JOURNAL
OF THE CANADIAN ACADEMY OF CHILD AND ADOLESCENT PSYCHIATRY / DE L'ACADÉMIE CANADIENNE DE PSYCHIATRIE DE L'ENFANT ET DE L'ADOLESCENT

RESEARCH ARTICLE

The Independent and Interactive Associations of Screen Time and Physical Activity on Mental Health, School Connectedness and Academic Achievement among a Population-Based Sample of Youth

Linda Trinh PhD[1]; Bonny Wong MA[1]; Guy E. Faulkner PhD[1]

Abstract

Objective: Few studies have addressed the links between sedentary behaviour (SED) and mental health in youth. Most studies on physical activity (PA) and SED examine their independent effects on mental health, or fail to account for PA in this relationship. The purpose of this study is to examine the independent effects of PA and screen time on mental health, school connectedness and academic achievement, and potential interactions between PA and screen time in such associations. **Methods:** Data was obtained through 2,660 adolescents who completed the self-administered Ontario Student Drug Use and Health Survey (OSDUHS) in 2009. Self-reported variables of demographics, PA, screen time, and mental health indicators were also collected. **Results:** Using logistic regression, screen time was inversely associated with all mental health indicators ($p<.05$). Although meeting PA guidelines was associated with lower school disconnectedness in males, the effects of high screen time were greater than the independent associations of PA among mental health indicators. An interaction between screen time and PA with low self-esteem was found only in males. Higher screen time was associated with lower self-esteem in males, independent of PA ($p<.001$). **Conclusion:** High screen time was associated with poorer mental health and academic outcomes. Being physically active did not result in higher self-esteem in the presence of high screen time among males. These results confirm the value in distinguishing the independent and interactive effects of PA and SED on mental health. Future research should promote PA and reduce screen time to improve mental health outcomes among youth.

Key Words: *screen time, physical activity, mental health, youth*

Résumé

Objectif: Peu d'études ont traité des liens entre le comportement sédentaire (SED) et la santé mentale chez les adolescents. La plupart des études sur l'activité physique (AP) et le SED examinent leurs effets indépendants sur la santé mentale, ou ne tiennent pas compte de l'AP dans cette relation. Le but de cette étude est d'examiner les effets indépendants de l'AP et du temps passé devant un écran sur la santé mentale, le sentiment d'appartenance à l'école et la réussite scolaire, et les interactions possibles entre l'AP et le temps passé devant un écran dans ces associations. **Méthodes:** Les données ont été obtenues auprès de 2 660 adolescents qui ont répondu au Sondage sur la consommation de drogues et la santé des élèves de l'Ontario (SCDSEO) auto-administré en 2009. Les variables auto-déclarées des indicateurs démographiques, de l'AP, du temps passé devant un écran, et de la santé mentale ont aussi été recueillies. **Résultats:** À l'aide de la régression logistique, le temps passé devant un écran était inversement associé à tous les indicateurs de la santé mentale ($p<0,05$). Même si satisfaire aux lignes directrices de l'AP était associé à une plus faible absence de sentiment d'appartenance à l'école chez les garçons, les effets du temps élevé passé devant un écran étaient plus importants que les associations indépendantes d'AP parmi les indicateurs de la santé mentale. Une interaction entre

[1] Faculty of Kinesiology & Physical Education, University of Toronto, Toronto, Ontario

Corresponding E-Mail: guy.faulkner@utoronto.ca

Submitted: May 9, 2014; Accepted: October 24, 2014

le temps passé devant un écran et l'AP avec une faible estime de soi n'a été constatée que chez les garçons. Le temps élevé passé devant un écran était associé à une faible estime de soi chez les garçons, indépendamment de l'AP (p<0,001). **Conclusion:** Le temps élevé passé devant un écran était associé à une santé mentale et des résultats scolaires moins bons. Être actif physiquement ne résultait pas en une meilleure estime de soi en présence de temps élevé passé devant un écran chez les garçons. Ces résultats confirment le bien-fondé de distinguer les effets indépendants et interactifs de l'AP et du SED sur la santé mentale. La future recherche devrait promouvoir l'AP et réduire le temps passé devant un écran pour améliorer les résultats de santé mentale chez les adolescents.

Mots clés: *temps passé devant un écran, activité physique, santé mentale, adolescent*

Introduction

Emerging evidence demonstrates the adverse health effects of sedentary behaviour (SED) that are distinct from the beneficial effects of moderate-to-vigorous intensity physical activity (PA) (Temmel & Rhodes, 2013; Tremblay et al., 2011a). Childhood obesity is a public health concern due to its associations with several cardiometabolic risk factors and the increased likelihood of adult obesity (Janssen et al., 2005; Tremblay, Colley, Saunders, Healy & Owen, 2010). There is strong evidence for the influence of modifiable lifestyle behaviours such as PA and SED on obesity in youth (Han, Lawlor, & Kimm, 2010). Reducing SED has been identified as an essential component for preventing the development of obesity among youth (Tremblay et al., 2011a; Barnett et al., 2010).

Despite the Canadian Sedentary Behaviour Guidelines, which recommend no more than two hours of recreational screen time per day (Tremblay et al., 2011b), only 19% of youth reported meeting these guidelines (Active Healthy Kids Canada, 2012). In fact, youth report an average of 7.8 hours of screen time per day, and spend 62% of their waking hours being sedentary (Active Healthy Kids Canada, 2012; Colley, Garriguet, Janssen, Craig, Clark, & Tremblay, 2011). Recent literature has begun to examine specific SEDs with respect to health indicators. Tremblay et al. (2011a) found that engaging in two or more hours a day of TV viewing was positively associated with higher body weight, lower fitness, and lower self-esteem. Moreover, children and youth who engaged in higher levels of TV viewing resulted in less time doing homework, studying, and reading for leisure which may potentially lead to poorer academic performance (Tremblay et al., 2011a). Of note, an earlier meta-analysis reviewing the associations between TV viewing, video/computer game use with body fatness and PA in children and youth reported a significant relationship between TV viewing and body fatness. However, the authors cautioned that the magnitude of the relationship was likely too small to be clinically relevant. This suggests that relationships between SED and weight are unlikely to be explained by a single domain of SED such as screen time (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004).

Emerging evidence also suggests that engaging in health promoting behaviours is related to the level of school connectedness (Yang, Tan, & Cheng, 2013). Adolescents who reported that their school climate was one of fairness, care and one with which they felt emotionally engaged were significantly more likely to report less risky behaviours, and higher levels of PA (Yang et al., 2013).

The majority of studies examining the associations between SED and health outcomes have focused on screen time (i.e., TV and computers) and weight status. In a review of mental health and PA among adolescents, approximately nine studies have addressed the links between SED, PA, and mental health (Biddle & Asare, 2011). Most studies on PA and SED examine their independent effects on mental health, or fail to account for PA when assessing this relationship (Biddle & Asare, 2011). Less is known as to whether PA and screen time interact and have an additive or compensating effect on mental health.

The purpose of this study is to examine the independent effects of PA and screen time on mental health, school connectedness, and academic achievement in a provincially representative sample of youth; and identify potential interactions between PA and screen time in such associations. We hypothesize that higher screen time among youth would be associated with poorer mental health and academic outcomes. The combined effects of physical activity and screen time on mental health outcomes remain exploratory.

Methods

Study Design and Participants

Data for this study were derived from the 2009 cycle of the Ontario Student Drug Use and Health Survey (OSDUHS). OSDUHS is a cross-sectional, self-administered, province-wide survey of Ontario students in grades seven through 12 in the public school system collected biennially since 1977 by the Centre for Addiction and Mental Health (CAMH) (Paglia-Boak, Mann, Adlaf, & Rehm, 2009; Paglia-Boak, Mann, Adlaf, Beitchman, Wolfe, & Rehm, 2010). The survey employed a stratified (region and school level), two-stage (school, class) cluster sample design used to assess epidemiological trends in student drug use, mental health,

PA, and health-risk behaviours. Schools were randomly selected first, followed by a random selection of classes of each grade within each selected school. Further details regarding the OSDUHS methodology can be found elsewhere (Paglia-Boak et al. 2009, 2010).

Measures

Physical activity. PA was assessed using a question concerning "On how many of the last seven days were you physically active for a total of at least 60 minutes each day, which aligns with the current public health PA guidelines for children and youth (Tremblay et al., 2011c). Response options ranged from 0-7 days. Participants were asked to sum up all of the time they spent in any kind of PA that increased their heart rate and breathing hard some of the time (e.g., brisk walking, running, biking) in both school and non-school activities. These PA minutes were then dichotomized into two categories: a) not meeting PA guidelines (<60 minutes) (coded 0), and b) meeting PA guidelines (≥60 minutes) (coded 1). This item has been previously used in recognized student surveys such as the WHO's Health Behaviour in School-aged Children (HBSC) survey, and has been shown to produce valid and reliable responses (Janssen et al., 2005).

Screen time. Screen time was assessed with the question: "In the last seven days, about how many hours a day, on average, did you spend: watching TV/movies, playing video/computer games, on a computer chatting, emailing, or surfing the internet?" with response options of none, ≤ 1 hour a day, 1 to 2 hours a day, 3 to 4 hours a day, 5 to 6 hours a day, and ≥ 7 hours a day. This measure reflects the current Canadian public health guidelines for SED in children and youth (Tremblay et al., 2011a). Screen time was dichotomized into 2 variables: a) not meeting screen time guidelines (>2 hours) (coded 1), and b) meeting screen time guidelines (≤2 hours) (coded 0). This item has been previously used in recognized student surveys and has been shown to produce valid and reliable responses (Janssen et al., 2005).

Psychological distress. The General Health Questionnaire (GHQ) consists of 12 items examining clinically relevant symptoms of psychological distress such as anxiety, social dysfunction, and self-esteem (Goldberg, Gater, Sartorius, Ustun, Piccinelli, Gureje, 1997). For example, items included "Have you recently been able to enjoy your normal day-to-day activities?" and "Have you recently been able to concentrate on whatever you're doing?" Response options were based on a four-point Likert scale ranging from "not at all" to "much more than usual." Scores ranged from 0-36, with higher scores indicating greater psychological distress. Experiencing elevated psychological distress was defined as reporting at least three of the 12 symptoms (coded 1), while a score of ≤2 indicated no psychological distress (coded 0). The scale has been shown to be well-validated and reliable (α=0.87) in the youth population (Paglia-Boak et al., 2010; Mann et al., 2011).

Depression. Depressive symptoms was assessed using four items adapted from the Center for Epidemiologic Studies Depression (CES-D) (Radloff, 1977). These questions were asked with the time referent being the "past seven days," including: "How often have you felt sad?" "How often have you felt lonely?" "How often have you felt depressed?" and "How often have you felt like crying?" The response options were based on a four-point Likert scale, ranging from "never or rarely" to "always." Having depressive symptoms was defined as reporting "often" or "always" on all four symptoms (coded 1). Higher scores indicated greater depressive symptomatology. The reliability coefficient for these items is 0.85 (Paglia-Boak, et al., 2010), and has exhibited strong psychometric properties in adolescent populations (Haroz, Ybarra, & Eaton, 2014).

Self-esteem. Self-esteem was assessed with six items adapted from the Rosenberg Self-Esteem Scale (Rosenberg, Schooler, & Schoenbach, 1989) rated on a five-point Likert-scale (1 = *strongly agree*, 5 = *strongly disagree*). The items included: 'I feel good about myself;' 'I feel that I am a person of worth;' 'I am able to do most things as well as other people can;' 'Sometimes I feel that I can't do anything right;' 'I feel I do not have much to be proud of;' and 'Sometimes I think I am no good at all.' Higher scores are indicative of lower self-esteem (coded as 1). The reliability coefficient for these items was 0.73 (Paglia-Boak, et al., 2010) and has been demonstrated to be a valid and reliable scale among Canadian high school students (Bagley, Bolitho, & Bertrand, 1997).

School disconnectedness. School disconnectedness was measured according to students' agreement with the following three statements: "I feel close to people at this school," "I feel like I am part of this school," and "I feel safe in my school." Response options were rated on a four-point Likert scale ranging from *1=strongly agree and 4=strongly disagree.* School disconnectedness was dichotomized into the following categories: a) disconnected (1 standard deviation) below the mean of school connectedness (coded 1); and b) not disconnected (coded 0). The reliability coefficient for these items was 0.64 (Paglia-Boak, et al., 2010), and have been used in adolescent populations (Bonny, Britto, Klostermann, Hornung, & Slap, 2000).

Perceived academic achievement. Academic achievement was assessed using self-report with the question: "On average, what marks do you usually get in school?" with the following response options: "A (80%-100%)," "B (67%-79%)," "C (60%-66%)," "D (50%-59%), and "less than D (below 50%)." The responses were dichotomized into two categories: a) A grade (coded 0), and b) B grade or below (coded 1).

Demographic variables. Demographic variables were assessed using self-report and included gender (coded "1" for girls and "0" for boys), grade, and age. Years of highest parental education were used as a proxy for socio-economic status and coded using the following: did not attend high school (coded as 8 years), attended high school (coded as 10 years); graduated from high school (coded as 12 years), attended college (coded as 13 years), graduated from college (coded as 14 years), attended university (coded as 15 years), and graduated from university (coded as 16 years). School location was classified as residing in urban (coded 1) or rural (coded 0) areas according to the postal code of the school. Self-reported height and weight were also collected to compute body mass index (BMI).

Data Analysis

All statistical analyses were conducted using Stata 11.0 (Stata Statistical Software, 2009), and used the Taylor series methods to account for the complex sampling design. Using logistic regression and post-estimation, we examined the independent effects of PA (i.e., engaging in 60 minutes of moderate-vigorous PA daily) and screen time (i.e., >2 hours daily) on mental health indicators (i.e., self-esteem, depressive symptoms, and elevated psychological distress), academic achievement and connectedness. Screen time and PA were mutually adjusted in each model. Interaction terms of screen time and PA were added to examine the interaction of PA and screen time. All analyses were stratified by boys and girls due to potential differences in PA and SED patterns (Marshall, Biddle, Sallis, McKenzie, & Conway, 2002). Analyses were adjusted for grade, years of highest parental education, BMI, and type of living (urban vs. rural).

Results

Of the 14,196 students, 9,241 participated in the survey resulting in a response rate of 65%. Non-response was due to absenteeism (13%) and unreturned parental consent forms or parental refusal (22%). Of the 9,241, 3,055 secondary students (Grade 9 to 12) completed Form A questionnaires that included measures of mental health and school connectedness. Of the 3,055 secondary students, 395 (12.9%) were excluded due to missing data on measures included in this study, resulting in 2,660 secondary students for the final analysis. Included and excluded students were comparable in terms of gender, PA, SED, and mental health indicators, with the exception of excluded students being younger than those included [$\chi^2(3)=31.84$; $p<0.001$].

Table 1 presents the demographic and behavioural characteristics of youth. Nineteen per cent and 59% of secondary school students were physically active and had high screen time, respectively. Male students were more likely to have slightly higher years of parental education (14.7 years vs. 14.5 years), higher BMI (22.5 kg/m^2 vs. 21.9 kg/m^2), live in a urban area (83.1% vs. 79.2%), have higher screen time (63.5% vs. 55.1%), be physically active (24.5% vs. 13.5%), have higher school disconnectedness (24.9% vs. 21.9%), and lower academic achievement (59.6% vs. 43.5%). Females were more likely to report psychological distress (42.7% vs. 25.1%), low self-esteem (10.3% vs. 5.2%) and depressive symptoms (8.2% vs. 2.9%).

Table 2 presents the associations between screen time, PA, and mental health. Overall, screen time was significantly associated with poor mental health outcomes including psychological distress (OR=2.01, 95% CI=1.40-2.89; d=0.39, p<.05), low self-esteem (OR=1.32, 95% CI=1.17-1.49; d=0.15, p<.05), depressive symptoms (OR=1.92, 95% CI=1.05-3.54; d=0.36, p<.05), school disconnectedness (OR=1.27, 95% CI=1.13-1.43; d=0.13, p<.05), and lower academic achievement (OR=1.29, 95% CI=1.10-1.51; d=0.14, p<.05). Meeting PA guidelines was only associated with a lower risk of school disconnectedness (OR=0.84, 95% CI 0.72-0.99; d=-0.10, p<.05).

In terms of differences by gender, higher screen time was associated with all mental outcomes in males including psychological distress (OR=2.40, 95% CI=1.63-3.54; d=0.48, p<.05), low self-esteem (OR=1.31, 95% CI=1.13-1.53; d=0.15, p<.05), depressive symptoms (OR=2.82, 95% CI=1.09-7.30; d=0.57, p<.05), school disconnectedness (OR=1.49, 95% CI=1.14-1.68; d=0.22; p<.05), and academic achievement (OR=1.21, 95% CI=0.92-1.59; d=0.11, p<.05). Higher screen time was associated with low self-esteem (OR=1.30, 95% CI=1.10-1.53; d=0.14, p<.05), school disconnectedness (OR=1.16, 95% CI=0.74-1.29; d=0.08, p<.05), and academic achievement (OR=1.39, 95% CI=1.16-1.66; d=0.18, p<.05) among females. Males who were meeting PA guidelines had lower school disconnectedness (OR=0.78, 95% CI=0.64-0.96; d=-0.14, p<.05). There were no associations with any mental health outcomes for females not meeting PA guidelines.

Table 3 presents the interaction of PA and SED with self-esteem. There was one interaction between screen time and PA with low self-esteem among males only. High screen time was associated with lower self-esteem, independent of whether males were attaining 60 minutes of daily moderate-vigorous PA (OR=1.34, 95% CI=1.14-1.57; d=0.16, p<.001). Notably, the odds ratio was larger when males reported both high screen time and being physically active (OR=1.84, 95% CI=1.29-2.61; d=0.34, p<0.001) in comparison to low screen time and being inactive (OR=1.14, 95% CI=0.99-1.33; d=0.07, p=.07).

Discussion

In this study, higher screen time was consistently associated with poorer mental health, school disconnectedness and academic achievement independent of PA levels. This is consistent with previous studies reporting associations

Table 1. Demographic and behavioural characteristics of youth overall and by gender in Ontario, Canada, 2009 (N=2,660)

Variables	All (n=2,660) Mean (SD)	Males (n=1,263) Mean (SD)	Females (n=1,397) Mean (SD)	p
Age	15.8 (1.30)	15.8 (1.33)	15.8 (1.27)	0.34
Years of highest parental education	14.6 (1.71)	14.7 (1.65)	14.5 (1.74)*	<0.001
Body mass index (BMI)	22.2 (4.07)	22.5 (3.95)	21.9 (4.15)*	<0.001
	% (n)	% (n)	% (n)	
Grade				0.93
9	23.5 (624)	23.4 (295)	23.6 (329)	
10	26.2 (696)	26.5 (335)	25.8 (361)	
11	23.7 (631)	23.2 (293)	24.2 (338)	
12	26.7 (709)	26.9 (340)	26.4 (369)	
Weight status				<0.001
Normal	76.2 (2026)	71.6 (904)	80.3 (1122)	
Overweight	17.0 (452)	20.7 (261)	13.7 (191)	
Obese	6.8 (182)	7.8 (98)	6.0 (84)	
Living in an urban area	81.1 (2156)	83.1 (1049)	79.2 (1107)*	0.012
>2hrs screen time	59.1 (1573)	63.5(803)	55.1(770)*	<0.001
Screen time				<0.001
None	0.6 (17)	0.6 (8)	0.6 (9)	
Less than 1 hour a day	10.0 (266)	8.1 (102)	11.7 (164)	
1-2 hours	30.2 (804)	27.7 (350)	32.5 (454)	
3-4 hours	37.5 (998)	38.8 (490)	36.4 (508)	
5-6 hours	14.2 (378)	15.5 (196)	13.0 (182)	
7 hours or more	7.4 (197)	9.3 (117)	5.7 (80)	
Engaging in at least 60 minutes of physical activity daily	18.8 (499)	24.5 (310)	13.5 (189)*	<0.001
Psychological Distress	34.3 (914)	25.1 (317)	42.7(592)*	<0.001
Self-esteem	7.9 (209)	5.2 (65)	10.3 (144)*	<0.001
Depressive symptoms	5.7(151)	2.9 (37)	8.2 (114)*	<0.001
School disconnectedness	23.4 (621)	24.9 (315)	21.9 (306)	0.065
School performance (B or below)	51.2 (1361)	59.6 (753)	43.5 (608)*	<0.001

Females coded as 1
*Significant gender difference (p<0.05)

between screen time and poorer academic achievement (Tremblay, et al., 2011a), lower self-esteem (Tremblay, et al., 2011a; Biddle & Asare, 2011; Temmel & Rhodes, 2013) and depressive symptoms (Biddle & Asare, 2011). Of interest is the novel finding that higher screen time was associated with greater risk of school disconnectedness. Tremblay et al. (2011a) found that sustained screen time (i.e. ≥2 hours per day) was a risk factor for behavioural problems, whereas those who engaged in lower levels of screen time were more emotionally stable, sensitive, imaginative, outgoing, self-controlled, intelligent, moralistic, college bound, and less likely to engage in risky behaviour. Given the cross-sectional nature of our study causality cannot be determined. There may be a reverse causality effect occurring, where depressed or disconnected youth may seek social isolation or comfort by engaging in excessive screen time. More longitudinal research is required to examine the temporal mechanisms of the progression and impact of screen time engagement on mental health outcomes like disconnectedness.

Another finding in our study was that meeting PA guidelines was associated with lower school disconnectedness,

Table 2. Associations between screen time, physical activity, and mental health in youth in Ontario, Canada, 2009 (n = 2,660)

	All						Males						Females					
	Screen time			Physical activity			Screen time			Physical activity			Screen time			Physical activity		
	OR	95%CI	*d*	OR	95%CI	*d*	OR	95%CI	*d*	OR	95%CI	*d*	OR	95%CI	*d*	OR	95%CI	*d*
Psychological Distress (coded as 1)	2.01[a]	1.40-2.89	0.39	0.87	0.53-1.43	-0.08	2.40[a]	1.63-3.54	0.48	0.90	0.56-1.47	-0.06	1.59	0.92-2.74	0.27	0.80	0.41-1.57	-0.12
Low self-esteem (coded as 1)	1.32[a]	1.17-1.49	0.15	1.07	0.88-1.30	0.04	1.31[a, b]	1.13-1.53	0.15	1.13[b]	0.90-1.42	0.07	1.30[a]	1.10-1.53	0.14	0.98	0.74-1.29	0.14
Depressive symptoms (coded as 1)	1.92[a]	1.05-3.54	0.36	1.10	0.42-2.96	0.05	2.82[a]	1.09-7.30	0.57	0.94	0.24-3.63	-0.03	1.65	0.87-3.16	0.28	1.19	0.51-2.79	0.28
School disconnectedness (coded as 1)	1.27[a]	1.13-1.43	0.13	0.84[a]	0.72-0.99	-0.10	1.49[a]	1.14-1.68	0.22	0.78[a]	0.64-0.96	-0.14	1.16[a]	1.00-1.34	0.08	0.98	0.74-1.29	-0.01
Academic achievement (B or below) (coded as 1)	1.29[a]	1.10-1.51	0.14	0.98	0.79-1.23	-0.01	1.21[a]	0.92-1.59	0.11	0.94	0.69-1.28	-0.03	1.39[a]	1.16-1.66	0.18	1.06	0.82-1.37	0.18

d = Cohen's *d*; OR = odds ratio, CI =confidence interval; females coded as 1; meeting PA guidelines (≥60 minutes) (coded 1); not meeting screen time guidelines (>2 hours) (coded 1)
[a] significant main effects ($p<0.05$); [b] significant interaction between screen time and physical activity ($p<0.05$)
Adjusted for physical activity/screen time, grade, parental education, weight status, and living in urban/rural areas

especially among males. This is consistent with previous research reporting higher levels of school connectedness with increased PA among 46,588 secondary school adolescents (Yang et al., 2013). Similarly, a survey of 652 adolescents in New Zealand reported higher levels of school engagement that were related with a higher frequency of being physically active (Carter, McGee, Taylor, & Williams, 2007). However, our results were inconsistent with previous findings where Faulkner, Adlaf, Irving, Allison and Dwyer (2009) found school disconnectedness were higher in female students who engaged in no vigorous PA. A cross-sectional study of 3918 Australian youth found no associations with PA levels and school disconnectedness (McLellan, Rissel, Donelley, & Bauman, 1999). These inconsistencies may be due largely to the variation in measures used, where our study focused on moderate-to-vigorous PA and Faulkner et al. (2009) and McLellan et al. (1999) measured vigorous PA only.

In terms of gender differences, higher screen time was associated with all mental health and academic outcomes for males. For females, screen time was associated with lower self-esteem, school disconnectedness, and lower academic achievement. The stronger effects of screen time seen for males may be explained partially by greater screen time observed in males compared to females. This is consistent with previous research reporting gender differences in SED, where males spend significantly more time in screen-based activities (i.e., computer, TV, video games) compared to females, who spend more time in non-screen based SED (i.e., talking on the telephone) (Temmel & Rhodes, 2013). In addition, studies have consistently reported negative mental health associations with SED, particularly screen time among youth regardless of gender (Biddle & Asare, 2011; Tremblay et al., 2011b). Although screen time remains the most prevalent SED in youth, future studies should consider other SED such as the school environment and travel, as well as the time frame in which SED occurs to understand the effects of different SED contexts on mental health outcomes.

A unique contribution of our study is the examination of the independent effects of screen time and PA on mental health, which has been a limitation in previous studies (Gopinath, Hardy, Baur, Burlutsky, & Mitchell, 2012; Iannottii, Kogan, Janssen, & Boyce, 2009; Vallance, Winkler, Gardiner, Healy, Lynch & Owen, 2011). A significant interaction between PA and screen time was noted for self-esteem in males. High screen time was associated with a greater risk of low self-esteem, independent of PA levels. The negative effect of screen time on self-esteem was greater when males were physically active. The positive effect of PA on self-esteem was attenuated when male students reported high screen time compared with those that

Table 3. Interaction of physical activity and sedentary behaviour with self-esteem in male youth in Ontario, Canada, 2009 (n = 1,263)

Low self-esteem	Low screen time	High screen time
Insufficiently active	OR=1.14; 95% CI:0.99-1.33; *d*=0.07; p=0.07	OR=1.34; 95% CI:1.14-1.57; *d*=0.16; p<0.001
Sufficiently active	Reference (coded as 0)	OR=1.84; 95% CI:1.29-2.61; *d*=0.34; p=0.001

OR = odds ratio, CI = confidence interval; not meeting screen time guidelines (>2 hours) (coded 1)
Adjusted for grade, parental education, weight status, and living in urban/rural areas

reported low screen time. This finding further suggests that high screen time may have a particularly pernicious association with mental health. Previous studies have provided evidence for a dose-response relationship, where each additional hour of screen time was associated with an increased risk for lower self-esteem (Russ, Larson, Franke, & Halfon, 2009). However, there may be a potential threshold where sufficient time spent being physically active compensates for high screen time. Previous studies have demonstrated a protective effect of higher levels of PA with psychological aspects of health including self-esteem (Biddle & Asare, 2011; Temmel & Rhodes, 2013). Future studies should continue exploring the interactive effects of PA and screen time on mental health outcomes, using accelerometer and detailed measurement of SED across a variety of contexts.

Our study should be interpreted within the context of important strengths and limitations. To the best of our knowledge, our study is the first to examine the interactive effects of SED and PA with mental health outcomes. Other study strengths include using an existing dataset which was based on a full-probability design that maintains a high response rate, has a large and heterogeneous sample with wide age variation, as well as a highly dispersed distribution of over 100 schools including students from urban and rural schools and at all levels of socio-economic status. Some limitations of this study include the use of self-reported measures of SED and PA, and proxy measures for SES that may contribute to measurement error and response bias. Future research should consider objective measures of SED and PA such as accelerometry, as well as postal codes for SES. Moreover, SED was assessed only through screen time, which represents only one context in which SED can occur. Consequently, the screen time measure was unable to differentiate between various types of screen-based activities. Future studies should consider a wide range of SED and different types of screen-based activities.

In conclusion, high screen time was independently associated with poorer mental health and academic outcomes in Ontario youth. The effects of high screen time are greater than the independent associations of PA among these outcomes. In particular, being physically active did not result in higher self-esteem in the presence of high screen time. These results confirm the value in distinguishing the independent and interactive effects of PA and SED on mental health, and point to the need to construct interventions that can tease out the mechanisms that are associated with this relationship. Adopting a multi-level approach among academic administrators and educators is warranted for promoting PA and reducing SED among youth.

Acknowledgements/Conflicts of Interest

Preparation of this work was funded in part by ongoing support from the Ontario Ministry of Health and Long Term Care. We would like to thank all the schools and students that participated in the study, and the Institute for Social Research at York University for assistance with the survey design and data collection. Bonny Yee-Man Wong is supported by the Heart and Stroke Foundation of Canada and the Canadian Institutes of Health Research (CIHR) Training Grant in Population Intervention for Chronic Disease Prevention: A Pan-Canadian Program (Grant #53893). Guy Faulkner is supported by a Canadian Institutes of Health Research-Public Health Agency of Canada (CIHR-PHAC) Chair in Applied Public Health.

References

Active Healthy Kids Canada (2012). *Is Active Play Extinct?* The Active Healthy Kids Canada 2012 Report Card on Physical Activity for Children and Youth. Toronto, ON: Active Healthy Kids Canada.

Bagley, C., Bolitho, F., & Bertrand, L. (1997). Norms and construct validity of the Rosenberg Self-Esteem Scale in Canadian high school populations: Implications for counselling. *Canadian Journal of Counselling and Psychotherapy*, *31*(1), 82-92.

Barnett, T. A., O'Loughlin, J., Sabiston, C. M., Karp, I., Bélanger, M., Van Hulst, A., & Lambert, M. (2010). Teens and screens: The influence of screen time on adiposity in adolescents. *American Journal of Epidemiology*, *172*(3), 255-262.

Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine, 45*(11), 886-895.

Bonny, A. E., Britto, M. T., Klostermann, B. K., Hornung, R. W., & Slap, G. B. (2000). School disconnectedness: Identifying adolescents at risk. *Pediatrics*,*106*(5), 1017-1021.

Carter, M., McGee, R., Taylor, B., & Williams, S. (2007). Health outcomes in adolescence: Associations with family, friends and school engagement. *Journal of Adolescence*, *30*(1), 51-62.

Colley, R. C., Garriguet, D., Janssen, I., Craig, C., Clarke, J., & Tremblay, M.S. (2011). *Physical activity of Canadian children and youth: Accelerometer results from the 2007-2009 Canadian Health Measures Survey (Health Reports, Catalogue no. 82-003-XPE).* Ottawa, ON: Statistics Canada.

Faulkner, G., Adlaf, E., Irving, H., Allison, K., & Dwyer, J. (2009). School disconnectedness: Identifying adolescents at risk in Ontario, Canada. *Journal of School Health, 79*, 312-318.

Goldberg, D. P., Gater, R., Sartorius, N., Ustun, T. B., Piccinelli, M., & Gureje, O. (1997). The validity of two versions of the GHQ in the WHO study of mental illness in general health care. *Psychological Medine, 27*, 191-197.

Gopinath, B., Hardy, L. L., Baur, L. A., Burlutsky, G., & Mitchell, P. (2012). Physical activity and sedentary behaviours and health-related quality of life in adolescents. *Pediatrics, 130*(1), 167-174.

Haroz, E. E., Ybarra, M. L., & Eaton, W. W. (2014). Psychometric evaluation of a self-report scale to measure adolescent depression: The CESDR-10 in two national adolescent samples in the United States. *Journal of Affective Disorders*, *158*, 154-160.

Han, J. C., Lawlor, D. A., & Kimm, S. (2010). Childhood obesity. *The Lancet*, *375*(9727), 1737-1748.

Iannotti, R. J., Kogan, M. D., Janssen, I., & Boyce, W. F. (2009). Patterns of adolescent physical activity, screen-based media use, and positive and negative health indicators in the U.S. and Canada. *Journal of Adolescent Health, 44*(5), 493-499.

Janssen, I., Katzmarzyk, P. T., Boyce, W. F., Vereecken, C., Mulvihill, C., Roberts, C.,…The Health Behaviour in School-Aged Children Obesity Working Group (2005). Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obesity Reviews, 6*, 123-132. doi: 10.1111/j.1467-789X.2005.00176.x

Janssen, I., & Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioural Nutrition and Physical Activity, 7*, 40, 1-16.

Mann, R. E., Paglia-Boak, A., Adlaf, E. M., Beitchman, J., Wolfe, D., Wekerle, C.,...Rehm, J. (2011). Estimating the prevalence of anxiety and mood disorders in an adolescent general population: An evaluation of the GHQ12. *International Journal of Mental Health and Addiction*, *9*(4), 410-420.

Marshall, S. J., Biddle, S. J., Gorely, T., Cameron, N., & Murdey, I. (2004). Relationships between media use, body fatness and physical activity in children and youth: A meta-analysis. *International Journal of Obesity*, *28*(10), 1238-1246.

Marshall, S. J., Biddle, S. J., Sallis, J. F., McKenzie, Thomas L., & Conway, T. L. (2002). Clustering of sedentary behaviour and physical activity among youth: A cross-national study. *Pediatric Exercise Science, 14*, 401-417.

McLellan, L., Rissel, C., Donnelly, N., & Bauman, A. (1999). Health behaviour and the school environment in New South Wales, Australia. *Social Science & Medicine*, *49*(5), 611-619.

Paglia-Boak, A., Mann, R. E., Adlaf, E. M., Beitchman, J. H., Wolfe, D., & Rehm, J. (2010). *The mental health and well-being of Ontario students, 1991-2009: Detailed OSDUHS findings (CAMH Research Document Series No. 29).* Toronto, ON: Centre for Addiction and Mental Health.

Paglia-Boak, A., Mann, R. E., Adlaf, E. M., & Rehm, J. (2009). *Drug use among Ontario students, 1977-2009: Detailed OSDUHS findings (CAMH Research Document Series No. 27).* Toronto, ON: Centre for Addiction and Mental Health.

Radloff, L. (1977). The CES-D scale: A self report degression scale for research in the general population. *Applied Psychological Measurement, 1*, 385-401.

Rosenberg, M., Schooler, C., & Schoenbach, C. (1989). Self-esteem and adolescent problems: Modeling reciprocal effects. *American Sociological Review, 54*, 1004-1018.

Russ, S. A., Larson, K., Franke, T. M., & Halfon, N. (2009). Associations between media use and health in US children. *Academic Pediatrics*, *9*(5), 300-306.

Temmel, C. S., & Rhodes, R. (2013). Correlates of sedentary behaviour in children and adolescents aged 7-18: A systematic review. *The Health & Fitness Journal of Canada*, *6*(1), 119-199.

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. *Applied Physiology, Nutrition, and Metabolism*, *35*(6), 725-740.

Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C.,...Gorber, S. C. (2011a). Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *International Journal of Behavioural Nutrition & Physical Activity, 8*, 98. doi:10.1186/1479-5868-8-98.

Tremblay, M. S., LeBlanc, A. G., Janssen, I., Kho, M. E., Hicks, A., Murumets, K.,…Duggan, M. (2011b). Canadian sedentary behaviour guidelines for children and youth. *Applied Physiology, Nutrition, and Metabolism,* 36(1), 59-64.

Tremblay, M. S., Warburton, D. E., Janssen, I., Paterson, D. H., Latimer, A. E., Rhodes, R. E.,...Duggan, M. (2011c). New Canadian physical activity guidelines. *Applied Physiology, Nutrition, and Metabolism*, *36*(1), 36-46.

Vallance, J. K., Winkler, E. A., Gardiner, P. A., Healy, G. N., Lynch, B. M., & Owen, N. (2011). Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005-2006). *Preventive Medicine, 53*(4), 284-288.

Yang, F., Tan, K. A., & Cheng, W. J. (2014). The effects of connectedness on health-promoting and health-compromising behaviors in adolescents: Evidence from a statewide survey. *The Journal of Primary Prevention*, *35*(1), 33-46.