at baseline) associated with higher initial ST and lower initial PA (Maras et al., 2015) and that higher initial symptoms of depression were associated with higher initial ST (Maras et al., 2015). Consequently, these findings suggest that health care practitioners, parents, and caregivers should attempt to reduce ST and increase PA given their initial concurrent associations with symptoms of depression and symptoms of anxiety.

Considering the bidirectional associations between baseline levels as predictors of change, our results indicated that adolescents with initially higher symptoms of depression at age 13.54 years had a greater decrease in PA over time, irrespective of initial PA, ST, and symptoms of anxiety. These findings are consistent with previous research that has also demonstrated that in young adults (Pinto Pereira et al., 2014) and

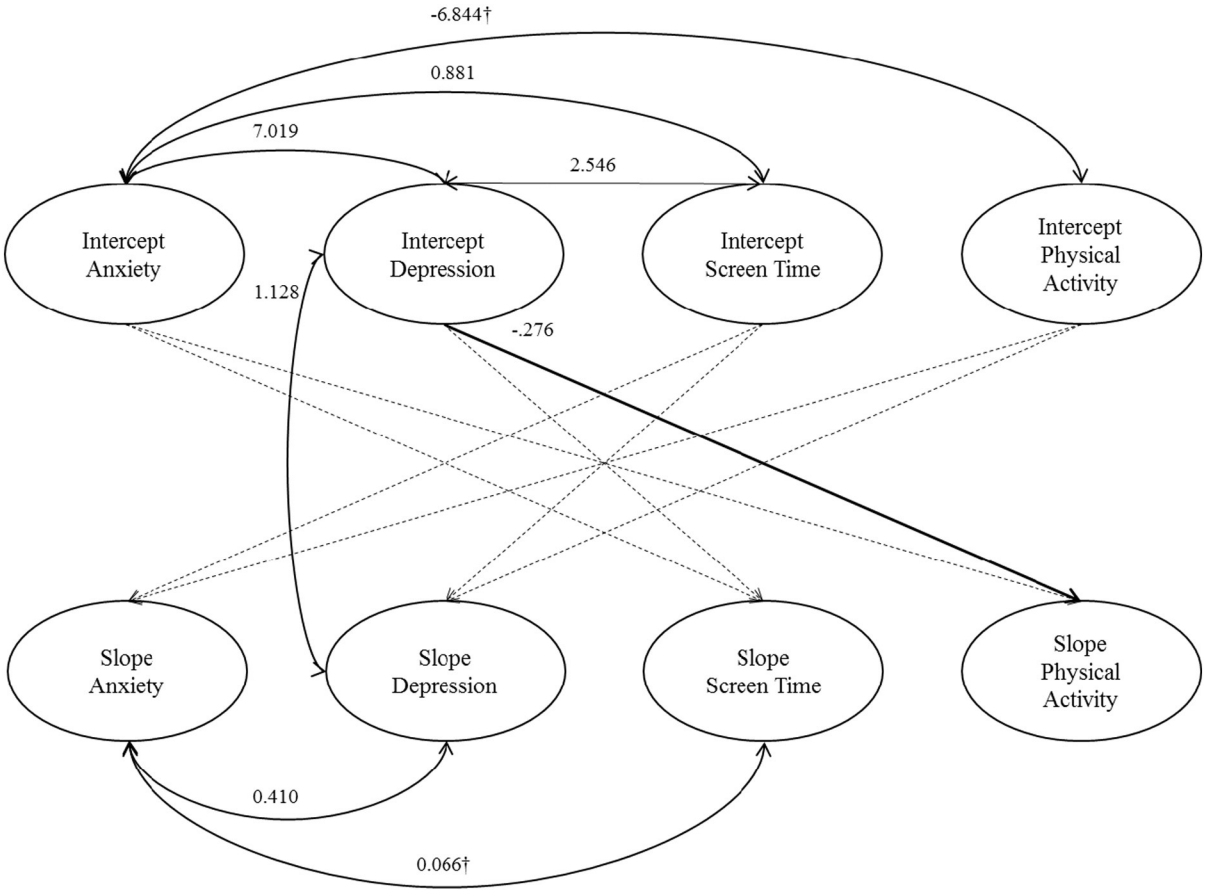

Fig. 1. Bidirectional model of physical activity, screen time, and symptoms of depression and anxiety. Note. Participants were recruited between 2006 and 2010 from Ottawa Canada. Solid lines $p < .05$, dashed lines $p > .071$, †$p \leq .071$. All values are unstandardized. Not shown here for clarity: (a) item indicators of each intercept and slope latent factor (b) error covariances between the same indicator and adjacent time points (e.g., Anxiety_Time1 with Anxiety_Time2) and indicators within time points (e.g., Anxiety_Time1 with Depression_Time1, ST_Time1, PA_Time1), (c) all covariances between all latent factors that were non-significant ($p > .71$), and (d) control variables (sex, birth year, zBMI, ethnicity, school location, and parent's education).

adolescents (Jerstad et al., 2010), symptoms of depression may be a risk factor for reduced PA over time. However, our results extend previous findings given that this finding emerged irrespective of the influence of initial ST, PA, and symptoms of anxiety. Based on self-determination theory (Deci and Ryan, 2000), it is possible that symptoms of depression lead to lower feelings of competence, autonomy, and relatedness (i.e., psychological needs) which in turn, can be associated with reduced PA over time in adolescents (Gunnell et al., 2016). Alternatively, others have hypothesized that higher symptoms of depression can lead to low energy, apathy, and social isolation which may in turn reduce PA (Azevedo Da Silva et al., 2012; Birkeland et al., 2009; Goodwin, 2003). Researchers would do well to begin to uncover causal mediators linking symptoms of depression to lower PA over time to better inform intervention strategies.

In line with one other study of adolescents (Birkeland et al., 2009), yet inconsistent with other studies in adults (Lindwall et al., 2011; Steinmo et al., 2014; Pinto Pereira et al., 2014) and one study with adolescents (Jerstad et al., 2010) we found weak support for our hypotheses regarding the overall bidirectional relationship between initial PA, ST, and symptoms of depression, and symptoms of anxiety and change in these constructs over time. Regarding the largely null bidirectional results, we echo sentiments from Birkeland and colleagues (Birkeland et al., 2009) who contend that the null findings between baseline levels and trajectories of change can be seen positively in that it implies that adolescents around the age of 13 years old with lower PA or higher ST, or with symptoms of depression or symptoms of anxiety are not destined to a trajectory of increased symptoms of depression and anxiety or maladaptive behavioral outcomes. In explaining why the bidirectional relationships were largely null at predicting trajectories of change, it is possible that age 13 years old is too early to begin examining symptoms of depression which have been shown to be more unstable during early adolescence (Holsen et al., 2000). Alternatively, it is possible that there were variables that impacted the relationships between PA, ST, symptoms of depression, and symptoms of anxiety that were not assessed in the present investigation and that moderate the predictive relationships between baseline and change over time. For example, researchers have noted that different uses of screens may have differential relationships with mental health (Maras et al., 2015; Brunet et al., 2014; Kowalski and Limber, 2013; Hamer and Stamatakis, 2014). The measure of ST used in the current study was general (i.e., it only assessed the *frequency* of video gaming, television viewing, and computer use) and did not query the *context* of ST. With screens becoming more prominent in adolescents' lives (e.g., touch screens being used in classrooms), more research is needed with more precise estimates of how screens are being used and in which context (e.g., computer use for homework vs. computer use for social networking; screen use while sedentary or active) to more closely examine the moderating role of ST context on the relationships examined herein. Finally, it is possible that our self-report measure of PA may not have been sensitive enough to capture variations in types of PA (e.g., sport vs. active play), duration (e.g., 20 min vs. 60 min) and contexts in which PA was being engaged (e.g., with friends or alone).

Although the bidirectional predictive relationships were generally unsupported (except for initial symptoms of depression predicting change in PA), our results regarding how variables "move together" over time were similar to Birkeland and colleagues (Birkeland et al., 2009) results. We found that increases in symptoms of anxiety increased alongside increases in symptoms of depression and ST. As such, preventing any increases in symptoms of anxiety may be beneficial for changes in symptoms of depression and ST given that these factors tend to covary over time.

6.1. Study limitations and strengths

Results of this study should be interpreted in light of its limitations. Self-report measures were used rather than more direct measures of activity. In future studies, researchers could collect information on PA and ST using more objective measures (e.g., accelerometers). Further, the measure of ST used has not undergone rigorous psychometric testing and therefore results should be interpreted with caution. Although scores from the ST measure demonstrate preliminary convergent validity evidence, researchers should examine its sensitivity to change and other sources of score validity and reliability. Results of this study are based on a sample of adolescents from one region in Canada and therefore may not generalize to other populations. Despite the longitudinal nature of this investigation, and our ability to begin to examine bidirectionality, the data are observational and without further manipulation, causation cannot be inferred. Finally, our analyses did not control for other factors that could to be associated with symptoms of depression and anxiety (e.g., smoking, clinical diagnosis of anxiety or depression, medication use). In the future, researchers should also begin to examine mediators and moderators that may link or influence the relationships between PA, ST, and symptoms of depression and anxiety over time. Another avenue for future research would be to use the full version of the MASC to determine if different subtypes of symptoms of anxiety (e.g., social anxiety symptoms) are differentially related to different contexts of ST given that socially anxious youth may be substituting face-to-face communication with online communication (Pierce, 2009), and that youth using online forms of entertainment may experience less social anxiety (Martončik and Lokša, 2016)

Finally, there was considerable participant attrition. The reduced sample size over time could have led to reduced statistical power. Nonetheless, estimation procedures were used that are known to be better than listwise or pairwise deletion of missing data (Schafer and Graham, 2002) and LGM is considered to be a powerful analytic technique for longitudinal analyses (Duncan et al., 2006). Other strengths of this investigation include the objective measures of height and weight, large sample size at baseline, 4 measurement points spanning 11-years, and the analytic strategy which allowed for examining the independent relationships of PA and ST on mental health symptoms in youth.

7. Conclusion

Generally, we found that symptoms of depression and symptoms of anxiety are independently related to ST and PA (cross-sectionally and longitudinally), yet only higher symptoms of depression at age 13.54 years predicted a reduced trajectory of PA over time. Other than the one bidirectional finding, our results are promising because they indicate that baseline levels of PA and ST, and symptoms of anxiety at age 13.54 years are not indicative of changes in symptoms of depression or anxiety, and change in PA or ST over time, respectively. Our results contribute to the literature because longitudinal and bidirectional relationships between PA and mental health are under-studied in adolescence and this is the first investigation to our knowledge that has included ST into the models. Treatment strategies that target symptoms of depression around the age of 13 years may be useful to prevent further declines in PA over the course of adolescence. Further, treatment strategies that seek to reduce ST may be beneficial for concurrent reductions in symptoms of depression and symptoms of anxiety, irrespective of PA.

Conflict of interest statement

No authors have financial relationships relevant to this article to disclose. The authors declare that there are no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2016.04.002.

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