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The relationship between physical activity, sedentary behaviour, and depressive symptoms: evidence from a population-based sample of Canadian adolescents

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3 **THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, SEDENTARY**
4 **BEHAVIOUR, AND DEPRESSIVE SYMPTOMS: EVIDENCE FROM A**
5 **POPULATION-BASED SAMPLE OF CANADIAN ADOLESCENTS**
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ABSTRACT

Objectives: Physical and sedentary activities have been identified as potentially modifiable risk factors for many diseases, including mental illness, and may be effective targets for public health policy and intervention. However, the relative contribution of physical activity versus sedentary behaviour to mental health is less clear. This study investigated the cross-sectional association between physical activity, sedentary activity, and depression in a large sample of Canadian teens.

Setting: The National Longitudinal Survey of Children and Youth

Participants: 9,702 survey members who were age 14-15 years between 1996 and 2009.

Primary outcome measure: Symptoms of depression and anxiety at age 14-15. Multinomial logistic regression was used to assess the relationship between physical and sedentary activity and symptoms of depression. Joint models including both physical and sedentary activity were also explored. Models were adjusted for sex, ethnicity, immigration status, family income, parental education, recent major stressful life events, and chronic health conditions.

Results: Physically inactive youth were 1.70 (95%CI: 1.32, 2.19) times more likely to have moderate depressive symptoms and 2.26 (95%CI: 1.74, 2.92) times more likely to have severe depressive symptoms compared to physically active youth. Sedentary activity was not consistently associated with depressive symptomatology. In joint models including both physical and sedentary activity, sedentary activity was not consistently associated with depressive symptoms.

Conclusions: Physical inactivity appears to be significantly related to depressive symptomatology, whilst the relationship between sedentary activity and symptoms of

1
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3 depression is not consistently apparent. The importance of distinguishing these two
4
5 behaviors has relevance for research as well as policies targeting physical activity and
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7 mental health in youth.
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What is already known on this subject?

- Increased physical activity appears to be protective against mental illness
- Several studies have suggested that sedentary behaviour may have a negative impact on mental health
- Few studies have investigated physical activity and sedentary behaviour at the same time

What does this study add?

- Physical inactivity showed a consistent relationship with symptoms of depression in adolescents, in unadjusted and adjusted models
- The relationship between sedentary behaviour and symptoms of depression in adolescents is less clear

Strengths and limitations of this study

- This study was conducted using a nationally representative sample of Canadian youth.
- The large sample size of this study provided sufficient power to detect smaller effects and allowed for a more nuanced approach to covariate selection to adjust for the complex socio-demographic factors present in psychiatric epidemiology.
- While this study used self-reported measures of physical and sedentary activity, the potential misclassifications tend to bias towards the null, suggesting that associations may be stronger than presented within.
- The present study is cross-sectional and cannot comment on the causality of associations.

INTRODUCTION

It has been estimated that more than 20% of adolescents meet diagnostic criteria for a mental disorder before the age of 18,[1] and many mental disorders have their origin in adolescence.[2] Given that the onset of mental illness occurs at a relatively early age compared to other chronic illnesses, it is particularly important to understand the correlates of mental health to identify potentially modifiable risk factors as well as to gain insight into possibilities for intervention. Physical activity such as participation in sports, exercise, etc. has benefits for physical health and has been linked in the primary and secondary prevention of a variety of underlying chronic medical conditions[3] and has also been demonstrated as an effective supplement to treatment for mental health problems.[4] A sedentary lifestyle, has been associated with poor mental health, however the distinction between the two is not often examined.[5,6] Intervening early to reduce sedentary activities and increase physical activity may reduce the odds of developing mental illness.[7]

Understanding the relationship between physical activity, sedentary activity, and mental health is challenging. The DSM-IV diagnostic criteria for major depressive disorder include loss of interest in previously-enjoyed activities, loss of energy, and other symptoms which may increase sedentary activity and decrease physical activity frequency.[8] Recent evidence supports an important role of physical activity in promoting both the physical and mental health and well-being in individuals. A recent study by Wiles et al. suggests that physically active adolescents have lower odds of symptoms of depression, but that no association was detected between the intensity of physical activity and depressive symptoms.[9]

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3 Individuals with depressive disorders have been demonstrated to spend more time engaged
4 in sedentary activities such as television watching, internet use, and video gaming.[10–12]
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6 Participation in sedentary activities, such as video games, has often been described as a
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8 coping mechanisms for depression.[13,14] Sedentary activity may contribute to the
9
10 development of mental illness through a variety of mechanisms. Sanders et al. found that
11
12 increased internet use has been linked to poorer social ties with friends and mothers,
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14 though directionality remained unclear.[15] Victims of cyber bullying have demonstrably
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16 higher levels of both internalizing and externalizing behavioural issues as a result of the
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18 depersonalized nature of online activity.[16] Some preliminary results have suggested that
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20 preference for online communications increases an individual's avoidance of face-to-face
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22 communications, which may lead to social isolation and depression.[17]
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33 It is unclear whether sedentary behaviour on its own increases risk for depression, or
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35 whether the association between sedentary behaviour and decreased physical activity drives
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37 this association - adolescents may be both very physically active and also engage in
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39 sedentary activities. Consequently, the objective of this study was to investigate the
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41 association between adolescent depressive symptoms and both sedentary behaviour and
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43 physical activity, in a large population-based sample.
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METHODS

Sample

This study used data from Statistics Canada's National Longitudinal Survey of Children and Youth. The study, which began data collection in 1994, examines the development of children and youth and their physical, mental and social well-being.[18] The survey was designed using complex survey design to be a representative sample of the children and youth population of Canada at the time of collection. All respondents aged 14-15 between 1996 and 2009 who responded to questions regarding depressive symptoms (see below) were selected and stacked for a single cross-sectional analysis. A total of 11,860 respondents were selected, of whom 2,158 (18.1%) respondents did not have any outcome data, resulting in a sample size of 9,702 respondents for analysis.

Measures

Depressive Symptoms

The primary outcome for this study was symptoms of depression, based on seven items taken from the Ontario Child Health Study.[19,20] Items on this scale closely match DSM criteria for emotional disorders.[21] The statements rated are “I am unhappy or sad,” “I am not as happy as other people my age,” “I am too fearful or nervous,” “I worry a lot,” “I cry a lot,” “I am nervous, high-strung, or tense,” and “I have trouble enjoying myself.” Respondents were asked to rate how well these statements described themselves using the statements “never or not true,” “sometimes or somewhat true,” or “often or very true.” Cronbach’s Alpha for this scale for 14-15 year-olds ranged from 0.76 to 0.81, indicating high internal reliability.[18]

Total scores were grouped into 4 categories representing degrees of severity to account for floor effects (i.e., positively skewed distributions): *no symptoms* (scores below the 50th percentile), *mild symptoms* (scores between the 51st and 75th percentile), *moderate symptoms* (scores between the 76th and 90th percentile), and *severe symptoms* (scores above the 90th percentile).[20,22,23]

Physical Activity

Physical activity was measured using three questions regarding the frequency of the survey member's participation in “in sports with a coach or instructor (except dance, gymnastics or martial arts)”, “... lessons or instruction in other organized physical activities with a coach or instructor such as dance, gymnastics or martial arts”, and “unorganized sports or physical activities without a coach or instructor?”[19] Respondents were provided with five responses, “Most days”, “A few times a week”, “About once a week”, “About once a month” and “Almost never”. Responses were recoded into dichotomous categories, such that “Physically Active” represents participation in the activity at least once a week or more, and “Physically Inactive” comprising “Almost never” and “About once a month”.[24] A composite physical activity score was derived where classification as “Physically Active” in at least one of the three activities was categorized as “Physically Active”, and others were classified as “Physically Inactive”.

Sedentary Activity

Sedentary activity was measured with the following question: “On average, how much time per day does he / she watch T.V., videos or DVDs or play video games?” Response options of “none”, “less than 30 minutes”, “30 minutes to less than an hour”, “1 hour to less than 2 hours”, “2 hours to less than 3 hours” and “3 hours or more”.[19,25,26] This question was

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3 validated using a 7-day television viewing diary and had Spearman correlation coefficients
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5 of 0.36-0.54, and test-retest intra-class correlation scores for the reliability of this ranging
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7 from 0.76 to 0.81.[25,27] Canadian sedentary activity guidelines recommend a maximum
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9 two hours per day for children aged 5-17.[28] To be consistent with recommendations,
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11 children with greater than two hours of sedentary activity per day were classified as
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15 “Sedentary”.

16 17 18 *Covariates*

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20 Covariates were chosen *a priori* due to their association with either physical or sedentary
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22 activity and depression. These included age, sex, child’s ethnicity (caucasian or non-
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24 caucasian), whether the respondent was Canadian born, parental education (less than
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26 secondary school, completion of secondary school, some post-secondary, university or
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28 secondary school, completion of secondary school, some post-secondary, university or
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30 college degree, and other), major stressful life events (such as death of a loved one, major
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32 injury, parental divorce, etc.), chronic health condition (parent and child reported
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34 diagnosed conditions), and substance use (tobacco and alcohol). A measure of income
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36 relative to neighborhood average income was included using the Low Income Cut-Off
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38 (LICO) ratio. This measure is the ratio between a family’s income divided by the low-
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40 income cut-off for that family’s neighbourhood.
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44 45 **Analysis**

46 Multinomial logistic regression was used to examine the relationship between physical and
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48 sedentary activity and symptoms of depression. Odds ratios were obtained for unadjusted
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50 models, as well as a model controlling for covariates.
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3 All frequencies, means, and models were weighted using bootstrapping survey weights to
4 account for complex survey design. In order to retain the greatest number of respondents
5 during the analysis, for each categorical variable an additional category of “missing” was
6 created. Individuals with incomplete or no outcome data, or who were missing
7 observations for continuous variables (age, LICO ratio) were dropped.
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10 All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC).
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13 **Ethical approval**

14 This study received ethical approval from the Ottawa Hospital Research Ethics Boards.
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RESULTS

Respondents tended to be physically active (76.4%) but also frequently engaged in sedentary behaviours (45.4%) (Table 1). They were primarily Caucasian (87.0%).

Respondents' parents tended to have high levels of education (46.4% were university educated), and were primarily Canadian born (74.5%). Respondents who reported higher symptoms of depression were more likely to be female, have a chronic health condition, have experienced recent stressful life events, have tried tobacco, and have a low family income. Respondents who reported higher symptoms of depression were less likely to be physically active but did not differ in their level of sedentary activity (Table 1).

Physical inactivity was associated with increased odds of mild, moderate, and severe depressive symptoms in both unadjusted and adjusted models (Table 2). Sedentary behaviour was less consistently associated with depressive symptoms. Sedentary behaviour was associated with increased odds of moderate depressive symptoms, but not mild or severe symptoms (Table 2).

In the joint model that included both physical activity and sedentary activity (Table 3), being physically inactive was statistically significantly associated with having higher odds of being in the moderate depressive symptom category (OR 1.40, 95% CI: 1.09, 1.80), and the severe depressive symptom category (OR 1.84, 95%CI: 1.42, 2.41). Those who were sedentary had 1.35 times the odds (95%CI: 1.10, 1.66) of being in the moderate depressive symptom category.

Table 1: Weighted Proportion of Respondents by Depressive Symptom Category and Outcome/Covariates¹

		Depressive Symptom Category					χ^2 p-value
Total	(unweighted n=9702)	Total	None	Mild	Moderate	Severe	
		100%	56.5%	21.1%	13.3%	9.1%	
Physical Activity Category	***						<.001
	Active	76.4%	80.3%	74.7%	70.8%	64.9%	
	Sedentary	22.7%	18.9%	24.3%	28.3%	34.4%	
	Missing	0.9%	0.9%	1.0%	0.9%	0.7%	
Sedentary Activity Category							0.384
	Sedentary	45.4%	43.9%	45.7%	49.5%	47.4%	
	Not Sedentary	53.3%	54.7%	53.1%	49.1%	51.2%	
	Missing	1.3%	1.4%	1.2%	1.4%	1.4%	
Sex	***						<.001
	Male	49.9%	59.3%	43.4%	35.7%	27.6%	
	Female	50.1%	40.7%	56.6%	64.3%	72.4%	
Ethnicity							0.832
	Caucasian	87.0%	88.0%	86.0%	85.4%	86.1%	
	Non-Caucasian	7.8%	7.3%	8.6%	8.7%	7.9%	
	Missing	5.2%	4.8%	5.4%	5.9%	5.9%	
PMK Education							0.365
	Less than Secondary	12.2%	11.4%	12.5%	15.6%	11.4%	
	Secondary School	23.9%	24.0%	24.8%	23.2%	21.9%	
	Some Post-Secondary	16.8%	15.8%	17.6%	17.0%	20.9%	
	University/College Degree	46.3%	47.9%	44.1%	43.5%	45.5%	
	Other	<0.1%	0.4%	0.6%	0.4%	0.2%	
	Missing	<0.1%	0.4%	0.4%	0.2%	0.1%	
PMK Canadian Born							0.361
	Yes	74.5%	75.9%	74.5%	70.0%	72.6%	
	No	14.9%	13.8%	15.5%	18.3%	15.5%	
	Missing	10.6%	10.3%	10.0%	11.8%	11.9%	
Presence of Chronic Condition	*						0.024
	Yes	31.1%	30.5%	30.3%	28.9%	39.2%	
	No	67.3%	68.0%	68.0%	69.4%	57.9%	
	Missing	1.7%	1.5%	1.7%	1.7%	2.9%	
Stressful Life Event	***						<.001
	Yes	33.3%	29.6%	35.4%	38.9%	42.9%	
	No	65.6%	69.4%	63.6%	59.7%	55.6%	
	Missing	1.1%	1.0%	1.0%	1.4%	1.5%	
Child Ever Smoked Tobacco	***						<.001
	Yes	39.1%	34.8%	40.3%	48.1%	49.5%	
	No	59.6%	63.9%	58.1%	50.7%	49.2%	
	Missing	1.3%	1.2%	1.6%	1.2%	1.3%	
Child Ever Consumed Alcohol							0.094

Yes	76.1%	75.2%	74.3%	80.1%	80.0%
No	22.3%	23.3%	24.1%	18.4%	18.3%
Missing	1.6%	1.5%	1.6%	1.5%	1.7%

Weighted Means and Standard Errors of Respondents by Depressive Symptom Category and Covariates

	Depressive Symptom Category				F-Test p-value
	Mean (SE)				
	None	Mild	Moderate	Severe	
Age	14.5 (0.023)	14.5 (0.024)	14.6 (0.031)	14.5 (0.036)	0.620
LICO Ratio² Missing (0.41%)	2.6 (0.007)	2.4 (0.067)	2.3 (0.117)	2.4 (0.079)	0.011*

¹Some percentages may not add up to exactly 100% due to rounding.

²The ratio between a family's income divided by the low-income cut-off for that family's neighbourhood. A value greater than one indicates a family has a family income greater than the low-income cut-off for that neighbourhood, whereas a value below 1 would indicate a level beneath the low-income cut-off.

Chi-Square and F-Test: *** p < .001 ** p < .01 * p < .05

Table 2: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

		Depressive Symptom Category		
		Unadjusted Odds Ratio (95% CI) (Weighted)		
		Mild vs None	Moderate vs None	Severe vs None
Adjusted Physical and Sedentary Activity Models				
Model 1: Adjusted Physical Activity¹				
(n missing = 40)				
	Active (Ref)	--	--	--
	Not Active	1.23 (0.99, 1.52)	1.43 (1.12, 1.84)*	1.88 (1.45, 2.44)*
	Missing	1.12 (0.54, 2.32)	1.23 (0.51, 2.94)	0.98 (0.26, 3.69)
Model 2: Adjusted Sedentary Activity¹				
(n missing = 40)				
	Not Sedentary (Ref)	--	--	--
	Sedentary	1.13 (0.94, 1.36)	1.38 (1.13, 1.69)*	1.28 (0.99, 1.65)
	Missing	0.86 (0.41, 1.81)	1.31 (0.68, 2.53)	1.45 (0.56, 3.77)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol) and LICO ratio.

Table 3: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Unadjusted and Adjusted Sedentary and Physical Activity				
Adjusted Model¹ (n missing = 40)		Depressive Symptom Category		
		Unadjusted Odds Ratio (95% CI) (Weighted)		
		Mild vs None	Moderate vs None	Severe vs None
Sedentary Activity Category				
	Not Sedentary (Ref)	--	--	--
	Sedentary	1.12 (0.93, 1.35)	1.35 (1.10, 1.66)*	1.23 (0.95, 1.59)
	Missing	0.80 (0.35, 1.85)	1.26 (0.58, 2.74)	1.57 (0.54, 4.53)
Physical Activity Category				
	Active (Ref)	--	--	--
	Not Active	1.21 (0.97, 1.51)	1.40 (1.09, 1.80)*	1.85 (1.42, 2.41)*
	Missing	1.26 (0.56, 2.83)	1.20 (0.44, 3.31)	0.85 (0.20, 3.66)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol) and LICO ratio.

DISCUSSION AND CONCLUSIONS

In a population-based study of more than 9,700 adolescents, lower physical activity was associated with higher symptoms of depression whereas sedentary activity appeared to have less consistent patterns with depression.

Physical Activity

Results from this study suggest that individuals who reported engaging in physical activity less than one day per week were at higher risk for being in higher depression symptom categories compared to those reporting at least 1 day of physical activity per week, suggesting that physical activity may be protective against depression. This finding is largely consistent with previous research demonstrating associations between physical inactivity and depression. Sund et al. demonstrated that low levels of vigorous physical activity were associated with depressive symptom levels cross-sectionally, and that low levels of vigorous physical activity were associated with high depressive symptom levels one year later in boys, but not girls.[5] This study did find a similar association for boys and girls in terms of lower physical activity levels and increased odds of depressive symptoms. In studies with adults, physical activity levels have also been associated with lower depressive symptomatology.[7,29] supporting findings from the present study.

Physical activity has been studied as a psychosocial buffer against mental illness because it can provide social support, increase self-esteem, as well as engender a feeling of achievement and validation.[30,31] This finding is important because physical activity is a modifiable risk factor and is amenable to intervention.[32,33] Interventions aimed at increasing physical activity among youth may have beneficial effects on risk of depressive

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3 symptoms in children and youth in children and youth,[34,35] as well as other positive
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5 physical health benefits.[3]
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8 9 **Sedentary Activity**

10 Our results show that sedentary activity was associated with increased odds of moderate
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12 depressive symptoms yet not with severe depressive symptoms. This pattern has been seen
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14 in the existing literature. For example, Sund et al. demonstrated that higher levels of
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16 sedentary activity were associated with higher depressive symptoms over time.[5] By
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18 contrast, Hume et al. did not find any cross-sectional or longitudinal associations between
19
20 sedentary time and depressive symptoms among either boys or girls with a mean age of 14
21
22 years.[36] The Hume study, however, had a small sample size (n=155) and skewed heavily
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24 female (60% of sample) compared to the Sund study which had a much larger sample (n=2
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26 644) with a more even distribution of males and females. Furthermore, a systematic
27
28 review of sedentary activity and depression has shown that sedentary activity may be a risk
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30 factor for depression, independent of physical activity, though the studies reviewed
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32 demonstrated methodological weaknesses such as small sample sizes and poor measures of
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34 sedentary activity.[37] This may explain the contradictory results.
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41 **Strengths & Limitations**

42 The large, nationally representative sample included in this study supports smaller studies
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44 which have shown similar associations between participation in physical activity and
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46 reduced levels of depressive symptoms. The data in the NLSCY, although somewhat
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48 dated, shows associations that we would not expect to change give more recent data. As
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50 this is the only population-based study of Canadian youth, this study warrants replication
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52 with other sources of data. The large sample size allows sufficient power to detect smaller
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3 effects and to include a more nuanced approach to covariate selection to properly adjust for
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5 a number of mitigating factors as was done in this study.
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9 The use of self-reported physical and sedentary activity has the potential to introduce bias.
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11 Studies have demonstrated that individuals tend to over-report their physical activity levels
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13 compared to objectively ascertained methods such as accelerometry.[38] This may
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15 misclassify physical activity levels, such that the number of participants who are truly
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17 physically active are lower than those reported in this study. This misclassification tends to
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19 bias results towards the null, suggesting that the associations may be stronger than
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21 presented here.
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26 More precise and objective measures of physical activity may yield different results due to
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28 lower reporting bias and recall bias. Research by Parfitt et. al. demonstrated that higher
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30 levels of vigorous physical activity are predictive of higher self-worth, but not statistically
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32 significantly associated with depressive symptoms.[39] Parfitt's study used accelerometry
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34 to measure physical activity level, a more objective and precise measurement of physical
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36 activity. In addition to more objective measures of physical activity, having longitudinal
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38 data, as opposed to point-measurements, would lead to more robust analyses that would be
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40 helpful in understanding the directionality of associations.
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45 Similarly, the definition of sedentary activity used in the present study may have been too
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47 restrictive. The Canadian Sedentary Activity Guidelines recommend no more than two
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49 hours per day of sedentary activity. However, it is possible that associations with
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51 depression are stronger at higher levels of sedentary activity.
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Conclusions

The present study suggests that physical inactivity is associated with increased risk of depressive symptoms among youth, while associations between sedentary behaviour and depressive symptoms are less clear. Interventions aimed at making youth more physically active may be effective in reducing risk of mental illness.

For peer review only

Contributorship Statement: MAB and IC conceived and designed the study. MAB did the data analysis. MAB, DK, MK, and IC interpreted the results. MAB drafted the manuscript. MAB, DK, MK, and IC critically reviewed the manuscript.

Competing Interest Statement: We have read and understood BMJ policy on declaration of interests and declare that we have no competing interests.

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Data sharing: The data source for this study, the National Longitudinal Study of Children and Youth, can be accessed through Statistics Canada's Research Data Centre program.

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THE RELATIONSHIP BETWEEN LEISURE TIME PHYSICAL ACTIVITY, SEDENTARY BEHAVIOUR, AND SYMPTOMS OF DEPRESSION AND ANXIETY: EVIDENCE FROM A POPULATION-BASED SAMPLE OF CANADIAN ADOLESCENTS

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4 **SEDENTARY BEHAVIOUR, AND SYMPTOMS OF DEPRESSION AND**
5 **ANXIETY: EVIDENCE FROM A POPULATION-BASED SAMPLE OF**
6 **CANADIAN ADOLESCENTS**
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ABSTRACT

Background

Physical and sedentary activities have been identified as potentially modifiable risk factors for many diseases, including mental illness, and may be effective targets for public health policy and intervention. However, the relative contribution of physical activity versus sedentary behaviour to mental health is less clear. This study investigated the cross-sectional association between physical activity, sedentary activity, and symptoms of depression and anxiety at age 14-15 in the National Longitudinal Survey of Children and Youth (NLSCY).

Methods

Respondents aged 14-15 years between 1996 and 2009 who reported on symptoms of depression in the NLSCY were included (n=9,702). Multinomial logistic regression was used to assess the relationship between physical and sedentary activity and symptoms of depression and anxiety. Joint models including both physical and sedentary activity were also explored. Models were adjusted for sex, ethnicity, immigration status, family income, parental education, recent major stressful life events, and chronic health conditions.

Results

The odds of having moderate and severe symptoms of depression and anxiety compared to no symptoms was 1.43 (1.11, 1.84) and 1.88 (1.45, 2.45) times higher, respectively, in physically inactive youth relative to physically active youth. The odds of having moderate and severe symptoms of depression and anxiety compared to no symptoms was 1.38 (1.13, 1.69) and 1.31 (1.02, 1.69) times higher, respectively, in sedentary youth relative to non-sedentary youth. In joint models including both physical and sedentary activity, sedentary activity was not consistently associated with symptoms of depression and anxiety.

Conclusions

Both physical inactivity and sedentary activity appear to be significantly related to symptoms of depression and anxiety. The importance of distinguishing these two behaviors has relevance for research as well as policies targeting physical activity and mental health in youth.

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Strengths and limitations of this study

- The sample was very large (n=9,702) and population-based
- Information was available on numerous potentially confounding factors
- The temporal association between physical activity, sedentary behavior, and symptoms of depression and anxiety can not be inferred in this study
- Physical activity and sedentary behaviour were based on self-report

INTRODUCTION

It has been estimated that more than 20% of adolescents meet diagnostic criteria for a mental disorder before the age of 18,[1] and many mental disorders have their origin in adolescence.[2] Given that the onset of mental illness occurs at a relatively early age compared to other chronic illnesses, it is particularly important to understand the correlates of mental health to identify potentially modifiable risk factors as well as to gain insight into possibilities for intervention. Physical activity such as participation in sports, exercise, etc. has benefits for physical health and has been linked in the primary and secondary prevention of a variety of underlying chronic medical conditions[3] and has also been demonstrated as an effective supplement to treatment for mental health problems.[4] A sedentary lifestyle, has been associated with poor mental health, however the distinction between the two is not often examined.[5,6] Intervening early to reduce sedentary activities and increase physical activity may reduce the odds of developing mental illness.[7]

The DSM-IV diagnostic criteria for major depressive disorder include loss of interest in previously-enjoyed activities, loss of energy, and other symptoms which may increase sedentary activity and decrease physical activity frequency.[8] Recent evidence supports an important role of physical activity in promoting both the physical and mental health and well-being in individuals. A study by Wiles et al. suggests that physically active adolescents have lower odds of symptoms of depression, but that no association was detected between the intensity of physical activity and depressive symptoms.[9] A meta-analysis conducted by Radovic, Gordon and Melvin concluded that there is some evidence to suggest that physical activity can be used to reduce depressive symptoms in adolescents

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3 [10] which is also supported by a systematic review conducted by Carter et. al. [11] A
4 meta-analysis by Korczak et. al. demonstrated that physical activity in childhood or
5
6 adolescence was linked to lower concurrent depressive symptomatology.[12]
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11 Among adolescents, higher levels of screen time was associated with poorer mental health
12 status[13] and that a dose-response may exist.[14] However, the evidence is mixed, with
13
14 some studies showing no link between sedentary activity and depressive symptoms in
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16 adolescents.[15] Individuals with depressive disorders have been demonstrated to spend
17
18 more time engaged in sedentary activities such as television watching, internet use, and
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20 video gaming.[16–18] Participation in sedentary activities, such as video games, has often
21
22 been described as a coping mechanisms for depression.[19,20] Sedentary activity may also
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24 contribute to the development of poor mental health outcomes independent of physical
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26 activity.[21] Sedentary activity may contribute to the development of mental illness
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28 through a variety of mechanisms. Sanders et al. found that increased internet use has been
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30 linked to poorer social ties with friends and mothers, though directionality remained
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32 unclear.[22] Victims of cyber bullying have demonstrably higher levels of both
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34 internalizing and externalizing behavioural issues as a result of the depersonalized nature of
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36 online activity.[23] Some preliminary results have suggested that preference for online
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38 communications increases an individual's avoidance of face-to-face communications,
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which may lead to social isolation and depression.[24]

It is unclear whether sedentary behaviour on its own increases risk for depression, or
whether the association between sedentary behaviour and decreased physical activity drives

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3 this association - adolescents may be both very physically active and also engage in
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5 sedentary activities. Consequently, the objective of this study was to investigate the
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7 association between adolescent depressive symptoms and both sedentary behaviour and
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9 physical activity, in a large population-based sample.
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METHODS

Sample

This study used data from Statistics Canada's National Longitudinal Survey of Children and Youth. The study, which began data collection in 1994, examines the development of children and youth and their physical, mental and social well-being.[25] The survey was designed using complex survey design to be a representative sample of the children and youth population of Canada at the time of collection. Participant consent was collected by Statistics Canada. All respondents aged 14-15 between 1996 and 2009 who responded to questions regarding symptoms of depression and anxiety (see below) were selected and stacked for a single cross-sectional analysis. A total of 11,860 respondents were selected, of whom 2,158 (18.1%) respondents did not have any outcome data, resulting in a sample size of 9,702 respondents for analysis.

Measures

Symptoms of Depression and Anxiety

The primary outcome for this study was symptoms of depression and anxiety, based on seven items taken from the Ontario Child Health Study.[26,27] Items on this scale closely match DSM-III-R criteria for emotional disorders.[28] The statements rated are “I am unhappy or sad,” “I am not as happy as other people my age,” “I am too fearful or nervous,” “I worry a lot,” “I cry a lot,” “I am nervous, high-strung, or tense,” and “I have trouble enjoying myself.” Respondents were asked to rate how well these statements described themselves using the statements “never or not true,” “sometimes or somewhat true,” or “often or very true.” Cronbach’s Alpha for this scale for 14-15 year-olds ranged from 0.76 to 0.81, indicating high internal reliability.[25]

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3 Total scores were grouped into 4 categories representing degrees of severity to account for
4 floor effects (i.e., positively skewed distributions): *no symptoms* (scores below the 50th
5 percentile), *mild symptoms* (scores between the 51st and 75th percentile), *moderate*
6 *symptoms* (scores between the 76th and 90th percentile), and *severe symptoms* (scores above
7 the 90th percentile).[27,29,30]
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10 11 12 13 14 15 16 *Leisure Time Physical Activity*

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18 Leisure time physical activity was measured using three questions regarding the frequency
19 of the survey member's participation in “in sports with a coach or instructor (except dance,
20 gymnastics or martial arts)”, “... lessons or instruction in other organized physical
21 activities with a coach or instructor such as dance, gymnastics or martial arts”, and
22 “unorganized sports or physical activities without a coach or instructor?”[26] Respondents
23 were provided with five responses, “Most days”, “A few times a week”, “About once a
24 week”, “About once a month” and “Almost never”. Responses were recoded into
25 dichotomous categories, such that “Physically Active” represents participation in the
26 activity at least once a week or more, and “Physically Inactive” comprising “Almost never”
27 and “About once a month”. [31] A composite physical activity score was derived where
28 classification as “Physically Active” in at least one of the three activities was categorized
29 as “Physically Active”, and others were classified as “Physically Inactive”.
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46 47 48 *Sedentary Activity*

49 Sedentary activity was measured with the following question: “On average, how much time
50 per day does he / she watch T.V., videos or DVDs or play video games?” Response options
51 of “none”, “less than 30 minutes”, “30 minutes to less than an hour”, “1 hour to less than 2
52 hours”, “2 hours to less than 3 hours” and “3 hours or more”. [26,32,33] This question was
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3 validated using a 7-day television viewing diary and had Spearman correlation coefficients
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5 of 0.36-0.54, and test-retest intra-class correlation scores for the reliability of this ranging
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7 from 0.76 to 0.81.[32,34,35] Canadian sedentary activity guidelines recommend a
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9 maximum two hours per day for children aged 5-17.[36] To be consistent with
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11 recommendations, children with greater than two hours of sedentary activity per day were
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13 classified as “Sedentary”.

14 15 16 17 18 *Covariates*

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20 Covariates were chosen *a priori* due to their association with either physical or sedentary
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22 activity and symptoms of depression and anxiety. These included age, sex, child’s
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24 ethnicity (caucasian or non-caucasian), whether the respondent was Canadian born,
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26 parental education (less than secondary school, completion of secondary school, some post-
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28 secondary, university or college degree, and other), major stressful life events (see
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30 Supplemental Table 1), chronic health condition (parent and child reported diagnosed
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32 conditions, see Supplemental Table 2), and substance use (ever smoked tobacco and ever
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34 consumed alcohol). A measure of income relative to neighborhood average income was
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36 included using the Low Income Cut-Off (LICO) ratio. This measure is the ratio between a
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38 family’s income divided by the low-income cut-off for that family’s neighbourhood.
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40 Additionally, a variable indicating from which cycle of the NLSCY the participant was
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42 from was added to account for the cohort effect.
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49 **Analysis**

50 Multinomial logistic regression was used to examine the relationship between physical and
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52 sedentary activity and symptoms of depression and anxiety. Odds ratios were obtained for
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54 unadjusted models, as well as a model controlling for covariates.
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3 All frequencies, means, and models were weighted using bootstrapping survey weights to
4 account for complex survey design. In order to retain the greatest number of respondents
5 during the analysis, for each categorical variable an additional category of “missing” was
6 created. Individuals with incomplete or no outcome data, or who were missing
7 observations for continuous variables (age, LICO ratio) were dropped. A sensitivity
8 analysis using respondents with complete data was conducted. Sex stratified models were
9 also run. A model including an interaction term between physical and sedentary activity
10 categories was also run.
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21 All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC).
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24 **Ethical approval**

25 This study received ethical approval from the Ottawa Hospital Research Ethics Boards.
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30 **Patient and public involvement**

31 This study is based on analysis of previously collected data. Patients nor members of the
32 public were not involved in this study.
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RESULTS

Respondents tended to be physically active (76.4%) but also frequently engaged in sedentary behaviours (45.4%) (Table 1). They were primarily Caucasian (87.0%).

Respondents' parents tended to have high levels of education (46.4% were university educated), and were primarily Canadian born (74.5%). Respondents who reported higher symptoms of depression and anxiety were more likely to be female, have a chronic health condition, have experienced recent stressful life events, have tried tobacco, and have a low family income. Respondents who reported higher symptoms of depression and anxiety were less likely to be physically active but did not differ in their level of sedentary activity (Table 1).

Physical inactivity was associated with increased odds of mild, moderate, and severe symptoms of depression and anxiety in both unadjusted and adjusted models (Table 2).

Sedentary behaviour also associated with symptoms of depression and anxiety. Sedentary behaviour was associated with increased odds of moderate and severe symptoms of depression and anxiety, but not mild symptoms (Table 2).

In the joint model that included both physical activity and sedentary activity (Table 3), being physically inactive was statistically significantly associated with having higher odds of being in the moderate symptoms of depression and anxiety category (OR 1.40, 95% CI: 1.09, 1.80), and the severe symptoms of depression and anxiety category (OR 1.84, 95%CI: 1.42, 2.41). Those who were sedentary had 1.35 times the odds (95%CI: 1.10, 1.66) of being in the moderate symptoms of depression and anxiety category.

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3 Sex stratified models showed no significant differences in the associations between sexes.
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5 The sensitivity analysis using cases with complete data only provided results consistent
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7 with those presented here. The model including an interaction between physical and
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9 sedentary activity showed no significant interactions.
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Table 1: Weighted Proportion of Respondents by Symptoms of Depression and Anxiety Category and Outcome/Covariates¹

		Symptoms of Depression and Anxiety Category					χ^2 p-value
		Total	None	Mild	Moderate	Severe	
Total	(unweighted n=9702)	100%	56.5%	21.1%	13.3%	9.1%	
Physical Activity Category	***						<.001
	Active	76.4%	80.3%	74.7%	70.8%	64.9%	
	Not Active	22.7%	18.9%	24.3%	28.3%	34.4%	
	Missing	0.9%	0.9%	1.0%	0.9%	0.7%	
Sedentary Activity Category							0.384
	Sedentary	45.4%	43.9%	45.7%	49.5%	47.4%	
	Not Sedentary	53.3%	54.7%	53.1%	49.1%	51.2%	
	Missing	1.3%	1.4%	1.2%	1.4%	1.4%	
Sex	***						<.001
	Male	49.9%	59.3%	43.4%	35.7%	27.6%	
	Female	50.1%	40.7%	56.6%	64.3%	72.4%	
Ethnicity							0.832
	Caucasian	87.0%	88.0%	86.0%	85.4%	86.1%	
	Non-Caucasian	7.8%	7.3%	8.6%	8.7%	7.9%	
	Missing	5.2%	4.8%	5.4%	5.9%	5.9%	
Education of Person Most Knowledgeable (PMK)							0.365
	Less than Secondary	12.2%	11.4%	12.5%	15.6%	11.4%	
	Secondary School	23.9%	24.0%	24.8%	23.2%	21.9%	
	Some Post-Secondary	16.8%	15.8%	17.6%	17.0%	20.9%	
	University/College Degree	46.3%	47.9%	44.1%	43.5%	45.5%	
	Other	<0.1%	0.4%	0.6%	0.4%	0.2%	
	Missing	<0.1%	0.4%	0.4%	0.2%	0.1%	
PMK Canadian Born							0.361
	Yes	74.5%	75.9%	74.5%	70.0%	72.6%	
	No	14.9%	13.8%	15.5%	18.3%	15.5%	
	Missing	10.6%	10.3%	10.0%	11.8%	11.9%	
Presence of Chronic Condition	*						0.024
	Yes	31.1%	30.5%	30.3%	28.9%	39.2%	
	No	67.3%	68.0%	68.0%	69.4%	57.9%	
	Missing	1.7%	1.5%	1.7%	1.7%	2.9%	
Stressful Life Event	***						<.001
	Yes	33.3%	29.6%	35.4%	38.9%	42.9%	
	No	65.6%	69.4%	63.6%	59.7%	55.6%	
	Missing	1.1%	1.0%	1.0%	1.4%	1.5%	
Child Ever Smoked Tobacco	***						<.001
	Yes	39.1%	34.8%	40.3%	48.1%	49.5%	
	No	59.6%	63.9%	58.1%	50.7%	49.2%	
	Missing	1.3%	1.2%	1.6%	1.2%	1.3%	

Child Ever Consumed Alcohol							0.094
Yes	76.1%	75.2%	74.3%	80.1%	80.0%		
No	22.3%	23.3%	24.1%	18.4%	18.3%		
Missing	1.6%	1.5%	1.6%	1.5%	1.7%		

Weighted Means and Standard Errors of Respondents by Symptoms of Depression and Anxiety Category and Covariates

	Symptoms of Depression and Anxiety Category				F-Test p-value
	Mean (SE)				
	None	Mild	Moderate	Severe	
Age	14.5 (0.023)	14.5 (0.024)	14.6 (0.031)	14.5 (0.036)	0.620
LICO Ratio² Missing (0.41%)	2.6 (0.007)	2.4 (0.067)	2.3 (0.117)	2.4 (0.079)	0.011*

¹Some percentages may not add up to exactly 100% due to rounding.

²The ratio between a family's income divided by the low-income cut-off for that family's neighbourhood. A value greater than one indicates a family has a family income greater than the low-income cut-off for that neighbourhood, whereas a value below 1 would indicate a level beneath the low-income cut-off.

Chi-Square and F-Test: *** p < .001 ** p < .01 * p < .05

Table 2: Results of Bootstrapped Multinomial Logistic Regression Modelling

		Symptoms of Depression and Anxiety Category		
		Mild vs None	Moderate vs None	Severe vs None
Adjusted Physical and Sedentary Activity Models				
Unadjusted Odds Ratio (95% CI) (Weighted)				
Model 1: Adjusted Physical Activity¹				
(n missing = 40)				
	Active (Ref)	--	--	--
	Not Active	1.23 (0.99, 1.52)	1.43 (1.11, 1.84)*	1.88 (1.45, 2.45)*
	Missing	1.11 (0.53, 2.31)	1.25 (0.52, 3.00)	1.08 (0.29, 4.10)
Model 2: Adjusted Sedentary Activity¹				
(n missing = 40)				
	Not Sedentary (Ref)	--	--	--
	Sedentary	1.13 (0.94, 1.36)	1.38 (1.13, 1.69)*	1.31 (1.02, 1.69)*
	Missing	0.87 (0.41, 1.81)	1.30 (0.68, 2.51)	1.50 (0.58, 3.86)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol), cycle number and LICO ratio.

Table 3: Results of Bootstrapped Multinomial Logistic Regression Modelling

Joint Adjusted Sedentary and Physical Activity			
Symptoms of Depression and Anxiety Category			
Unadjusted Odds Ratio (95% CI) (Weighted)			
	Mild vs None	Moderate vs None	Severe vs None
Adjusted Model¹ (n missing = 40)			
Sedentary Activity Category			
Not Sedentary (Ref)	--	--	--
Sedentary	1.12 (0.93, 1.35)	1.36 (1.11, 1.67)*	1.26 (0.98, 1.63)
Missing	0.81 (0.35, 1.86)	1.24 (0.57, 2.69)	1.58 (0.54, 4.69)
Physical Activity Category			
Active (Ref)	--	--	--
Not Active	1.21 (0.98, 1.51)	1.40 (1.09, 1.79)*	1.85 (1.42, 2.41)*
Missing	1.25 (0.35, 1.86)	1.24 (0.45, 3.40)	0.93 (0.21, 4.17)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol), cycle number and LICO ratio.

DISCUSSION AND CONCLUSIONS

In a population-based study of more than 9,700 adolescents, lower physical activity was associated with higher symptoms of depression and anxiety whereas sedentary activity appeared to have less consistent patterns with symptoms of depression and anxiety.

Physical Activity

Results from this study suggest that individuals who reported engaging in physical activity less than one day per week were at higher risk for being in higher depression and anxiety symptoms categories compared to those reporting at least 1 day of physical activity per week, suggesting that physical activity may be protective against depression. This finding is largely consistent with previous research demonstrating associations between physical inactivity and depression. Sund et al. demonstrated that low levels of vigorous physical activity were associated with depressive symptoms levels cross-sectionally, and that low levels of vigorous physical activity were associated with high depressive symptoms levels one year later in boys, but not girls.[5] This study did find a similar association for boys and girls in terms of lower physical activity levels and increased odds of depressive symptoms.

Physical activity has been studied as a psychosocial buffer against symptoms of depression and anxiety because it can provide social support, increase self-esteem, as well as engender a feeling of achievement and validation.[37,38] This finding is important because physical activity is a modifiable risk factor and is amenable to intervention.[39,40] Interventions aimed at increasing physical activity among youth may have beneficial effects on risk of

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3 depressive symptoms in children and youth,[41,42] as well as other positive physical health
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5 benefits.[43]
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8 9 **Sedentary Activity**

10 Our results show that sedentary activity was associated with increased odds of moderate
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12 and severe symptoms of depression and anxiety. This pattern has been seen in the existing
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14 literature. For example, Sund et al. demonstrated that higher levels of sedentary activity
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16 were associated with higher depressive symptoms over time.[5] Additionally, a study of
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18 Canadian youth demonstrated an association between increased screen-time and severity
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20 symptoms of depression and anxiety.[18] By contrast, Hume et al. did not find any cross-
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22 sectional or longitudinal associations between sedentary time and depressive symptoms
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24 among either boys or girls with a mean age of 14 years.[15] The Hume study, however,
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26 had a small sample size (n=155) and skewed heavily female (60% of sample) compared to
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28 the Sund study which had a much larger sample (n=2 644) with a more even distribution of
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30 males and females. Furthermore, a systematic review of sedentary activity and depression
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32 has shown that sedentary activity may be a risk factor for depression, independent of
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34 physical activity, though the studies reviewed demonstrated methodological weaknesses
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36 such as small sample sizes and poor measures of sedentary activity.[21] This may explain
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38 the contradictory results.
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45 46 **Strengths & Limitations**

47 The large, nationally representative sample included in this study supports smaller studies
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49 which have shown similar associations between participation in physical activity and
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51 reduced levels of symptoms of depression and anxiety. The data in the NLSCY, although
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53 somewhat dated, shows associations that we would not expect to change give more recent
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3 data. Modern trends indicate a rise in screen use among adolescents. Recent studies have
4 suggested that moderate use of digital screens may not be harmful and may confer some
5 benefits.[44] As this is the only population-based study of Canadian youth, this study
6 warrants replication with other sources of data. The large sample size allows sufficient
7 power to detect smaller effects and to include a more nuanced approach to covariate
8 selection to properly adjust for a number of mitigating factors as was done in this study.
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12 The use of self-reported physical and sedentary activity has the potential to introduce bias.
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14 Studies have demonstrated that individuals tend to over-report their physical activity levels
15 compared to objectively ascertained methods such as accelerometry.[45] This may
16 misclassify physical activity levels, such that the number of participants who are truly
17 physically active are lower than those reported in this study. This misclassification may
18 bias results.
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22 More precise and objective measures of physical activity may yield different results due to
23 lower reporting bias and recall bias. Research by Parfitt et. al. demonstrated that higher
24 levels of vigorous physical activity are predictive of higher self-worth, but not statistically
25 significantly associated with depressive symptoms.[46] Parfitt's study used accelerometry
26 to measure physical activity level, a more objective and precise measurement of physical
27 activity. In addition to more objective measures of physical activity, having longitudinal
28 data, as opposed to point-measurements, would lead to more robust analyses that would be
29 helpful in understanding the directionality of associations.
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3 Having better survey measures to capture other types of physical and sedentary activity,
4 such as active community, incidental physical activity and non-screen based sedentary
5 activity could provide more robust and nuanced results.
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11 Similarly, the definition of sedentary activity used in the present study may have been too
12 restrictive. The Canadian Sedentary Activity Guidelines recommend no more than two
13 hours per day of sedentary activity. However, it is possible that associations with
14 depression are stronger at higher levels of sedentary activity.
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21 **Conclusions**

22 The present study suggests that physical inactivity is associated with increased risk of
23 symptoms of depression and anxiety among youth, while associations between sedentary
24 behaviour and depressive symptoms are less clear. Interventions aimed at making youth
25 more physically active may be effective in reducing risk of mental illness.
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Supplemental Table 1: List of Stressful Life Events in the NLSCY

- Death of parent(s)
- Death in family (other than parents)
- Divorce/separation of parents
- Move
- Stay in hospital
- Stay in foster home
- Other separation from parents
- Illness/injury of child
- Illness/injury of a family member
- Abuse/fear of abuse
- Change in household members
- Alcoholism or mental health disorder in family
- Conflict between parents
- Other

Supplemental Table 2: List of Chronic Conditions in the NLSCY

- Food or digestive allergies
- Respiratory allergies such as hay fever
- Any other allergies
- Asthma
- Arthritis or rheumatism
- Back problems excluding arthritis
- High blood pressure
- Migraine headaches
- Chronic bronchitis or emphysema
- Sinusitis
- Diabetes
- Epilepsy
- Heart disease
- Cancer
- Stomach or intestinal ulcers
- Effects of stroke
- Any other long term condition

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

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract page 1 (b) Provide in the abstract an informative and balanced summary of what was done and what was found page 2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported pages 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses page 5
Methods		
Study design	4	Present key elements of study design early in the paper page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection page 6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants page 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable pages 6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group pages 6-9
Bias	9	Describe any efforts to address potential sources of bias page 9
Study size	10	Explain how the study size was arrived at page 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why pages 6-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding pages 8-9 (b) Describe any methods used to examine subgroups and interactions page 9 (c) Explain how missing data were addressed page 9 (d) If applicable, describe analytical methods taking account of sampling strategy page 9 (e) Describe any sensitivity analyses page 9
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed page 6 (b) Give reasons for non-participation at each stage page 6 (c) Consider use of a flow diagram n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders page 10, 13-14 (b) Indicate number of participants with missing data for each variable of interest page 13-14
Outcome data	15*	Report numbers of outcome events or summary measures page 13
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included page 10-16

		(b) Report category boundaries when continuous variables were categorized page 6-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses page 10-11
Discussion		
Key results	18	Summarise key results with reference to study objectives page 17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias page 18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence page 17-20
Generalisability	21	Discuss the generalisability (external validity) of the study results page 17-20
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based n/a

*Give information separately for exposed and unexposed groups.

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

BMJ Open

THE RELATIONSHIP BETWEEN LEISURE TIME PHYSICAL ACTIVITY, SEDENTARY BEHAVIOUR, AND SYMPTOMS OF DEPRESSION AND ANXIETY: EVIDENCE FROM A POPULATION-BASED SAMPLE OF CANADIAN ADOLESCENTS

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3 **THE RELATIONSHIP BETWEEN LEISURE TIME PHYSICAL ACTIVITY,**
4 **SEDENTARY BEHAVIOUR, AND SYMPTOMS OF DEPRESSION AND**
5 **ANXIETY: EVIDENCE FROM A POPULATION-BASED SAMPLE OF**
6 **CANADIAN ADOLESCENTS**
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38 Number of Appendices: 2

39 Number of Supplementary Files: N/A

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44
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46 MAB did the data analysis. MAB, IC, DK, and MK interpreted the results. MAB wrote the
47 first draft of the manuscript. IC, DK, and MK critically reviewed the manuscript and
48 approved it for submission.

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ABSTRACT

Background

Physical and sedentary activities have been identified as potentially modifiable risk factors for many diseases, including mental illness, and may be effective targets for public health policy and intervention. However, the relative contribution of physical activity versus sedentary behaviour to mental health is less clear. This study investigated the cross-sectional association between physical activity, sedentary activity, and symptoms of depression and anxiety at age 14-15 in the National Longitudinal Survey of Children and Youth (NLSCY).

Methods

Respondents aged 14-15 years between 1996 and 2009 who reported on symptoms of depression in the NLSCY were included (n=9,702). Multinomial logistic regression was used to assess the relationship between physical and sedentary activity and symptoms of depression and anxiety. Joint models including both physical and sedentary activity were also explored. Models were adjusted for sex, ethnicity, immigration status, family income, parental education, recent major stressful life events, and chronic health conditions.

Results

The odds of having moderate and severe symptoms of depression and anxiety compared to no symptoms was 1.43 (1.11, 1.84) and 1.88 (1.45, 2.45) times higher, respectively, in physically inactive youth relative to physically active youth. The odds of having moderate and severe symptoms of depression and anxiety compared to no symptoms was 1.38 (1.13, 1.69) and 1.31 (1.02, 1.69) times higher, respectively, in sedentary youth relative to non-sedentary youth. In joint models including both physical and sedentary activity, sedentary activity was not consistently associated with symptoms of depression and anxiety.

Conclusions

Both physical inactivity and sedentary activity appear to be significantly related to symptoms of depression and anxiety. The importance of distinguishing these two behaviors has relevance for research as well as policies targeting physical activity and mental health in youth.

(282/300 Words)

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Strengths and limitations of this study

- The sample was very large (n=9,702) and population-based
- Information was available on numerous potentially confounding factors
- The temporal association between physical activity, sedentary behavior, and symptoms of depression and anxiety can not be inferred in this study
- Physical activity and sedentary behaviour were based on self-report

INTRODUCTION

It has been estimated that more than 20% of adolescents meet diagnostic criteria for a mental disorder before the age of 18,[1] and many mental disorders have their origin in adolescence.[2] Given that the onset of mental illness occurs at a relatively early age compared to other chronic illnesses, it is particularly important to understand the correlates of mental health to identify potentially modifiable risk factors as well as to gain insight into possibilities for intervention. Physical activity such as participation in sports, exercise, etc. has benefits for physical health and has been linked in the primary and secondary prevention of a variety of underlying chronic medical conditions[3] and has also been demonstrated as an effective supplement to treatment for mental health problems.[4] A sedentary lifestyle, has been associated with poor mental health, however the distinction between the two is not often examined.[5,6] Intervening early to reduce sedentary activities and increase physical activity may reduce the odds of developing mental illness.[7]

The symptoms of depression and anxiety may include loss of interest in previously-enjoyed activities, loss of energy, excessive anxiety, difficulty controlling worry, restlessness, and other symptoms which may increase sedentary activity and decrease physical activity frequency.[8] Recent evidence supports an important role of physical activity in promoting both the physical and mental health and well-being in individuals. A study by Wiles et al. suggests that physically active adolescents have lower odds of symptoms of depression, but that no association was detected between the intensity of physical activity and depressive symptoms.[9] A meta-analysis conducted by Radovic, Gordon and Melvin concluded that there is some evidence to suggest that physical activity can be used to reduce depressive

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3 symptoms in adolescents [10] which is also supported by a systematic review conducted by
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5 Carter et. al. [11] A meta-analysis by Korczak et. al. demonstrated that physical activity in
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7 childhood or adolescence was linked to lower concurrent depressive symptomatology.[12]
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11 Among adolescents, higher levels of screen time was associated with poorer mental health
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13 status[13] and that a dose-response may exist.[14] However, the evidence is mixed, with
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15 some studies showing no link between sedentary activity and depressive symptoms in
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17 adolescents.[15] Individuals with depressive disorders have been demonstrated to spend
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19 more time engaged in sedentary activities such as television watching, internet use, and
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21 video gaming.[16–18] Participation in sedentary activities, such as video games, has often
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23 been described as a coping mechanisms for depression.[19,20] Sedentary activity may also
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25 contribute to the development of poor mental health outcomes independent of physical
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27 activity.[21] Sedentary activity may contribute to the development of mental illness
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29 through a variety of mechanisms. Sanders et al. found that increased internet use has been
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31 linked to poorer social ties with friends and mothers, though directionality remained
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33 unclear.[22] Victims of cyber bullying have demonstrably higher levels of both
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35 internalizing and externalizing behavioural issues as a result of the depersonalized nature of
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37 online activity.[23] Some preliminary results have suggested that preference for online
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39 communications increases an individual's avoidance of face-to-face communications,
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41 which may lead to social isolation and depression.[24]
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52 It is unclear whether sedentary behaviour on its own increases risk for depression, or
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54 whether the association between sedentary behaviour and decreased physical activity drives
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3 this association - adolescents may be both very physically active and also engage in
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5 sedentary activities. Consequently, the objective of this study was to investigate the
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7 association between adolescent depressive symptoms and both sedentary behaviour and
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9 physical activity, in a large population-based sample.
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METHODS

Sample

This study used data from Statistics Canada's National Longitudinal Survey of Children and Youth. The study, which began data collection in 1994, examines the development of children and youth and their physical, mental and social well-being.[25] The survey was designed using complex survey design to be a representative sample of the children and youth population of Canada at the time of collection. Participant consent was collected by Statistics Canada. All respondents aged 14-15 between 1996 and 2009 who responded to questions regarding symptoms of depression and anxiety (see below) were selected and stacked for a single cross-sectional analysis. A total of 11,860 respondents were selected, of whom 2,158 (18.1%) respondents did not have any outcome data, resulting in a sample size of 9,702 respondents for analysis.

Measures

Symptoms of Depression and Anxiety

The primary outcome for this study was symptoms of depression and anxiety, based on seven items taken from the Ontario Child Health Study.[26,27] Items on this scale closely match DSM-III-R criteria for emotional disorders.[28] The statements rated are “I am unhappy or sad,” “I am not as happy as other people my age,” “I am too fearful or nervous,” “I worry a lot,” “I cry a lot,” “I am nervous, high-strung, or tense,” and “I have trouble enjoying myself.” Respondents were asked to rate how well these statements described themselves using the statements “never or not true,” “sometimes or somewhat true,” or “often or very true.” Cronbach’s Alpha for this scale for 14-15 year-olds ranged from 0.76 to 0.81, indicating high internal reliability.[25]

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3 Total scores were grouped into 4 categories representing degrees of severity to account for
4 floor effects (i.e., positively skewed distributions): *no symptoms* (scores below the 50th
5 percentile), *mild symptoms* (scores between the 51st and 75th percentile), *moderate*
6 *symptoms* (scores between the 76th and 90th percentile), and *severe symptoms* (scores above
7 the 90th percentile).[27,29,30]
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10 11 12 13 14 15 16 *Leisure Time Physical Activity*

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18 Leisure time physical activity was measured using three questions regarding the frequency
19 of the survey member's participation in “in sports with a coach or instructor (except dance,
20 gymnastics or martial arts)”, “... lessons or instruction in other organized physical
21 activities with a coach or instructor such as dance, gymnastics or martial arts”, and
22 “unorganized sports or physical activities without a coach or instructor?”[26] Respondents
23 were provided with five responses, “Most days”, “A few times a week”, “About once a
24 week”, “About once a month” and “Almost never”. Responses were recoded into
25 dichotomous categories, such that “Physically Active” represents participation in the
26 activity at least once a week or more, and “Physically Inactive” comprising “Almost never”
27 and “About once a month”. [31] A composite leisure time physical activity score was
28 derived where classification as “Physically Active” in at least one of the three activities
29 was categorized as “Physically Active”, and others were classified as “Physically Inactive”.
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46 47 48 *Sedentary Activity*

49 Sedentary activity was measured with the following question: “On average, how much time
50 per day does he / she watch T.V., videos or DVDs or play video games?” Response options
51 of “none”, “less than 30 minutes”, “30 minutes to less than an hour”, “1 hour to less than 2
52 hours”, “2 hours to less than 3 hours” and “3 hours or more”. [26,32,33] This question was
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3 validated using a 7-day television viewing diary and had Spearman correlation coefficients
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5 of 0.36-0.54, and test-retest intra-class correlation scores for the reliability of this ranging
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7 from 0.76 to 0.81.[32,34,35] Canadian sedentary activity guidelines recommend a
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9 maximum two hours per day for children aged 5-17.[36] To be consistent with
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11 recommendations, children with greater than two hours of sedentary activity per day were
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13 classified as “Sedentary”.

14 15 16 17 18 *Covariates*

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20 Covariates were chosen *a priori* due to their association with either physical or sedentary
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22 activity and symptoms of depression and anxiety. These included age, sex, child’s
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24 ethnicity (caucasian or non-caucasian), whether the respondent was Canadian born,
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26 parental education (less than secondary school, completion of secondary school, some post-
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28 secondary, university or college degree, and other), major stressful life events (see
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30 Supplemental Table 1), chronic health condition (parent and child reported diagnosed
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32 conditions, see Supplemental Table 2), and substance use (ever smoked tobacco and ever
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34 consumed alcohol). A measure of income relative to neighborhood average income was
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36 included using the Low Income Cut-Off (LICO) ratio. This measure is the ratio between a
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38 family’s income divided by the low-income cut-off for that family’s neighbourhood.
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40 Additionally, a variable indicating from which cycle of the NLSCY the participant was
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42 from was added to account for the cohort effect.
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49 **Analysis**

50 Multinomial logistic regression was used to examine the relationship between physical and
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52 sedentary activity and symptoms of depression and anxiety. Odds ratios were obtained for
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54 unadjusted models, as well as a model controlling for covariates.
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3 All frequencies, means, and models were weighted using bootstrapping survey weights to
4 account for complex survey design. In order to retain the greatest number of respondents
5 during the analysis, for each categorical variable an additional category of “missing” was
6 created. Individuals with incomplete or no outcome data, or who were missing
7 observations for continuous variables (age, LICO ratio) were dropped. A sensitivity
8 analysis using respondents with complete data was conducted. Sex stratified models were
9 also run. A model including an interaction term between physical and sedentary activity
10 categories was also run.
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21 All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC).
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24 **Ethical approval**

25 This study received ethical approval from the Ottawa Hospital Research Ethics Boards.
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30 **Patient and public involvement**

31 This study is based on analysis of previously collected data. Patients nor members of the
32 public were not involved in this study.
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RESULTS

Respondents tended to be physically active (76.4%) but also frequently engaged in sedentary behaviours (45.4%) (Table 1). They were primarily Caucasian (87.0%).

Respondents' parents tended to have high levels of education (46.4% were university educated), and were primarily Canadian born (74.5%). Respondents who reported higher symptoms of depression and anxiety were more likely to be female, have a chronic health condition, have experienced recent stressful life events, have tried tobacco, and have a low family income. Respondents who reported higher symptoms of depression and anxiety were less likely to be physically active but did not differ in their level of sedentary activity (Table 1).

Physical inactivity was associated with increased odds of mild, moderate, and severe symptoms of depression and anxiety in both unadjusted and adjusted models (Table 2).

Sedentary behaviour also associated with symptoms of depression and anxiety. Sedentary behaviour was associated with increased odds of moderate and severe symptoms of depression and anxiety, but not mild symptoms (Table 2).

In the joint model that included both leisure time physical activity and sedentary activity (Table 3), being physically inactive was statistically significantly associated with having higher odds of being in the moderate symptoms of depression and anxiety category (OR 1.40, 95% CI: 1.09, 1.80), and the severe symptoms of depression and anxiety category (OR 1.84, 95%CI: 1.42, 2.41) . Those who were sedentary had 1.35 times the odds (95%CI: 1.10, 1.66) of being in the moderate symptoms of depression and anxiety category.

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3 Sex stratified models showed no significant differences in the associations between sexes.
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5 The sensitivity analysis using cases with complete data only provided results consistent
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7 with those presented here. The model including an interaction between physical and
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9 sedentary activity showed no significant interactions.
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Table 1: Weighted Proportion of Respondents by Symptoms of Depression and Anxiety Category and Outcome/Covariates¹

		Symptoms of Depression and Anxiety Category					χ^2 p-value
		Total	None	Mild	Moderate	Severe	
Total	(unweighted n=9702)	100%	56.5%	21.1%	13.3%	9.1%	
Physical Activity Category	***						<.001
	Active	76.4%	80.3%	74.7%	70.8%	64.9%	
	Not Active	22.7%	18.9%	24.3%	28.3%	34.4%	
	Missing	0.9%	0.9%	1.0%	0.9%	0.7%	
Sedentary Activity Category							0.384
	Sedentary	45.4%	43.9%	45.7%	49.5%	47.4%	
	Not Sedentary	53.3%	54.7%	53.1%	49.1%	51.2%	
	Missing	1.3%	1.4%	1.2%	1.4%	1.4%	
Sex	***						<.001
	Male	49.9%	59.3%	43.4%	35.7%	27.6%	
	Female	50.1%	40.7%	56.6%	64.3%	72.4%	
Ethnicity							0.832
	Caucasian	87.0%	88.0%	86.0%	85.4%	86.1%	
	Non-Caucasian	7.8%	7.3%	8.6%	8.7%	7.9%	
	Missing	5.2%	4.8%	5.4%	5.9%	5.9%	
Education of Person Most Knowledgeable (PMK)							0.365
	Less than Secondary	12.2%	11.4%	12.5%	15.6%	11.4%	
	Secondary School	23.9%	24.0%	24.8%	23.2%	21.9%	
	Some Post-Secondary	16.8%	15.8%	17.6%	17.0%	20.9%	
	University/College Degree	46.3%	47.9%	44.1%	43.5%	45.5%	
	Other	<0.1%	0.4%	0.6%	0.4%	0.2%	
	Missing	<0.1%	0.4%	0.4%	0.2%	0.1%	
PMK Canadian Born							0.361
	Yes	74.5%	75.9%	74.5%	70.0%	72.6%	
	No	14.9%	13.8%	15.5%	18.3%	15.5%	
	Missing	10.6%	10.3%	10.0%	11.8%	11.9%	
Presence of Chronic Condition	*						0.024
	Yes	31.1%	30.5%	30.3%	28.9%	39.2%	
	No	67.3%	68.0%	68.0%	69.4%	57.9%	
	Missing	1.7%	1.5%	1.7%	1.7%	2.9%	
Stressful Life Event	***						<.001
	Yes	33.3%	29.6%	35.4%	38.9%	42.9%	
	No	65.6%	69.4%	63.6%	59.7%	55.6%	
	Missing	1.1%	1.0%	1.0%	1.4%	1.5%	
Child Ever Smoked Tobacco	***						<.001
	Yes	39.1%	34.8%	40.3%	48.1%	49.5%	
	No	59.6%	63.9%	58.1%	50.7%	49.2%	
	Missing	1.3%	1.2%	1.6%	1.2%	1.3%	

Child Ever Consumed Alcohol							0.094
Yes	76.1%	75.2%	74.3%	80.1%	80.0%		
No	22.3%	23.3%	24.1%	18.4%	18.3%		
Missing	1.6%	1.5%	1.6%	1.5%	1.7%		

Weighted Means and Standard Errors of Respondents by Symptoms of Depression and Anxiety Category and Covariates

	Symptoms of Depression and Anxiety Category				F-Test p-value
	Mean (SE)				
	None	Mild	Moderate	Severe	
Age	14.5 (0.023)	14.5 (0.024)	14.6 (0.031)	14.5 (0.036)	0.620
LICO Ratio² Missing (0.41%)	2.6 (0.007)	2.4 (0.067)	2.3 (0.117)	2.4 (0.079)	0.011*

¹Some percentages may not add up to exactly 100% due to rounding.

²The ratio between a family's income divided by the low-income cut-off for that family's neighbourhood. A value greater than one indicates a family has a family income greater than the low-income cut-off for that neighbourhood, whereas a value below 1 would indicate a level beneath the low-income cut-off.

Chi-Square and F-Test: *** p < .001 ** p < .01 * p < .05

Table 2: Results of Bootstrapped Multinomial Logistic Regression Modelling

		Symptoms of Depression and Anxiety Category		
		Mild vs None	Moderate vs None	Severe vs None
Adjusted Physical and Sedentary Activity Models				
Unadjusted Odds Ratio (95% CI) (Weighted)				
Model 1: Adjusted Physical Activity¹				
(n missing = 40)				
	Active (Ref)	--	--	--
	Not Active	1.23 (0.99, 1.52)	1.43 (1.11, 1.84)*	1.88 (1.45, 2.45)*
	Missing	1.11 (0.53, 2.31)	1.25 (0.52, 3.00)	1.08 (0.29, 4.10)
Model 2: Adjusted Sedentary Activity¹				
(n missing = 40)				
	Not Sedentary (Ref)	--	--	--
	Sedentary	1.13 (0.94, 1.36)	1.38 (1.13, 1.69)*	1.31 (1.02, 1.69)*
	Missing	0.87 (0.41, 1.81)	1.30 (0.68, 2.51)	1.50 (0.58, 3.86)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol), cycle number and LICO ratio.

Table 3: Results of Bootstrapped Multinomial Logistic Regression Modelling

Joint Adjusted Sedentary and Physical Activity			
Symptoms of Depression and Anxiety Category			
Unadjusted Odds Ratio (95% CI) (Weighted)			
	Mild vs None	Moderate vs None	Severe vs None
Adjusted Model¹ (n missing = 40)			
Sedentary Activity Category			
Not Sedentary (Ref)	--	--	--
Sedentary	1.12 (0.93, 1.35)	1.36 (1.11, 1.67)*	1.26 (0.98, 1.63)
Missing	0.81 (0.35, 1.86)	1.24 (0.57, 2.69)	1.58 (0.54, 4.69)
Physical Activity Category			
Active (Ref)	--	--	--
Not Active	1.21 (0.98, 1.51)	1.40 (1.09, 1.79)*	1.85 (1.42, 2.41)*
Missing	1.25 (0.35, 1.86)	1.24 (0.45, 3.40)	0.93 (0.21, 4.17)

* Statistically significant at $\alpha = 0.05$.

¹Adjusted for age, sex, child's ethnicity, whether the respondent was Canadian born, parental education, major stressful life, chronic health condition, substance use (tobacco and alcohol), cycle number and LICO ratio.

DISCUSSION AND CONCLUSIONS

In a population-based study of more than 9,700 adolescents, lower leisure time physical activity was associated with higher symptoms of depression and anxiety whereas sedentary activity appeared to have less consistent patterns with symptoms of depression and anxiety.

Leisure Time Physical Activity

Results from this study suggest that individuals who reported engaging in leisure time physical activity less than one day per week were at higher risk for being in higher depression and anxiety symptoms categories compared to those reporting at least 1 day of physical activity per week, suggesting that physical activity may be protective against depression. This finding is largely consistent with previous research demonstrating associations between physical inactivity and depression. Sund et al. demonstrated that low levels of vigorous physical activity were associated with depressive symptoms levels cross-sectionally, and that low levels of vigorous physical activity were associated with high depressive symptoms levels one year later in boys, but not girls.[5] This study did find a similar association for boys and girls in terms of lower physical activity levels and increased odds of depressive symptoms.

Physical activity has been studied as a psychosocial buffer against symptoms of depression and anxiety because it can provide social support, increase self-esteem, as well as engender a feeling of achievement and validation.[37,38] This finding is important because physical activity is a modifiable risk factor and is amenable to intervention.[39,40] Interventions aimed at increasing physical activity among youth may have beneficial effects on risk of

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3 depressive symptoms in children and youth,[41,42] as well as other positive physical health
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5 benefits.[43]
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8 9 **Sedentary Activity**

10 Our results show that sedentary activity was associated with increased odds of moderate
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12 and severe symptoms of depression and anxiety. This pattern has been seen in the existing
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14 literature. For example, Sund et al. demonstrated that higher levels of sedentary activity
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16 were associated with higher depressive symptoms over time.[5] Additionally, a study of
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18 Canadian youth demonstrated an association between increased screen-time and severity
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20 symptoms of depression and anxiety.[18] By contrast, Hume et al. did not find any cross-
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22 sectional or longitudinal associations between sedentary time and depressive symptoms
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24 among either boys or girls with a mean age of 14 years.[15] The Hume study, however,
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26 had a small sample size (n=155) and skewed heavily female (60% of sample) compared to
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28 the Sund study which had a much larger sample (n=2 644) with a more even distribution of
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30 males and females. Furthermore, a systematic review of sedentary activity and depression
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32 has shown that sedentary activity may be a risk factor for depression, independent of
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34 physical activity, though the studies reviewed demonstrated methodological weaknesses
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36 such as small sample sizes and poor measures of sedentary activity.[21] This may explain
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38 the contradictory results.
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45 **Joint Physical and Sedentary Activity**

46 When both sedentary and leisure-time physical activity were included in the same model,
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48 sedentary activity was associated with moderate but not with severe symptoms of
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50 depression and anxiety. While the odds ratio in the sedentary activity only model and the
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3 joint model were close (1.31 vs 1.26), it is possible that the slight attenuation of the effect
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5 as a result of including physical activity in the model led to the loss of statistical
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8 significance for those with severe symptoms of depression and anxiety.
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10 11 **Strengths & Limitations**

12 The large, nationally representative sample included in this study supports smaller studies
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14 which have shown similar associations between participation in physical activity and
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16 reduced levels of symptoms of depression and anxiety. The data in the NLSCY, although
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18 somewhat dated, shows associations that we would not expect to change give more recent
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20 data. Modern trends indicate a rise in screen use among adolescents. Recent studies have
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22 suggested that moderate use of digital screens may not be harmful and may confer some
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24 benefits.[44] As this is the only population-based study examining physical and sedentary
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26 activity and its relationship with symptoms of depression and anxiety in Canadian youth,
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28 this study warrants replication with other sources of data. The large sample size allows
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30 sufficient power to detect smaller effects and to include a more nuanced approach to
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32 covariate selection to properly adjust for a number of mitigating factors as was done in this
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34 study.
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41 The use of self-reported physical and sedentary activity has the potential to introduce bias.
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43 Studies have demonstrated that individuals tend to over-report their physical activity levels
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45 compared to objectively ascertained methods such as accelerometry.[45] This may
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47 misclassify physical activity levels, such that the number of participants who are truly
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49 physically active are lower than those reported in this study. This misclassification may
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51 bias results.
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3 More precise and objective measures of physical activity may yield different results due to
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5 lower reporting bias and recall bias. Research by Parfitt et. al. demonstrated that higher
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7 levels of vigorous physical activity are predictive of higher self-worth, but not statistically
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9 significantly associated with depressive symptoms.[46] Parfitt's study used accelerometry
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11 to measure physical activity level, a more objective and precise measurement of physical
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13 activity. In addition to more objective measures of physical activity, having longitudinal
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15 data, as opposed to point-measurements, would lead to more robust analyses that would be
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17 helpful in understanding the directionality of associations.
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22 Having better survey measures to capture other types of physical and sedentary activity,
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24 such as active community, incidental physical activity and non-screen based sedentary
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26 activity could provide more robust and nuanced results.
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30 Similarly, the definition of sedentary activity used in the present study may have been too
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32 restrictive. The Canadian Sedentary Activity Guidelines recommend no more than two
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34 hours per day of sedentary activity. However, it is possible that associations with
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36 depression are stronger at higher levels of sedentary activity.
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39 40 **Conclusions**

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42 The present study suggests that physical inactivity is associated with increased risk of
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44 symptoms of depression and anxiety among youth, while associations between sedentary
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46 behaviour and depressive symptoms are less clear. Interventions aimed at making youth
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48 more physically active may be effective in reducing risk of mental illness.
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Supplemental Table 1: List of Stressful Life Events in the NLSCY

- Death of parent(s)
- Death in family (other than parents)
- Divorce/separation of parents
- Move
- Stay in hospital
- Stay in foster home
- Other separation from parents
- Illness/injury of child
- Illness/injury of a family member
- Abuse/fear of abuse
- Change in household members
- Alcoholism or mental health disorder in family
- Conflict between parents
- Other

Supplemental Table 2: List of Chronic Conditions in the NLSCY

- Food or digestive allergies
- Respiratory allergies such as hay fever
- Any other allergies
- Asthma
- Arthritis or rheumatism
- Back problems excluding arthritis
- High blood pressure
- Migraine headaches
- Chronic bronchitis or emphysema
- Sinusitis
- Diabetes
- Epilepsy
- Heart disease
- Cancer
- Stomach or intestinal ulcers
- Effects of stroke
- Any other long term condition

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

	Item No	Recommendation
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract page 1 (b) Provide in the abstract an informative and balanced summary of what was done and what was found page 2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported pages 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses page 5
Methods		
Study design	4	Present key elements of study design early in the paper page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection page 6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants page 6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable pages 6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group pages 6-9
Bias	9	Describe any efforts to address potential sources of bias page 9
Study size	10	Explain how the study size was arrived at page 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why pages 6-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding pages 8-9 (b) Describe any methods used to examine subgroups and interactions page 9 (c) Explain how missing data were addressed page 9 (d) If applicable, describe analytical methods taking account of sampling strategy page 9 (e) Describe any sensitivity analyses page 9
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed page 6 (b) Give reasons for non-participation at each stage page 6 (c) Consider use of a flow diagram n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders page 10, 13-14 (b) Indicate number of participants with missing data for each variable of interest page 13-14
Outcome data	15*	Report numbers of outcome events or summary measures page 13
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included page 10-16

		(b) Report category boundaries when continuous variables were categorized page 6-8
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses page 10-11
Discussion		
Key results	18	Summarise key results with reference to study objectives page 17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias page 18-19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence page 17-20
Generalisability	21	Discuss the generalisability (external validity) of the study results page 17-20
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based n/a

*Give information separately for exposed and unexposed groups.

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