The relationship between physical and sedentary activity on the mental health outcomes of children and youth in the National Longitudinal Survey of Children and Youth

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Disclaimer

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I leave you with a passage that has resonated with me personally during these challenging times:

> ***O lumière ! c'est le cri de tous les personnages placés, dans le drame antique, devant leur destin. Ce recours dernier était aussi le nôtre et je le savais maintenant. Au milieu de l'hiver, j'apprenais enfin qu'il y avait en moi un été invincible.***
>
> **Retour à Tipasa, Albert Camus (1952)**

Abstract

Introduction:
Mood disorders are a serious burden on Canadians. Physical and sedentary activity are easily modifiable risk factors for many diseases. An association with depression could have important implications

Objective:
To investigate any cross-sectional or longitudinal association between physical activity, sedentary activity, and depression in the National Longitudinal Survey of Children and Youth (NLSCY).

Methods:
These studies used both a stacked cross-sectional and a trajectory/latent class analysis design Univariate and multivariate multinomial logistic regressions were used to assess the relationship between physical and sedentary activity and depression using the emotional disorder-anxiety scale for children and youth available in the NLSCY.

Results:
When accounting for covariates, physically inactive respondents had increased odds of higher depressive symptom scores. Sedentary activity was only statistically significantly associated with depressive symptoms in the cross-sectional design.

Conclusions:
Physical inactivity is significantly associated to depressive symptomatology. The relationship between sedentary activity and depression is inconclusive.

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Chapter 1: Introduction

Introduction

Increased research and policy focus is being brought to bear on the issue of mental health and illness. In 2010, the global economic burden of mental illness was estimated to be US$ 2,493 billion and is expected to rise to USD$ 6,046 billion by 2030.[1] 2003 Canadian estimates place the economic burden of mental illness at CAD$ 50.8 billion.[2] Aside from the direct medical costs of treating and managing mental illness, there are a number of indirect costs, such as lost productivity, absenteeism, unnecessary incarceration, and homelessness.[3]

At the federal level, a policy focus has been placed on mental health, especially through Bill C-300, which calls for the development of a federal framework for suicide prevention[4], as well as the recently released report by the Mental Health Commission of Canada which outlines a series of mental health priorities for Canada.[5]

There are many forms of mental illness, with mood disorders, including depression, and anxiety disorders being among the most common. Estimates show that between 0.8 and 4.6% of Canadians have had a mood disorder in the past year, and 12.2% have had an anxiety disorder.[6] The onset of half of all lifetime mental disorders is estimated to be at the median age of 14 years, with anxiety disorders having an estimated median age of onset of 11 years, and mood disorders having an estimated median age of onset of 30 years.[7] Given that the onset of mental illness is at a relatively early age compared to most chronic illnesses such as type 2 diabetes mellitus[8] and cardiovascular disease[9], it is particularly

important to understand the pathways to mental illness starting from conception to early adulthood. In addition, depression and anxiety have been linked to suicidal ideation,[10,11] which can be a precursor to suicidal behaviour.[12]

A number of factors have been posited as being causative or proxies for causative factors for mental illness. For mood disorders and anxiety, risk factors include socioeconomic status[13], genetic predispositions[14,15], maternal depression[16], stressful and traumatic life events[17], underlying medical conditions[18] and being non-heterosexual[19,20].

Effective treatments for mood and anxiety disorders are available and include pharmacotherapy, through a wide variety of classes of drugs such as selective serotonin reuptake inhibitors[21–23] and benzodiazepines[24,25], as well as psychotherapies, including cognitive behavioural therapies[26,27]. In addition, physical activity has been used successfully alone and as an adjunct to other therapies as a means of reducing symptoms on both depression and anxiety in both healthy and clinical populations[28–32].

While access to effective treatments is an important part of managing the health of those with mental illness, it is becoming apparent that small actions on the series of modifiable risk factors for disease can have disproportionately large impacts on the prevention or development of a disease. Physical activity has benefits for physical health and has been linked in the primary and secondary prevention of a variety of underlying chronic medical conditions[33]. A sedentary lifestyle has been associated with mental illness but causality remains unclear[34,35]. Intervening early to reduce the amount of hours spent on sedentary activities and increase the number of hours spent on physical activities, may reduce the odds of developing a mental illness[36].

Current Evidence

Sedentary activity may contribute to the development of mental illness through a variety of mechanisms. A study by Sanders et al. found that increased internet use has been linked to poorer social ties with friends and mothers, but not fathers, though directionality remained unclear[37]. While it is suggested that certain types of internet use, such as online role-playing games were related to increased social network formation among players, this effect has not been successfully demonstrated[38]. Victims of cyber bullying have demonstrably higher levels of both internalizing and externalizing behavioural issues as a result of the depersonalized nature of online activity[39]. Some preliminary results have suggested that preference for online communications increases an individual's avoidance of face-to-face communications[40]. Online gaming can also be used by individuals as a means of avoidance of the challenges of daily life[41]. In a latent class analysis of a large sample, Carli et. al. found that in addition to a primary high-risk group of adolescents with elevated levels of sedentary activity and media use that were more likely to use alcohol and drugs excessively, smoke heavily, had reduced sleep, and increased truancy, another high risk class of adolescents emerged that only had reduced sleep, sedentary behaviour and high media use, and no other risk factors. Termed the "invisible risk" group, for not being a traditionally high-risk for suicidal behaviour and other psychiatric disorders, when compared to the more traditional "high risk" group, the "invisible risk" group was just as likely to experience depression both clinical and subclinical, anxiety, and suicidal thoughts[42].

In a cross-sectional analysis conducted by King, Parkinson, Adamson, et.al., children who were overweight or obese were more likely to be associated with lower levels

of accelerometrically-measured physical activity and sedentary activity[43]. Individuals who engage in higher levels of sedentary activity may be stigmatized as a result of body weight or other personality characteristics. Vartanian and Novak demonstrated that 97% of their survey sample had experienced weight stigma at some point in their lives and that nearly half of respondents experience it regularly (defined as at least once per week). Having experienced weight stigma was also associated with exercise-avoidance behaviour, which has implications for weight management programs for those who are obese[44]. This is consistent with research by Storch, et.al., who demonstrated that peer victimization of overweight or obese children was inversely associated with physical activity levels[45].

Addiction to sedentary activity, particularly increased internet use and video gaming, may also be associated with mental illness[46–48]. A recent literature review by Ko et. al. evaluated the associations of internet addiction to psychiatric disorders and found that a relationship exists between internet addictions and attention deficit hyperactivity disorder (ADHD), social phobias, substance use disorders, depression, and hostility. However, the literature review was unable to comment on the temporal relationship between the internet addiction and the psychiatric disorders.[49] However, internet addiction and excessive internet use has been associated with co-morbid affective disorders, anxiety disorders, and attention deficit disorders in cross-sectional analyses[50].

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. Sigfusdottir et. al. examined the role that physical activity can play in moderating the relationship between family conflict and depression for adolescents. The study concludes that in the absence of physical activity, the relationship between

family conflict and depressed mood is strengthened, and that the presence of physical activity can mitigate some of the depressed mood that can arise as a result of family conflict. This mitigation effect is more apparent in girls than boys, though do not speculate as to why this effect exists[51].

. Babiss and Gangwisch conclude in their study that participation in sporting activities reduces the odds of depression and suicidal ideation. Furthermore, the results of their study suggest that self-esteem and social support act as mediators in the relationship between sports participation and depression and suicidal ideation, demonstrated by the fact that the association between depression and sports participation was attenuated when self-esteem and social support levels were included in modelling. However, given the cross-sectional nature of this analysis, the authors caution that directionality cannot be commented on[52].

A number of biological and biochemical processes are influenced by physical and sedentary activity, including catecholamines, serotonin, γ-Aminobutyric acid, CO_2 reactivity, and sleep regulation.

Catecholamines are a class of neurotransmitters made up primarily of epinephrine, norepinephrine and dopamine. These neurotransmitters are involved in a variety of neurological processes such as the fight-or-flight response of the sympathetic nervous system (epinephrine, norepinephrine), stress (norepinephrine) and engagement of the reward-driven learning systems (dopamine). In a sample of individuals with high and low trait anxiety, levels of epinephrine and norepinephrine were the same at both rest and after low-intensity exercise, but subjects with high trait anxiety showed a statistically significant

increase in plasma norepinephrine in response to moderate-to-high intensity exercise demonstrating increased stress reactivity to physical exercise.[53] Additionally, a combination of a mental stressor followed by physical activity can increase blood cortisol levels and indicates a sustained hypothalamic-pituitary-adrenal axis response, which results in an increased stress reaction.[54]

Serotonin is a neurotransmitter of the monoamine class and is important in the regulation of mood, as well as playing an important role in food intake and the gastrointestinal tract. Serotonin is a primary target of many of the modern class of antidepressant drugs known as selective serotonin reuptake inhibitors (SSRIs). Physical activity has been demonstrated to have an impact on blood serotonin concentrations. In a recent trial, individuals assigned to an exercise group versus a stretching-only control group showed significant decreases in blood serotonin levels compared to controls, an effect which the authors state is similar to the action of SSRIs.[55]

γ-Aminobutyric acid (GABA) is a neurotransmitter involved in regulating neuronal excitation whose activity is inhibited in mood and anxiety disorders. A study examining the effect of a yoga exercise program compared to a walking exercise program of the same intensity demonstrated that participants in the yoga program showed a greater improvement in mood and state anxiety scores than those in the walking program. Additionally, increased levels of GABA were shown in the yoga group, indicating that different types of exercises may have different impacts on the psychological functioning of individuals.[56] Studies have also demonstrated that the decreased levels of physical activity observed in patients with major depression are related to a "dopaminergic deficit" effect.[57]

Physical activity may also play a role in mitigating the sensations of fear associated with panic disorders. For example, anxiety symptoms can reliably be induced using a carbon dioxide (CO_2) reactivity challenge through the inhalation of a 65% O_2 / 35% CO_2 air mixture. Challenge reactivity anxiety symptom intensity was lower in subjects who were engaged in physical exercise versus a non-exercise control group.[58] Additionally the intensity of exercise can also modify this effect.[59]

Physical activity also plays a role in regulating sleep, while certain sedentary activities may impact sleep. Disordered sleeping patterns are noted as one of the diagnostic signs for depressive disorders. For example, in a prospective study, frequent internet surfers at baseline were more likely to report sleep disturbances versus less frequent users one year later.[60] Major depressive disorder outpatients with higher levels of physical activity have been noted to have cortisol patterns that are more consistent with appropriate diurnal cycles than those with lower levels of physical activity, which could indicate an impact of physical exercise in sleep regulation and cortisol regulation.[61] Increases in physical activity have also been associated with better sleep outcomes, as demonstrated by reduced sleep-maintenance disorders in those who are physically active.[62]

The multitude of biological and social factors at play in both physical and sedentary activity makes understanding the relationship between physical activity, sedentary activity and depression and anxiety particularly 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 the number of hours spent on sedentary activities and decrease physical activity frequency.[63] Individuals with depressive and anxiety disorders have been demonstrated to spend more time engaged in sedentary

activities such as television watching, internet use and video gaming.[49,64–66] In addition, various sedentary activities are often used as coping mechanisms for depression and anxiety. Video game use, for example, has been suggested as a means through which escapism and pleasure-seeking coping behaviour is expressed.[38,41,67] Consequently, disentangling cause and effect can be challenging.

Recent empirical evidence supports an important role for physical activity in promoting both the physical and mental health and well-being in individuals, and a growing body of evidence supports the assertion that sedentary activity can have a negative impact on individual health and well-being. A recent cross-sectional study conducted by Wiles et al. suggests that adolescents who are more physically active have lower odds of symptoms of depression, but that no association was detected between the intensity of physical activity and depressive symptoms.[68] A study among men aged 20-87 years also confirmed the assertion that meeting minimum physical activity guidelines in the United States showed decreased depressive symptomology.[69] A study by Pasco, Jacka et. al. noted that individuals with higher positive affect scores were more likely to be regular exercisers.[70] The challenge inherent in these cross-sectional studies is that they cannot unpack the complex longitudinal nature of depression and anxiety given their long period of onset and the inability to distinguish between cause and effect.

Some longitudinal studies do exist, but are currently inconclusive. A longitudinal study of adolescents aged 13-23 conducted by Birkeland, Torsheim and Wold concluded that physical activity and depressive symptoms are inversely related, however, they could not provide conclusive evidence for the directionality of this relationship.[71] A longitudinal evaluation of the Maastricht Aging Study concluded that engaging in physical activity at

study baseline could predict a protective factor for depression at the end of the study, and that consistent physical activity across the 6-year follow-up also was a protective factor against depression at the end of follow-up. Mean age for this population was 48.9 years at baseline. [72] Additionally, Jacka, Pasco et. al. noted that lower levels of physical activity in childhood was associated with a 35% increase in the odds for developing depression in adulthood, however physical activity was measured retrospectively and as a single measure, limiting the usefulness of this finding.[73]

Patten et al. concluded that the onset of major depression was predictive of decreased physical activity levels in the Canadian National Population Health Survey, however, they noted that the measures of physical activity and depression were relatively unsophisticated and were not confirmed in an objective way, which could impact the relevance of the study.[74] Additionally, a study by Al Mamun et al. demonstrated that self-perception of being overweight in adolescence, after controlling for physical activity and other factors, was also significantly predictive as a risk factor for the onset of depression in young adulthood in both males and females.[75] A difference in the relationship between physical activity and the context of the physical activity (workplace versus leisure-time) has been noted.[76]

However, a recent study by Mekary et. al used isotemporal substitution to examine the substitution of physical exercise with sedentary activity using the Nurses' Health Study. Their results demonstrate that when 60 minutes of walking of any of three speeds (slow, medium and high) is replaced by television watching, participants in the study were at a greater risk of depression. However, when slow- and medium-paced walking replaced television watching, no such effect existed, but when high-speed walking replaced

television watching, participants were at a lower risk for depression.[77] This study and its associated methodology hold promise for future areas or research in substitution of sedentary activity with different types of physical activities and their effect on mental health outcomes.

A recent Cochrane review of exercise interventions for depression concluded that exercise seems to improve the symptoms of depression in those with a diagnosis of depression. However, when only the three methodologically sound trials were included, as opposed to all twenty-five studies included in the meta-analysis, the effect size was both small and non-significant. The authors of that review suggest that additional methodologically sound research is required to draw any further conclusions.[78] Supporting this assertion, a systematic review conducted by Mammen and Faulkner of studies evaluating physical activity as a means to prevent depression found high-quality evidence in prospective studies in using physical activity to prevent future episodes of depression.[79] However, a study conducted by Toseeb et. al. on 736 adolescent participants using accelerometry and heart-rate sensing equipment to objectively measure physical activity at study baseline found no association with baseline physical activity and depressive symptomatology at the termination of the study three years later, positing that physical activity did not play a role in preventing adolescent depressive symptomatology.[80]

Given the inconclusive nature of the current evidence on the longitudinal relationship between depression and anxiety and physical and sedentary activity, further research is needed. It is evident given the symptom profile of depression that the onset of depression and anxiety can lead to a decrease in motivation to engage in all activities, including physical activity.[63] It remains to be seen whether exercise can be used to prevent

the development of depression, and what role sedentary behaviour plays in this relationship.

Objectives

This research project has three primary research objectives:

1. **To examine, cross-sectionally, the relationship between physical activity, sedentary activity and symptoms of depression in children and youth.**

   Hypothesis: Individuals who engage in less sedentary activity and more physical activity are less likely to demonstrate symptoms of depression.

2. **To determine how trajectories of physical and sedentary activity in childhood affect the development of symptoms of depression in adolescence.**

   Hypothesis: Physical activity in childhood and youth can both act as a protective factor for developing depression later in life and that early childhood sedentary activity can be a risk factor for the development of depression later in life. (See Figure 1.1).

3. **To longitudinally examine the association between sedentary and physical activity and suicidal ideation.**

   Hypothesis: Children and youth who are more physically active are less likely to be having suicidal thoughts than kids who are more sedentary.

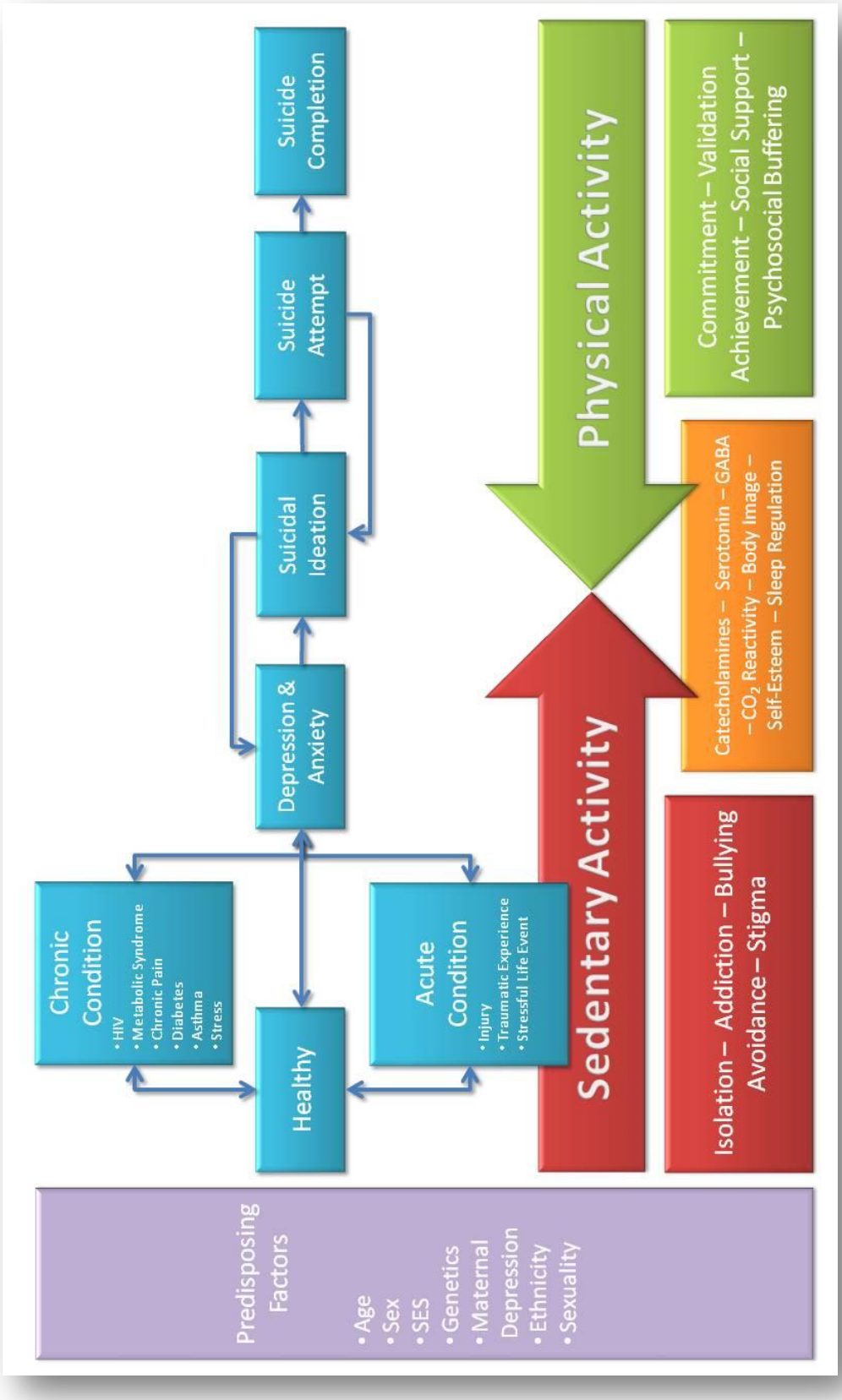
Theoretical Model

Figure 1 presents a theoretical model outlining the hypothesised relationship between physical activity, sedentary activity and the pathway from depression to suicide via suicidal ideation/attempt.

According to this model, individuals may have a number of pre-disposing factors for depression and anxiety, as indicated in the leftmost column. In the top half of the model is the proposed pathway from health, on the left, to suicide on the right. An individual may move from a healthy status to depressed/anxious status either via a chronic health condition or an acute event, or directly due to no discernible cause. Once depressed, an individual may return to health either because of treatment of the depression/anxiety, the underlying chronic condition or the end of an acute event, or directly for no discernable reason. However, a depressed individual may progress further to suicidal ideation, suicidal attempt, and ultimately suicide completion. Suicide completion is a terminal node, and so no further movement along the pathway may occur. However, those who engage in suicidal ideation or attempt suicide may return to depressed/anxious status and even healthy status depending on a number of factors, such as social support, treatment interventions, physical activity, etc.

Finally, underneath the pathway are two arrows representing sedentary activity and physical activity. This model suggests that sedentary activity may push an individual from left to right along the pathway (worsening health outcomes) while physical activity may work counter to that, pushing people from right to left (improving health outcomes), the mechanisms by which this action is taking place being indicated under each respective arrow, with common mechanisms between both arrows.

Figure 1 – A theoretical model of the relationship between depression, suicide, sedentary activity and physical activity.



On the Difference between Being Physically Inactive and Sedentary

Understanding the difference between physical inactivity and sedentary activity is important. While it may be intuitive to think of either being physically active or sedentary, in fact it is possible to meet physical activity guidelines or lead a physically active lifestyle while still engaging in high levels of sedentary activity. A review by Tremblay et. al. differentiated between "active couch potatoes" and "active non-couch potatoes".[81] Both are individuals that engage in at least daily minimum physical activity during the day, but the active couch potatoes had consistently more sedentary activity such as sitting, laying down, than active non-couch potatoes, which may engage in more activities such as standing, light walking, bending down or reaching.

For example, consider an individual who works all day in an office setting, only getting up from their desk maybe once or twice during the day, who then drives to and from work, spends an hour at the gym, and then returns home to watch some Netflix while enjoying delivery from that new place down the street. Contrast this with an individual who cycles in to their office job, gets up every hour or so to stretch their legs and body for five minutes, cycles home, spends half an hour in the gym, makes dinner at home (standing in the kitchen, of course), and then has a little walk before settling with a book for bed. While both might be considered physically active, meeting daily physical activity targets, clearly the latter individual is engaging in less sedentary activity.

With this in mind, it's important to remember that being physically active does not mean not being sedentary, and vice-versa.

Chapter 2: Physical and Sedentary Activity and Their Relationship to Depressive Symptom Scores in the National Longitudinal Survey of Children and Youth: A Cross-Sectional Analysis.

Abstract

Introduction:
Between 0.8 and 4.6% of Canadians have had a mood disorder, including depression, in the past year. A growing body of research is beginning to explore the relationship between depression and physical and sedentary activity. As physical activity is a low-cost, easily modifiable risk factor for many diseases including diabetes, heart disease, metabolic syndrome, a demonstrated association with physical activity could have important health and policy implications

Objective:
To investigate if there exists a cross-sectional association between physical activity, sedentary activity, and depression in the National Longitudinal Survey of Children and Youth (NLSCY).

Methods:
9,702 respondents aged 14-15 from each cycle of the NLSCY with complete Ontario Child Study (OCS) emotional disorder scores were selected and stacked for a single

cross-sectional analysis. Univariate and multivariate multinomial logistic regressions were used to assess the relationship between physical and sedentary activity and depression using the emotional disorder-anxiety scale for children and youth available in the NLSCY. Joint models including both physical and sedentary activity were also explored.

Results:

When controlling for age, sex, parental immigration status, education, neighborhood socio-economic status, substance use (alcohol, tobacco), presence of chronic condition and experience of major stressful life event, physically inactive respondents had odds 1.70 (95%CI: 1.32, 2.19) higher than in the reference group (physically active) of being in the medium depressive symptom category. Physically inactive individuals had odds 2.26 (95%CI: 1.74, 2.92) times higher than those in the physically active reference group of being in the high depressive symptom category. Sedentary activity was not statistically significantly associated with depressive symptom category. In joint models including both physical and sedentary activity, sedentary activity was not statistically significantly associated with depression.

Conclusions:

Physical inactivity appears to be significantly related to depressive symptomatology, but the relationship between sedentary activity and depression is inconclusive and continues to be unclear, and there does not appear to be any interaction between physical and sedentary activity levels.

Introduction

Estimates show that between 0.8 and 4.6% of Canadians had a mood disorder in the past year, and 12.2% have had an anxiety disorder.[6] The onset of half of all lifetime mental disorders is estimated to be at the median age of 14 years, with anxiety disorders having an estimated median age of onset of 11 years and mood disorders having an estimated median age of onset of 30 years.[7] Given that the onset of mental illness occurs at a relatively early age compared to most chronic illnesses such as type 2 diabetes mellitus[8] and cardiovascular disease[9], it is particularly important to understand the pathways and intervention points to mental illness. In addition, depression and anxiety have been linked to suicidal ideation.[10,11]

While having effective treatments is an important part of managing the health of those with mental illness, it is becoming increasingly important and recognized that small actions on the series of modifiable risk factors for disease can have disproportionately large impacts on the prevention of the development of a disease. For example, physical activity has benefits for physical health and has been linked in the primary and secondary prevention of a variety of underlying chronic medical conditions[33] and has also been demonstrated as an effective treatment adjunct for mental health.[78] A sedentary lifestyle has been associated with mental illness but the causal pathway remains unclear[34,35], much as the pathway leading to the prevention of mental illness by physical activity currently remains unclear. Intervening early to reduce the amount of time spent on sedentary activities and increase the number of hours spent on physical activities, may reduce the odds of developing a mental illness[36].

The multitude of biological and social factors at play in both physical and sedentary activity makes understanding the relationship between physical activity, sedentary activity, and depression and anxiety particularly 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 the number of hours spent on sedentary activities and decrease physical activity frequency.[63] Individuals with depressive and anxiety disorders have been demonstrated to spend more time engaged in sedentary activities such as television watching, internet use, and video gaming.[49,64–66] In addition, various sedentary activities are often used as coping mechanisms for depression and anxiety. Video game use, for example, has been suggested as a means through which escapism and pleasure-seeking coping behaviour is expressed.[38,41,67]

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 but the directionality of these relationships remain problematic. For example, Sigfusdottir et. al. examined the role that physical activity can play in moderating the relationship between family conflict and depression for adolescents. The study concludes that in the absence of physical activity, the relationship between family conflict and depressed mood is strengthened, and that the presence of physical activity can mitigate some of the depressed mood that can arise as a result of family conflict, and that this effect is more apparent in girls than in boys.[51]

Recent empirical evidence supports an important role of physical activity in promoting both the physical and mental health and well-being in individuals, and a growing body of evidence supports the assertion that sedentary activity can have a negative impact on individual health and well-being. A recent cross-sectional study conducted by Wiles et al. suggests that adolescents who are more physically active have lower odds of symptoms of depression, but that no association was detected between the intensity of

physical activity and depressive symptoms.[68] A study among men aged 20-87 years also confirmed the assertion that physical activity meeting minimum guidelines in the United States showed decreased depressive symptomology.[69]

It is evident, given the symptom profile of depression, that the onset of depression and anxiety can lead to a decrease in motivation to engage in all activities, including physical activity. It remains to be seen whether exercise can be used to prevent the development of depression and anxiety, or what role sedentary behaviour plays in this relationship.

Hypothesis

This study hypothesizes that increased physical activity will be associated with lower depressive symptom scores, and that increased sedentary activity will be associated with higher depressive symptom scores. Additionally, this study hypothesizes that there exists an interaction between physical and sedentary activity on depressive symptom scores.

Materials and Methods

Study Design

This study uses data from the National Longitudinal Survey of Children and Youth, which is a bi-annual study conducted and published by Statistics Canada and sponsored by Human Resources and Skills Development Canada. The study, which began data collection in 1994, examines the development of children and youth and their physical, mental and social well-being.[82] The survey comprises 8 cycles, with respondents aged 0-25 years old in multiple cohorts.

In Cycle 1, respondents were selected from the pre- and post-1994 Labour Force Survey and followed longitudinally. Some respondents were also included in the National Population Health Survey. A maximum of four respondents was selected from each household. In Cycle 2, some respondents were dropped due to budgetary constraints and the restriction on the maximum number of respondents per household was dropped to two to reduce the burden on participating households. In Cycle 4, "households with two or more consecutive cycles of non-response would be dropped from collection (along with households with one cycle of non-response followed by the status 'Temporarily moved')".[83] In following cycles, respondents with too many consecutive non-responses were also dropped.

Information contained in the survey is primarily conducted by a household interview with the person most knowledgeable (PMK) about the child. This was typically the mother. Other PMK included fathers, step-parents or adoptive parents.[83] A youth component was conducted for selected respondents aged 16 and above. An adult component for the PMK was also administered. Data was collected by trained Statistics Canada personnel and interviews were only conducted in English and French.

At cycle 8 of the survey, the total number of respondents is 26,662, with an overall response rate of 73.7%. 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.

Sample Population

All respondents aged 14-15 from each cycle with complete Ontario Child Health Study Emotional Disorder/Anxiety scale data were selected and stacked for a single cross-sectional analysis. A total of 11,860 respondents were selected of which 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, similar to a study conducted by Naicker et. al,[84] is an emotional disorder-anxiety scale for children and youth, based on seven items taken from the Ontario Child Health Study. Higher scores on this scale are indicative of greater emotional disorder.[84,85] This scale is chosen as it closely matches the DSM-III criteria for emotional disorders.[86] 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." The Chronbach's Alpha for this scale for 14-15 year-olds in cycle 5 was 0.760[a], in cycle 6 was 0.784, in cycle 7 was 0.793, in cycle 8 was 0.810, indicating high internal reliability.[82]. As in previous studies, data was categorized into quantiles to address skewness and floor effects in the data.[87]

Total scores were grouped into 4 categories representing degrees of severity while accounting for floor effects (i.e., positively skewed distributions): *no symptoms* (scores below the 50th percentile), *low 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). These percentile scores were calculated for the whole stacked cross-sectional sample. This method is consistent with previous studies.[84,87–91]

As a result, the outcome for this study is a respondent's depressive symptom category (as enumerated above) for the emotional disorder-anxiety scale measured at ages 14-15, as data

[a] A Cronbach's alpha was only calculated in cycles 1, 6, 7, and 8. In cycles 2-5, only the cycle 1 Cronbach's alpha was reported.

was collected at this age group in 5 out of 8 cycles, thus maximizing sample size, and would capture early onset cases of emotional disorders.[82]

Physical Activity

The first major exposure for this study is physical activity, which was measured using three questions in the child self-report survey. The three questions asked children the frequency of the their 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?" [85] Respondents were provided with five responses, "Most days", "A few times a week", "About once a week", "About once a month" and "Almost never". Consistent with Arim, et. al., 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" composing "Almost never" and "About once a month".[92] Finally, a composite physical activity score was derived for the final analysis, 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, the second primary exposure, is measured by a question asking how many hours of television or videos watched per day or video games played at home per day [93,94]. The question is derived from the World Health Organization Health Behaviour in School-Aged Children survey. The question posed is "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".[85] This question was validated using a 7-day television viewing diary and had Spearman correlation coefficients of 0.36-0.54, and test-retest intra-class correlation scores for the reliability of this ranging from 0.76 to 0.81.[93,95,96]

Canadian sedentary activity guidelines recommend a maximum two hours per day for children aged 5-17.[97] To be consistent with recommendations, children with greater than two hours of sedentary activity per day were classified as "Sedentary", and those with less than or equal to two hours classified as not sedentary for the purposes of this analysis.

Covariates

Covariates were chosen *a priori* due to their association with either physical or sedentary activity and depression. Covariates include age, sex, child's ethnicity, whether the PMK is Canadian born, parental education, family income relative to neighbourhood income using the LICO ratio, major stressful life events (such as death of a loved one, exposure to suicide, major injury, loss of job, etc., as reported by PMK or self-reported), whether there is the presence of a chronic health condition (parent and child reported diagnosed conditions) and substance use (tobacco and alcohol). Illicit drug use was originally chosen but could not be used at it was not measured consistently across cycles.

Age was chosen as a covariate as it has been associated with trends in physical and sedentary activity among children and youth as well as depression, namely that as children grow older they are more likely to develop emotional disorders such as depression.[98–100] Males and females engage in differing patterns of sedentary and physical behaviours and females are associated with increased risk of depression and so sex has been chosen as a covariate. [52,101,102]

Ethnicity was chosen as it has also been associated with different patterns of physical activity among children as well as depression.[100,103] Whether a child is an immigrant or was born in Canada has also been associated with different health behaviours, including physical activity and has also been associated with depression.[104,105] Parental education has been noted as a mediator between socioeconomic status and mental health outcomes.[13] Neighbourhood characteristics have been associated with both sedentary and physical activity levels and mental health outcomes.[106–108] Major stressful life events have been associated with depression among adolescents.[109] An individual's health status has been associated with differing levels of physical activity as well as mental health status.[18,110] Substance use has also been associated with differing levels of physical activity as well as mental health status. [111,112]

All covariates are from the cycle in which the respondent was 14-15.

Due to the relatively large sample size of this study, all analyses were conducted with the appropriate consideration towards power, as well as respecting the minimum 10 respondents per independent variable used in modelling.

Missingness

While no one variable exhibited more than 19% missingness (see Table 1), dropped observations due to any missing variables in the multinomial logistic regression modeling was as high as 33% in adjusted models and varied from 17-25% in unadjusted models. In order to retain the greatest number of respondents during the analysis, for each categorical variable an additional category of "missing" was created and those with missing data for those variables were assigned. This helped to limit the dropped observations in each of the models to approximately 19% in adjusted models, and also provided insight to see if

having a missing value for that exposure or covariate was statistically significantly different for the reference category for that variable.

Analytical Methods

All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC). Descriptive statistics were generated and are presented in Table 2.1.

Ordinal logistic regression was originally used to examine the relationship between physical and sedentary activity and symptoms of anxiety and depression at ages 14-15 in a stacked cross-sectional analysis covering cycles 3-8. However, as the proportional odds assumption was violated, multinomial logistic regression was used instead. Odds ratios were obtained for unadjusted models, as well as a model controlling for covariates Additionally, an interaction between physical and sedentary activity was included in two models to investigate if there was any interaction between one's physical activity status and sedentary activity status.

All frequencies, means, and models were weighted using bootstrapping weights. As individuals were pulled from multiple cycles, bootstrapping weights from cycle 1, in which every respondent in this subsample appeared were selected. This was done to ensure that all individuals had weights from a common cycle.

Results

Sample descriptive statistics are found in Tables 2.1 and 2.2. The sample had a mean age of 14.5 years old, are evenly split between females (50.1%) and males (49.9%), tended to be physically active (76.4%), somewhat sedentary (53.3%), and primarily Caucasian (87.0%). Respondents' PMK tended to have high levels of education, nearly half were university

educated (46.4%), Canadian born (74.5%), with a mean LICO ratio of 2.6. Respondents tended not to have a chronic condition (67.3%), not have experienced a stressful life event as described above (67.3%), not have ever tried tobacco (59.6%), but tended to have tried alcohol (76.1%).

Statistically significant difference in groups by symptom category are detected in physical activity category ($p < .001$), sex ($p < .001$), presence of chronic condition ($p = 0.024$), child ever having experienced a stressful life event ($p < .001$) and having ever tried tobacco ($p < .001$). Significant group differences were also present in LICO ratios ($p = 0.011$).

Tables 2.3a and 2.3b show results from the unadjusted and adjusted models for physical activity, respectively. In the unadjusted model (Table 2.3a), physically inactive individuals had odds 1.39 (95%CI: 1.14, 1.70) times higher of being in the low depressive symptom category than those who are physically active. Physically inactive respondents had odds 1.70 (95%CI: 1.32, 2.19) higher of being in the medium depressive symptom category those who are physically active. Physically inactive individuals had odds 2.26 (95%CI: 1.74, 2.92) times higher of being in the high depressive symptom category than those who are physically active. Respondents for whom the physical activity category was missing had no statistically significant differences compared to the reference group, regardless of depressive symptom category.

When controlling for all covariates in the adjusted model (Table 2.3b), physically inactive respondents no longer had statistically significant different odds than those who were physically active for being in the low depressive symptom category with odds 1.23 (95%CI: 0.99, 1.52) times higher than those who were physically active. However, this particular result is marginal. Physically inactive respondents had odds 1.43 (95%CI: 1.12, 1.84) higher than

physically active respondents of being in the medium depressive symptom category, and also had odds 1.88 (95%CI: 1.45, 2.44) higher than those who are physically active of being in the high depressive symptom category. Statistically significant covariates associated with depression across all score categories included being female, age in the medium depressive symptom category, having a PMK not born in Canada in the medium category, having a chronic condition in the high depressive symptom category, having ever experienced a stressful life event across all score categories, and having ever smoked tobacco across all score categories. No odds ratios in any of the missing categories of the primary outcome or of the covariates were statistically significantly different from the reference group.

In the unadjusted sedentary activity model (Table 2.3c), sedentary respondents had odds 1.26 times higher (95%CI: 1.04, 1.52) of being in the medium depressive symptom category, versus those who were not sedentary. However, sedentary respondents had no statistically significantly increased odds of being in other depressive symptom categories. When adjusting for covariates (Table 2.3d), sedentary respondents continued to have statistically significant odds of being in the medium depressive symptom category, but those odds had increased to 1.38 (95%CI: 1.13, 1.69) times those who were not sedentary. No other depressive symptom category had statistically significantly increased odds. Statistically significant covariates included being female across all score categories, age in the medium depressive symptom category, having a PMK not born in Canada in the medium depressive symptom category, having a chronic condition in the high depressive symptom category, having ever experienced a stressful life event across all score categories, and having ever smoked tobacco across all score categories. No odds ratios in any of the missing categories of the primary outcome or of the covariates were statistically significantly different from the reference group.

In a joint unadjusted model of physical activity and sedentary activity (Table 2.3e), the relationship between being sedentary and depressive symptom category disappeared across all depressive symptom categories. Being physically inactive was statistically significantly associated with having higher odds of being in the low depressive symptom category (OR 1.38, 95%CI: 1.13, 1.69), medium depressive symptom category (OR 1.67, 95% CI: 1.30, 2.15), and the high depressive symptom category (OR 2.24, 95%CI: 1.72, 2.91), versus those who were physically active .

In a joint adjusted model of physical and sedentary activity (Table 2.3f), those who were sedentary had 1.35 times the odds (95%CI: 1.10, 1.66) of being in the medium depressive symptom category, but no statistically significant increase in odds of being in the low or high depressive symptom category, versus those who were not sedentary. This is a change from the unadjusted model, where no statistically significant increases in odds were present across all categories. Being physically inactive did not have a statistically significant increase in odds in the low depressive symptom category (OR: 1.21, 95%CI: 0.97, 1.51) which marks a difference from the unadjusted model. However, being physically inactive did have statistically significant increases in being in the medium depressive symptom category (OR 1.40, 95%CI: 1.09, 1.80) and in the high depressive symptom category (OR: 1.85, 95%CI: 1.42, 2.41[b]). versus those who are physically inactive. Statistically significant associations between covariates and depressive symptom category also existed for being female across all score categories, for a 1 year age increase in the medium depressive symptom category, for having a PMK not Canadian born in the medium depressive symptom category, for the presence of a chronic condition in the high depressive symptom category, for having experience a stressful

[b] Hey look! A palindromic 95% confidence interval. Neat!

life event across all symptom categories, and for having ever smoked tobacco across all score categories.

Two additional models exploring a joint relationship between physical and sedentary activity with a multiplicative interaction term, and depressive symptom category were also generated, however for both models the interaction term was not statistically significant, and provided no further insight into the analysis (interaction term p-value for unadjusted model: p=0.9977; for adjusted model: p=0.9987). Additionally, additive interaction terms were explored, but were found not significant based on the method developed by Andersson et al.[113]

Table 2.1: Weighted Proportion of Respondents by Depressive Symptom Category and Outcome/Covariates[1]

	Depressive Symptom Category					χ^2 p-value
	Total	**None**	**Low**	**Medium**	**High**	
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%	
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%	

[1]Some percentages may not add up to exactly 100% due to rounding.
Chi-Square: *** $p < .001$ ** $p < .01$ * $p < .05$

Table 2.2: Weighted Means and Standard Errors of Respondents by Depressive Symptom Category and Covariates

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

* Statistically significant at $\alpha = 0.05$.

Table 2.3a: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 1 – Unadjusted Physical Activity (n missing = 0)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Category			
Active (Ref)	--	--	--
Not Active	1.39 (1.14, 1.70) *	1.70 (1.32, 2.19) *	2.26 (1.74, 2.92) *
Missing	1.21 (0.62, 2.36)	1.20 (0.53, 2.68)	1.01 (0.29, 3.47)

* Statistically significant at $\alpha = 0.05$.

Table 2.3b: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 2 – Adjusted Physical Activity (n missing = 40)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Category			
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)
Sex			
Male (Ref)	--	--	--
Female	1.85 (1.56, 2.21)*	2.56 (2.07, 3.16)*	3.68 (2.83, 4.78)*
Age (per 1 year increase)	1.10 (0.91, 1.31)	1.28 (1.03, 1.60)*	1.11 (0.86, 1.43)
LICO Ratio (per 1 unit increase)	0.94 (0.88, 1.00)	0.95 (0.88, 1.03)	0.98 (0.90, 1.06)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.10 (0.69, 1.76)	0.99 (0.57, 1.74)	1.11 (0.56, 2.17)
Missing	1.08 (0.70, 1.67)	1.08 (0.62, 1.86)	1.11 (0.63, 1.94)
PMK Education			
University/College Degree	--	--	--
Some Post-Secondary	1.09 (0.86, 1.37)	1.05 (0.76, 1.46)	1.23 (0.90, 1.70)
Secondary School	1.03 (0.81, 1.30)	0.96 (0.76, 1.22)	0.84 (0.61, 1.16)
Less than Secondary	1.01 (0.74, 1.38)	1.22 (0.84, 1.80)	0.80 (0.54, 1.20)
Other	1.38 (0.14, 13.17)	1.15 (0.19, 7.17)	0.45 (<0.01, 52.83)
Missing	0.87 (0.10, 7.91)	0.39 (<0.01, 55.75)	0.12 (<0.01, >999.99)
PMK Canadian Born			
Yes (Ref)	--	--	--
No	1.14 (0.76, 1.72)	1.60 (1.03, 2.47)*	1.35 (0.81, 2.24)
Missing	0.92 (0.68, 1.24)	1.15 (0.81, 1.64)	1.13 (0.76, 1.72)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.01 (0.81, 1.25)	0.95 (0.77, 1.18)	1.56 (1.21, 2.00)*
Missing	0.73 (0.25, 2.13)	1.22 (0.35, 4.29)	0.47 (0.17, 1.26)
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.24 (1.02, 1.50)*	1.39 (1.12, 1.72)*	1.50 (1.19, 1.89)*
Missing	1.84 (0.60, 5.62)	0.83 (0.19, 3.58)	2.96 (0.60, 14.49)
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.23 (1.02, 1.47)*	1.52 (1.22, 1.88)*	1.59 (1.20, 2.11)*
Missing	0.86 (0.34, 2.22)	1.29 (0.54, 3.09)	1.21 (0.42, 3.51)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	0.89 (0.70, 1.13)	1.14 (0.86, 1.51)	1.14 (0.81, 1.60)
Missing	0.94 (0.36, 2.41)	0.98 (0.42, 2.27)	0.88 (0.41, 1.87)

* Statistically significant at $\alpha = 0.05$.

Table 2.3c: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 3 – Unadjusted Sedentary Activity (n missing = 0)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Category			
Not Sedentary (Ref)	--	--	--
Sedentary	1.07 (0.90, 1.27)	1.26 (1.04, 1.52) *	1.15 (0.92, 1.45)
Missing	0.88 (0.39, 2.00)	1.11 (0.60, 2.07)	1.12 (0.45, 2.78)

* Statistically significant at $\alpha = 0.05$.

Table 2.3d: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 4 – Adjusted Sedentary Activity (n missing = 40)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Category			
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)
Sex			
Male (Ref)	--	--	--
Female	1.91 (1.60, 2.28) *	2.73 (2.20, 3.39) *	3.98 (3.07, 5.17) *
Age (per 1 year increase)	1.10 (0.92, 1.32)	1.30 (1.04, 1.62) *	1.13 (0.88, 1.46)
LICO Ratio (per 1 unit increase)	0.94 (0.88, 1.00)	0.95 (0.87, 1.03)	0.96 (0.88, 1.06)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.10 (0.68, 1.77)	0.97 (0.55, 1.72)	1.11 (0.56, 2.19)
Missing	1.10 (0.71, 1.69)	1.12 (0.66, 1.91)	1.16 (0.65, 2.06)
PMK Education			
University/College Degree	--	--	--
Some Post-Secondary	1.08 (0.85, 1.36)	1.03 (0.74, 1.43)	1.22 (0.89, 1.68)
Secondary School	1.03 (0.82, 1.30)	0.96 (0.75, 1.22)	0.86 (0.62, 1.20)
Less than Secondary	1.02 (0.75, 1.40)	1.23 (0.85, 1.80)	0.85 (0.57, 1.26)
Other	1.35 (0.14, 12.68)	1.06 (0.17, 6.67)	†
Missing	0.92 (0.10, 8.18)	†	†
PMK Canadian Born			
Yes (Ref)	--	--	--
No	1.15 (0.76, 1.73)	1.63 (1.05, 2.52) *	1.38 (0.83, 2.29)
Missing	0.92 (0.69, 1.24)	1.17 (0.83, 1.64)	1.17 (0.78, 1.75)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.00 (0.81, 1.25)	0.95 (0.76, 1.18)	1.56 (1.22, 2.00) *
Missing	0.73 (0.25, 2.12)	1.26 (0.36, 4.41)	0.43 (0.17, 1.24)
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.25 (1.03, 1.51) *	1.41 (1.14, 1.75) *	1.56 (1.24, 1.96) *
Missing	1.84 (0.60, 5.62)	0.82 (0.19, 3.53)	3.00 (0.59, 15.38)
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.23 (1.03, 1.48) *	1.52 (1.23, 1.88) *	1.63 (1.23, 2.18) *
Missing	0.83 (0.34, 2.06)	1.36 (0.54, 3.38)	1.39 (0.46, 4.22)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	0.88 (0.69, 1.11)	1.11 (0.84, 1.48)	1.09 (0.77, 1.53)
Missing	0.92 (0.37, 2.33)	0.95 (0.41, 2.22)	0.85 (0.40, 1.80)

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Table 2.3e: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 5 – Unadjusted Sedentary and Physical Activity, No Interaction (n missing = 0)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Category			
Not Sedentary (Ref)	--	--	--
Sedentary	1.05 (0.89, 1.25)	1.21 (1.00, 1.48)[†]	1.09 (0.86, 1.38)
Missing	0.81 (0.32, 2.07)	1.06 (0.51, 2.21)	1.15 (0.41, 3.22)
Physical Activity Category			
Active (Ref)	--	--	--
Not Active	1.38 (1.13, 1.69)[*]	1.67 (1.30, 2.15)[*]	2.24 (1.72, 2.91)[*]
Missing	1.34 (0.61, 2.94)	1.22 (0.48, 3.08)	0.96 (0.25, 3.76)

[*] Statistically significant at $\alpha = 0.05$.
[†] $p = 0.0520$

Table 2.3f: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 6 – Adjusted Sedentary and Physical Activity, No Interaction (n missing = 40)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High 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)
Sex			
Male (Ref)	--	--	--
Female	1.88 (1.57, 2.25) *	2.65 (2.14, 3.29) *	3.78 (2.91, 4.91) *
Age (per 1 year increase)	1.10 (0.92, 1.32)	1.29 (1.04, 1.61) *	1.12 (0.86, 1.44)
LICO Ratio (per 1 unit increase)	0.94 (0.88, 1.00)	0.95 (0.88, 1.03)	0.98 (0.90, 1.06)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.09 (0.68, 1.74)	0.96 (0.54, 1.69)	1.08 (0.55, 2.12)
Missing	1.09 (0.70, 1.68)	1.10 (0.64, 1.89)	1.12 (0.64, 1.97)
PMK Education			
University/College Degree	--	--	--
Some Post-Secondary	1.08 (0.85, 1.36)	1.03 (0.74, 1.43)	1.22 (0.88, 1.69)
Secondary School			
Less than Secondary	1.00 (0.73, 1.37)	1.19 (0.82, 1.73)	0.78 (0.53, 1.17)
Other	1.37 (0.14, 13.01)	1.09 (0.17, 6.93)	†
Missing	0.87 (0.10, 7.73)	†	†
PMK Canadian Born			
Yes (Ref)	--	--	--
No	1.15 (0.76, 1.73)	1.62 (1.05, 2.51) *	1.37 (0.82, 2.27)
Missing	0.91 (0.67, 1.24)	1.14 (0.81, 1.62)	1.12 (0.74, 1.70)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.00 (0.81, 1.24)	0.94 (0.76, 1.17)	1.54 (1.20, 1.98) *
Missing	0.73 (0.25, 2.14)	1.28 (0.36, 4.52)	0.47 (0.18, 1.28)
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.24 (1.02, 1.50) *	1.39 (1.13, 1.73) *	1.51 (1.20, 1.91) *
Missing	1.85 (0.61, 5.65)	0.83 (0.19, 3.62)	3.02 (0.61, 14.93)
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.22 (1.02, 1.47) *	1.49 (1.20, 1.85) *	1.58 (1.18, 2.10) *
Missing	0.82 (0.33, 2.08)	1.32 (0.53, 3.29)	1.29 (0.43, 3.83)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	0.89 (0.70, 1.13)	1.14 (0.86, 1.52)	1.15 (0.82, 1.62)
Missing	0.94 (0.37, 2.40)	0.97 (0.41, 2.29)	0.88 (0.41, 1.86)

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Discussion and Conclusions

This present study sought to better understand the relationship between physical and sedentary activity and depressive symptom severity through the use of a depressive symptom category.

Physical Activity

The primary findings of the study are that physical activity is significantly associated with the depressive symptom category in unadjusted and adjusted models, however falling out of significance in the low depressive symptom category in adjusted models. In joint models including both sedentary and physical activity, sedentary activity is not significantly associated with the depressive symptom category in the unadjusted models, but enters into significance in the medium depressive symptom category in the adjusted models. In the unadjusted model the value is borderline insignificant (p=0.0520) and in the adjusted model the p-value becomes significant (0.0035). This provides some evidence of an association but it is not consistent across analyses. As the medium depressive symptom category is larger than the high depressive symptom category, this allows greater power to detect a difference, though caution should be used when interpreting this result. Physical activity is statistically significant at all depressive symptom category levels in unadjusted models and falls out of significance in the low category in the adjusted models.

These results suggest that individuals who don't get at least 1 day/week of physical activity were at higher risk for being in higher symptom depression categories compared those getting at least 1 day/week of physical activity. Stated otherwise, individuals in higher

depressive symptom score categories were less likely to be physically active. This finding is important because physical activity can be an easily modifiable. It is an inexpensive health behaviour amenable to intervention which has been demonstrated to modify risks for a number of conditions, including heart disease, diabetes and other physical conditions. [114–116] However, the direction of causality in this case is unclear, as this is a cross-sectional study. Therefore, while it may be plausible that individuals who are physically active are less likely to be depressed, it is equally plausible that individuals who are depressed are less likely to be physically active. This is consistent with the presentation of depression, as indicated in the DSM-IV, of reduced interest in activites and increased lethargy.[117] Therefore this study cannot comment on the directionality and instead only suggests that physical activity may be protective against depression, while being aware that the opposite, that depressed adolescents are more likely to not be physically active, may be true.

With respect to how these findings relate to previous studies, Sund et al. demonstrate that low levels of vigorous physical activity were predictive of depressive symptom levels cross-sectionally, and that low levels of vigorous physical activity were a predictor of high depressive symptom levels one year later in boys, but not girls.[34] While the present study did not examine sex-differences specifically, we did find a similar effect across sexes in terms of lower physical activity levels and increased odds of depressive symptom category. Harvey et al. also found that among adults, individuals engaging in leisure-time physical activity were more likely to have lower depressive symptomatology.[36] Though this study focused on adolescents, the effect appears to be consistent. Similarly, McKercher's study demonstrated that retrospectively reported adolescent persistent physical activity was associated with reduced depression risk in adulthood among males and females.[118] Additionally, in college students,

"vigorous physical activity" was associated with reduced depressive symptomatology according to a study by Harbour et al.[119]

More precise and objective measures of physical activity may yield different results due to lower reporting bias and recall bias. For example, research by Parfitt et. al. demonstrated that higher levels of vigorous physical activity are protective against lower levels of anxiety and higher levels of self-worth, but not statistically significantly associated with depressive scores.[120] Parfitt's study used accelerometry to measure physical activity level, a more objective and precise measurement of physical activity, which could explain the differences in results.

Sedentary Activity

With respect to sedentary activity, the present study did not find any conclusive links between the depressive symptom category and sedentary activity. Sedentary activity was only significantly associated with the depressive symptom category at the medium severity level (in both adjusted and unadjusted models). Individuals who were sedentary, as per study definitions above, were no more nor less likely to have higher depressive symptom score categories than those who were not engaged in sedentary activity, with the exception of the medium depressive symptom category, which may be a spurious association. This finding should be replicated in future research, but suggests that interventions to improve depressive symptomatology don't necessarily need to be aimed at reducing sedentary activity time, such as reading, watching TV, playing video games, or surfing the internet, but more at increasing overall physical activity time, which can be done by targeting, structural physical activity, an example of which may be to walk to school rather than getting a ride from a family member or

friend. Also important, interventions targeting increased levels of non-structural vigorous physical activity to reduce depressive symptomatology could be rewarded with screen time, as examined by Goldfield et al.,[121] as it does not appear that sedentary activity is consistently related to depressive symptom category.

Increased sedentary activity may be a presentation for depression and other mental conditions, however, it is possible that the required levels of sedentary activity may be at a higher threshold than defined in this study. Using the Canadian Sedentary Activity Guidelines of no more than two hours per day of sedentary activity is restrictive. It could be that higher levels of sedentary activity are seen in those exhibiting depressive symptoms. As this study was only able to dichotomize the sedentary activity, there may be some sensitivity to the effect being lost which may be more apparent with a more robust measure of sedentary activity hours.

Sedentary activity bordered on statistical significance, even in adjusted models, with the lower bounds of odds ratios approaching significance. While this study was well powered with a large and robust sample, there may be an effect that this study was not able to detect due to the low cutoff and limited variability. This bears some consideration when designing future studies.

Sund et al. demonstrate that higher levels of sedentary activity was predictive of higher depressive symptoms one year later[34], which is inconsistent with this study. However, this may be due to the study design which looks at depressive symptomatology one year later, as opposed to our study which looks at current sedentary activity levels and current depressive symptomatology.

Another study by Hume et al. did not find any cross-sectional or longitudinal associations between sedentary time and depressive symptoms among either boys or girls with a mean age of 14.4 years. "However, having symptoms of depression in 2004 did predict higher TV viewing among adolescent girls in 2006."[122] The cross-sectional portion of this small-sampled study is consistent with the present study.

de Wit suggests that those with Major Depressive Disorder spend "significantly more leisure time using the computer" and that "sedentary behaviors occur more frequently among persons with a mental disorder, independent of general physical activity level."[64] Our study did not demonstrate this particular association but likely because sedentary activity was dichotomized into a single category due to the nature of the survey.

A study by Teychenne et al. found that disadvantaged women with higher levels of sedentary activity, including screen time and time spent at the computer, were at higher odds for depression compared to a low-level reference group.[123] The Teychenne study is likely not generalizable to the population of the present study as it only includes disadvantaged women aged 18-45, whereas this study is of 14-15 year-olds of both sexes and a nationally representative socio-economic profile.

Interaction between Physical and Sedentary Activity

A final finding of this study was that physical and sedentary activity do not appear to impact each other when it comes to the odds of depressive symptom category. Models with both terms in them appear to have similar odds and a model with an interaction term between physical and sedentary activity was not significant. This finding could be very interesting in designing interventions, again, because it appears that targeting physical activity does not necessarily have to result in a reduction in sedentary activity time.

Strengths & Limitations

The large, nationally representative sample included in this study helps provide additional credence to smaller studies which have shown similar effects, however the stacked cross-sectional sample created for this study may not be nationally representative. The large sample size allows sufficient power to examine smaller effects and to include a more nuanced approach to covariate selection to properly adjust for a number of mitigating factors in complex psychiatric epidemiology.The dichotomization of the exposure variables (sedentary and physical activity) was necessary due to how questions were asked in the NLSCY. Some of the inconsistency with other studies may be a result of these measurement differences. As a result, some precision and nuance is missing which might have been better captured with a continuous outcome such as hours of physical activity or sedentary activity per day or week, for example. However, due to the nature of these large, multi-year cohorts, where there is a large burden on the participant to answer many questions, accurately capturing hours performed on certain activities can itself be problematic. Additionally, the measures of physical activity do not capture all physical activity, which may include structural physical activity such as walking to and from school, as well as intentional physical exercise such as free unstructured play, for example. The Spearmen correlation coefficients for the sedentary activity variables ranged from 0.36 to 0.54, indicating a weak to moderate monotonic relationship, which may suggest that the sedentary activity variables are not accurately reflecting actual sedentary activity patterns. Future studies using accelerometry and other advanced data collection techniques may help alleviate some of these concerns.

The use of self-reported physical activity and sedentary activity has the potential to introduce bias in the results presented above. Studies have demonstrated that individuals tended to over-report their physical activity levels compared to objectively ascertained methods such as accelerometry.[124] This has the potential to introduce some misclassification for physical activity, such that the number of individuals who are truly physically active are lower than those reported in this study, which would be consistent with results of other studies. However, this over-reporting of physical activity levels tends to attenuate relationships towards the null, suggesting that the associations may be stronger in reality than presented in this research. Some differential misclassification may be occurring. For example, that those who are more depressed may be over-reporting their physical activity more than those who are less depressed, which would also suggest that the results of this study are being attenuated towards the null. However, no research on over/underreporting of self-reported physical activity among depressed individuals currently exists in the literature and this remains speculative.

Body Mass Index (BMI) was not included in this analysis as the self-reported measures of height and weight used in the NLSCY show both inconsistent data across time, as well as high levels of bias and error. As a result, the derived BMI variables in the NLSCY were deemed unreliable.[125] The rates of missingness in key exposure and outcome variables was relatively low, and its effect was mitigated in covariate categorical variables by the inclusion of a "missing" category, which demonstrated no statistically significant differences between respondents with missing covariate or outcome data and reference.

Given that this study is cross-sectional, this study does not comment on causality. However the evidence presented here suggests that a more detailed longitudinal analysis may

provide a clearer picture of the causality at play in this complicated effect of physical and sedentary activity on adolescent mental health outcomes.

Finally, a cohort effect that may be present in this stacked sample is that physical and sedentary activity patterns may change over time, and is not accounted for in the design of this study.

Conclusions

Low levels of physical activity appear to be significantly related to depressive symptomatology, but the relationship between sedentary activity and depressive symptoms is inconsistent and continues to be unclear, and there does not appear to be any interaction between physical and sedentary activity levels.

Physical activity may be a very low-cost and effective intervention strategy to help treat and/or prevent mental health problems in young populations. Further research of a longitudinal nature to confirm the direction of causal relationship (if any), as well as to further explore the timing of interventions versus outcomes is required. Advanced data collection techniques such as accelerometry to provide more objective and precise measures of physical activity, as well as the development of new techniques to log sedentary activity would be beneficial to further understanding the relationship between physical activity and sedentary activity and depressive symptoms.

Chapter 3: Physical and Sedentary Activity and their Relationship to Depression and Suicidal Ideation in the National Longitudinal Survey of Children and Youth: A Trajectory and Latent Class Analysis

Abstract

Introduction:

Between 0.8 and 4.6% of Canadians have had a mood disorder in the past year. Physical and sedentary activity are a low-cost, easily modifiable risk factors for many diseases including diabetes, heart disease, metabolic syndrome, etc. A growing body of research is beginning to explore the relationship between depression and physical and sedentary activity.

Objective:

To investigate if there exists a longitudinal association between physical and sedentary activity and depression in the National Longitudinal Survey of Children and Youth (NLSCY). As a secondary outcome, this study also examines the relationship between physical and sedentary activity and suicidal ideation and suicide attempt.

Methods:

5,064 respondents aged 14-15 complete depression score outcome data and 5,067 respondents with complete suicidal ideation/attempt outcome data were selected and included in modelling. Trajectory analysis was used to generate physical activity trajectories. Latent class analysis was used to generate sedentary activity latent classes. Univariate and multivariate multinomial logistic regression was used to assess the relationship between physical and sedentary activity and depression using the OCHS emotional disorder-anxiety scale, as well as the CES-D scale, and suicidal ideation and suicide attempt. Sex stratified models for physical activity were explored.

Results:

In unadjusted models, members of the consistently low physical activity trajectory had odds 1.95 (95% CI: 1.16, 3.27) times higher of being in the low depressive symptom category than physically active participants, and those who were physically inactive also had odds 2.71 (95% CI: 1.40, 5.24) times higher of being in the high depressive symptom category than those who are physically active. When controlling for age, sex, parental immigration status, education, neighborhood socio-economic status, substance use (alcohol, tobacco), presence of chronic condition and experience of major stressful life event, members of the consistently low physical activity trajectory had odds 2.23 (95% CI: 1.14, 4.34) times higher of being in the high depressive symptom category than those in the physically active group. Physical activity was not significantly associated with suicidal ideation, suicide attempt or CES-D score. Sedentary activity was not consistently associated with depression.

Conclusions:
Consistently low levels of childhood physical activity are significantly related to depression in adolescence, but the relationship between sedentary activity and depression is inconsistent and continues to be unclear. Suicidal ideation and suicide attempt does not appear to be associated with either physical activity or sedentary activity.

Introduction

The previous chapter examined physical and sedentary activity and their relation to depressive symptoms cross-sectionally. Those who were physically inactive had higher odds of being the medium and high depressive symptom category, respectively compared to physically active respondents. This result suggests that there may be some mechanism at play which is leading respondents with lower physical activity levels to have higher symptoms of depression or those with depression less likely to engage in physical activity. However, as the previous chapter was cross-sectional, no inferences can be made about the causality of the associations.

It is necessary to examine cross-sectional associations longitudinally in order to better understand causality and the direction of associations found in cross-sectional research. This is particularly relevant in the study of mental illness where there are complex causal mechanisms and bi-directional relationships between risk factors and outcomes. For example, research has demonstrated that there exists a cross-sectional link between alcohol use and depression. Initial research demonstrated that the association between alcohol abuse and depression and other internalizing disorders had odds 1.5 to 2 times higher than those with no alcohol abuse when controlling for covariates.[126]

However, as these associations were cross-sectional, causality continued to remain unclear. Other cross-sectional research strengthened the evidence of the association between alcohol use and depression[127–131], which built the case for more robust longitudinal analysis to tease out the causal relationship, if any. A 2009 study by Fergusson et. al. demonstrated that a structural equation model that alcohol dependence disorder caused higher levels of major depression was a superior fit to a model which suggested that major depression led to self-medication with alcohol, leading to alcohol abuse disorder.[132] This study helped pave the way for future studies which would serve to further support the assertion that alcohol abuse disorder is more likely cause major depression, and not vice-versa. A 2011 meta-analysis demonstrated that the literature now supports a causal relationship between alcohol abuse and major depression.[133]

This example illustrates the need for the longitudinal analysis conducted below, in order to better understand the nature of the relationship between physical and sedentary activity and depression.

Hypothesis

This study hypothesizes that increased physical activity will be associated with lower depressive symptom scores and lower rates suicidal ideation. This study also hypothesizes that higher levels of sedentary activity will be associated with higher depressive symptom scores and higher rates of suicidal ideation.

Materials and Methods

Study Design

This study uses data from the National Longitudinal Survey on Children and Youth, which is a bi-annual study conducted and published by Statistics Canada and sponsored by Human Resources and Skills Development Canada. The study, which began data collection in 1994, examines the development of children and youth and their physical, mental and social well-being.[82] The survey comprises 8 cycles, with respondents aged 0-25 years old in multiple cohorts.

In Cycle 1, respondents were selected from the pre- and post-1994 Labour Force Survey. Some respondents were also included in the National Population Health Survey. A maximum of four respondents were selected from each household. In Cycle 2, some respondents were dropped due to budgetary constraints and the restriction on the maximum number of respondents per household was dropped to two to reduce the burden on participating households. In Cycle 4, "households with two or more consecutive cycles of non-response would be dropped from collection (along with households with one cycle of non-response followed by the status 'Temporarily moved')".[83] In following cycles, respondents with too many consecutive non-responses were also dropped.

Information contained in the survey is primarily conducted by a household interview with the person most knowledgeable (PMK) about the child. This was typically the mother. Other PMK included fathers, step-parents or adoptive parents.[83] A youth component was conducted for selected respondents aged 16 and above. An adult

component for the PMK was also administered. Data was collected by trained Statistics Canada personnel and interviews were only conducted in English and French.

At cycle 8 of the survey, the total number of respondents is 26,662, with an overall response rate of 73.7%. 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.

Sample Population

All respondents aged 2-3 at cycle one, who have at least one additional data collection point beyond cycle one were selected for the generation of physical activity trajectories. A total of 8,292 respondents were included in the analysis. Of this sample, 8,271 provided data on sedentary activity that allowed for inclusion in the sedentary activity latent class analysis. Respondents having depressive symptom (n=5,064) scores or suicidal ideation outcomes (n=5,067) at age 14-15 were retained for final regression analysis. There were 2,504 respondents had CES-D outcome data at aged 16-17.

Measures

Depressive Symptoms

The primary outcome for this study, similar to a study conducted by Naicker et. al, is an emotional disorder-anxiety scale for children and youth, based on seven items taken from the Ontario Child Health Study (OCHS). Higher scores on this scale are indicative of greater emotional disorder.[84,85] This scale is chosen as it closely matches the DSM-III criteria for emotional disorders.[86] 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." In Cycle 8, the Cronbach's Alpha for this scale was 0.638 in 2-3 year-olds, 0.691 in 4-5 year-olds, 0.737 in 6-7 year-olds, 0.810 for 14-15 year-olds and so is reliable in older age groups. Previous studies have categorized this data into quantiles to address skewness in the data.[87] This study will take the same approach and use quantiles if appropriate.

Scores were grouped into 4 ordered categories representing degrees of severity while accounting for floor effects (i.e., positively skewed distributions): *no symptoms* (scores below the 50th percentile), *low 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). This method is consistent with previous studies.[84,87–91]

As a result, the primary outcome for this study is a respondent's ordered category (as enumerated above) for the OCHS emotional disorder scale measured at ages 14-15, as data has been collected at this age group in 5 out of 8 cycles, thus maximizing sample size, and is the age group for which there is the highest reliability.[82]

Secondary Outcomes

Three additional outcomes were examined in this study: the CES-D Category, suicidal ideation and suicide attempt.

A shortened version of the Centre for Epidemiological Studies Depression Scale (CES-D-12) by Radloff[134] was administered to respondents at ages 16-17. This is a 36-

point scale which asks questions about specific feelings related to depression over the last week. Each item has four response categories which map on to how many days (0,1-2 days, 3-4 days, 5-7 days) a particular feeling or behaviour was experienced. In order to compare results between the OCHS depressive symptom category above, this scale was also divided into ordered categories with matching percentiles (0 to 50th percentile, 51st to 75th percentile, 76th to 90th percentile and 91st to 100th percentile).

Two questions of interest related to a respondent's suicidality were asked at age 14-15. The first question was "In the past 12 months, did you seriously consider attempting suicide?", and respondents were given the choice of "Yes" or "No". Respondents were classified as having suicidal ideation if they answered yes. For those answering "Yes" to the above, a second question was asked: "In the past 12 months, how many times did you attempt suicide?" Respondents answering either "once" or "more than once" were deemed to have attempted suicide for the purposes of this analysis. If respondents answered "No" to the question on ideation, they were deemed to have not attempted suicide for the purposes of this analysis.

Physical Activity

Similar to the cross-sectional analysis in Chapter 2, the first major exposure for this study is physical activity, which was measured using three questions for the PMK up to and including age 9 and child self-report for ages greater than 10. The three questions asked the frequency of the child'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?" [85] Respondents were provided with five

responses, “Most days”, “A few times a week”, “About once a week”, “About once a month” and “Almost never”. Consistent with Arim, et. al., 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” composing “Almost never” and “About once a month”.[92] Finally, a composite physical activity score was derived for the final analysis, 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”.

A measure for physical activity was recorded at each cycle, which was used in the generation of trajectories.

Sedentary Activity

Sedentary activity, the second primary exposure, is measured by a question asking how many hours of television or videos watched per day or video games played at home per day [93,94]. The question is derived from the World Health Organization Health Behaviour in School-Aged Children survey. The question posed is “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”.[85] This question was validated using a 7-day television viewing diary and had Spearman correlation coefficients of 0.36-0.54, and test-retest intra-class correlation scores for the reliability of this ranging from 0.76 to 0.81.[93,95,96] This question was posed of parents of children aged 3 and above.

Starting at the age of 10, children were asked a similar question about their frequency of television, video game or movie watching. The question posed was “On average, about how many hours a day do you watch TV or videos, or play video games?” Responses were “I don’t

watch TV or videos or play video games", "Less than 1 hour a day", "1 or 2 hours a day", "3 or 4 hours a day", "5 or 6 hours a day" or "7 or more hours a day."[85] Responses were recoded to be in closely equivalent categories based on the table 10.

Canadian sedentary activity guidelines recommend a maximum two hours per day for children aged 5-17.[97] These same guidelines recommend a maximum of one hour per day of screen time for children aged 2-4. While the categories did not match very closely in the PMK reported sedentary activity categories, this study chose to use more rigorous definitions of sedentary activity for children aged 9 and under to reflect more stringent guidelines for younger children.

Covariates

Covariates were chosen *a priori* due to their association with either physical or sedentary activity and depression. Covariates include age, sex, child's ethnicity, whether the PMK is Canadian born, parental education, family income relative to neighbourhood income using the Low Income Cut-Off (LICO) ratio[c], major stressful life events (such as death of a loved one, exposure to suicide, major injury, loss of job, etc., as reported by PMK or self-reported), whether there is the presence of a chronic health condition (parent and child reported diagnosed conditions) and substance use (tobacco and alcohol). Illicit drug use was originally chosen but could not be used at it was not measured consistently across cycles.

Age was chosen as a covariate as it has been associated with trends in physical and sedentary activity among children and youth as well as depression.[98–100] Males and females engage in

[c] LICO is the level below which a family is likely to spend a significantly higher proportion of its income to purchase necessities such as food, lodging and clothing than the average family, and is calculated depending on family size and area of residence. The LICO ratio is a family's income compared to the LICO for its family size and geographic area. For example, a family with a LICO ratio of 4 has an income of four times the low-income cutoff for their area and family size.

differing patterns of sedentary and physical behaviours and so sex has been chosen as a covariate, and sex has been identified as being associated with depression[52,101,102] Ethnicity was chosen as it has also been associated with different patterns of physical activity among children as well as depression.[100,103] Whether a child is an immigrant or was born in Canada has also been associated with different health behaviours, including physical activity and has also been associated with depression.[104,105] Parental education has been noted as a mediator between socioeconomic status and mental health outcomes.[13] Neighbourhood characteristics have been associated with both sedentary and physical activity levels and mental health outcomes.[106–108] Major stressful life events have been associated with depression among adolescents.[109] An individual's health status has been associated with differing levels of physical activity as well as mental health status.[18,110] Substance use has also been associated with differing levels of physical activity as well as mental health status. [111,112]

All covariates are from the same cycle in which the respondent was selected.

Due to the relatively large sample size of this study, all analyses were conducted with the appropriate consideration towards power, as well as respecting the minimum 10 respondents per independent variable used in modelling.

Analytical Methods

All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, NC). Descriptive statistics are presented in Table 1.

Physical activity trajectories were derived using Proc Traj, a custom SAS procedure developed by Jones and Nagin[135,136] which estimates groups based on longitudinal data

which represents a subpopulation. Models with two, three, and four groups as well as linear, quadratic, cubic and quartic trajectory shapes were examined and were chosen based on Bayesian Information Criterion (BIC) as a measure of model parsimony, and group membership posterior probabilities, with consideration given to a model's ability to provide interpretable information. Sedentary activity latent classes were generated using latent class analysis, which assigns respondents to classes based on their responses to multivariate data. Models with two, three and four classes were examined and chosen based on Bayesian Information Criteria (BIC) as a measure of parsimony.

Multinomial ordinal logistic regression was used to examine the relationship between physical activity trajectories and sedentary activity latent classes and symptoms of anxiety and depression at ages 14-15 as represented by the OCSH depressive symptom category, and ages 16-17 using the CES-D depressive symptom category. Odds ratios were obtained for unadjusted models, as well as adjusted models controlling for age, ethnicity, parent immigrant status, parental education, neighborhood LICO ratio, major stressful life events (such as death of a loved one, exposure to suicide, major injury, loss of job, etc., as reported by PMK or self-reported), PMK reported chronic condition and substance use (tobacco, alcohol). Additionally, an interaction between physical activity trajectory and sex was included in the physical activity modelling.

All frequencies, means and multinomial logistic regression models were weighted using bootstrapping weights provided by Statistics Canada. Trajectories and latent classes were weighted using a respondent's cycle 1 longitudinal weight.

Missingness

Respondents must have had at least two data exposure to contribute to trajectory generation or latent class generation. For PROC TRAJ, missing data were addressed using full information maximum likelihood (FIML). Underlying missing data were assumed to be Missing At Random (MAR). For PROC LCA, missing data were also assumed to be MAR.

In order to retain the greatest number of respondents during the regression analysis, for each categorical variable an additional category of "missing" was created and assigned for those with missing data for those variables. This helped to limit the dropped observations in each of the adjusted models, and also provided insight to see if having a missing value for that exposure or covariate was statistically significantly different for the reference category for that variable.

Results

Sample descriptive statistics were generated and are found in Tables 3.1 and 3.2. The respondents were aged 14 and 15 years old, were evenly distributed among males (49.8%) and females (50.2%), predominantly caucasian (90.7%), had PMKs with either a university of college degree (56.3%), some post-secondary education (11.6%) or had completed secondary school (22.3%). PMKs were largely Canadian-born (70.0%). 31.4% of sample respondents had a chronic condition, 33.7% had experienced a major stressful life event, 27.9% had ever smoked tobacco and 75.0% had ever consumed alcohol.

Females were more likely to be in a more severe depressive symptom category, compared to males (p<.001). Older individuals were also more likely to be in a higher depressive symptom category (p <.001). Respondents having ever smoked tobacco were also more likely to be in a higher depressive symptom category (p=0.02). The effect of age is likely a cohort effect, as older individuals are by their nature more likely to have depressive symptoms.

Physical Activity Trajectory

Trajectory modelling resulted in two candidate models, a two-group and a three-group model, depicted in Figures 3.1 and 3.2, respectively. Each connected line in the trajectory model shows how likely a participant in that trajectory is physically active. Table 3.3 demonstrates pertinent model selection statistics. While both models had group higher-order terms that met statistical significance tests (p < .05), the 2-group model had a slightly superior BIC (-16397.43) than the 3-group model BIC (-16376.40). BIC tends to favour more parsimonious models, suggesting that the two group model would benefit from its smaller number of groups. Both models exhibited adequate posterior group probabilities, however the posterior probability of the low-to-high group in the three group model (64.4%) was slightly below the preferred threshold of 70%. Tables 3.4a, b, c and d show the results for both the adjusted and unadjusted 2-group and 3-group models. The 2- and 3-group model results are roughly analogous, suggesting that using the 3-group model will not unduly compromise this study.

However, this study opted to use the 3-group model for the exposure in modelling, despite the inferior BIC, as the 3-group model has superior explanatory (with two parallel

groups and one group changing from low-to-high) compared to the two-group model (two parallel groups evenly distributed). The 3 groups in the analysis are a consistently low physical activity trajectory (11.6% of respondents), a consistently high physical activity trajectory (67.9% of respondents) and a physical activity trajectory characterized by a move from low to high levels of physical activity (20.6% of respondents).

Tables 3.4a and 3.4c show the results of unadjusted and adjusted multinomial logistic regression models for physical activity trajectory, respectively. In the unadjusted multinomial logistic regression model (Table 3.4a), compared to those in the consistently high activity groups, members of the consistently low physical activity trajectory had odds 1.95 (95% CI: 1.16, 3.27) times higher of being in the low depressive symptom category compared to those in the high physical activity group. Members of the consistently low physical activity trajectory had odds 2.71 (95% CI: 1.40, 5.24) times higher of being in the high depressive symptom than those in the high physical activity group.

The adjusted multinomial logistic regression model (Table 3.4c) controlled for all covariates enumerated above. Members of the consistently low physical activity trajectory had odds 2.23 (95% CI: 1.14, 4.34) times higher of being in the high depressive symptom category compared to those in the high physical activity group. Covariates demonstrating statistically significant association with depressive symptom category includes being female across all depressive symptom score categories, age in the low and medium depressive symptom score categories, having a non-Canadian born PMK in the medium depressive symptom category, having a chronic condition in the high depressive symptom category, having ever experienced a stressful life event across all depressive symptom

score categories and having ever smoked tobacco across all depressive symptom score categories.

A multiplicative interaction term between physical activity trajectory and sex was included in an adjusted model, however the interaction term was non-significant ($p = 0.52$). Additive exploration was explored using a method developed by Andersson et al., but no evidence of a significant additive interaction was found.[113]

Suicidal ideation was not statistically significantly associated with physical activity trajectory in unadjusted univariate modelling (Table 3.5a). Suicide attempt was not statistically significantly associated with physical activity trajectory in unadjusted univariate modelling (Table 3.5b). CESD category at ages 16-17 was also not significant in unadjusted univariate modelling (Table 3.6).

Sedentary Activity Latent Class

Latent class modelling yielded a 3-group model, depicted in Figure 3.3. This figure demonstrates the mean sedentary activity class for each time point. While each group, or class, has been linked together by a line, it is important to note that latent class analysis does not yield trajectories such as trajectory analysis does, and only provides the most likely response category for each variable provided, in this case a series of para-longitudinal sedentary activity classes. The three group model provides us with three latent classes, namely a consistently low class (57.8% of respondents), a consistently medium class (18.6% of respondents) and a low to medium class (22.5% of respondents).

Tables 3.7a and 3.7b show the results of unadjusted and adjusted multinomial logistic regressions, respectively. No statistically significant association was found for any sedentary activity latent class across all depressive symptom score categories (Table 3.7a).

In the adjusted model (Table 3.7b), when adjusting for all covariates enumerated above, no statistically significant association between sedentary activity latent class and depressive symptom category was found. However, statistically significant associations between covariates and depressive symptom category were found for females across all depressive symptom score categories, age for the low and medium depressive symptom score categories, having a PMK not Canadian born in the medium depressive symptom category, having a chronic condition in the high depressive symptom category, having ever experienced a stressful life event in all depressive symptom score categories, and having ever smoked tobacco across all depressive symptom categories.

No statistically significant association between sedentary activity latent class and suicidal ideation was found (Table 3.8). A statistically significant association was found in the unadjusted model (Table 3.9a) between the medium-to-low sedentary activity latent class in the low CESD symptom category (OR (95% CI): 1.61 (1.00, 2.57), p=0.0484), however this association disappeared in the adjusted model (Table 3.9b).

Figure 3.1 - Physical Activity Trajectories (95% CI), 2 Group Model

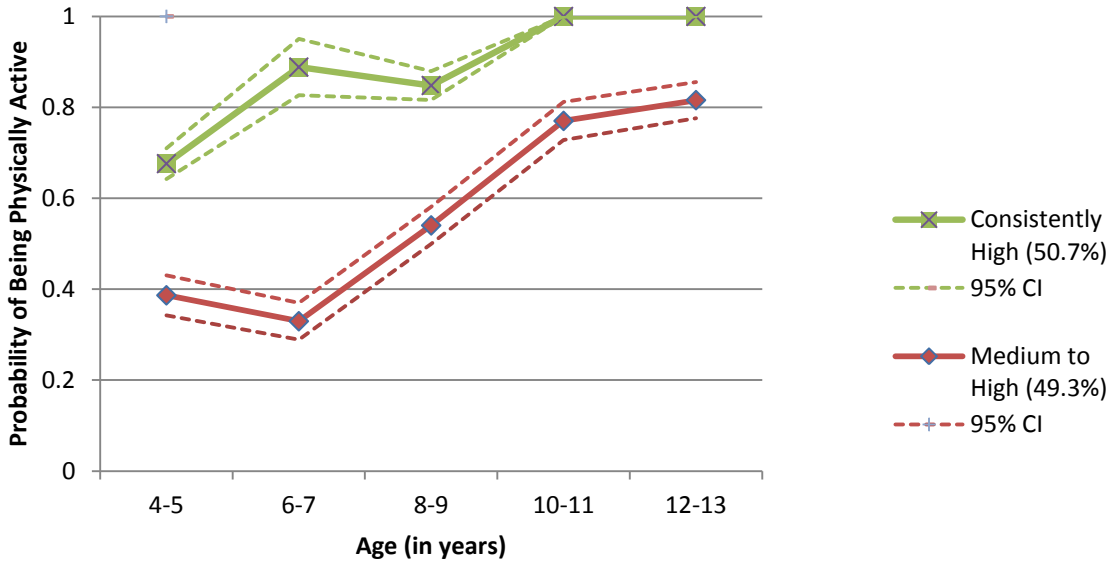
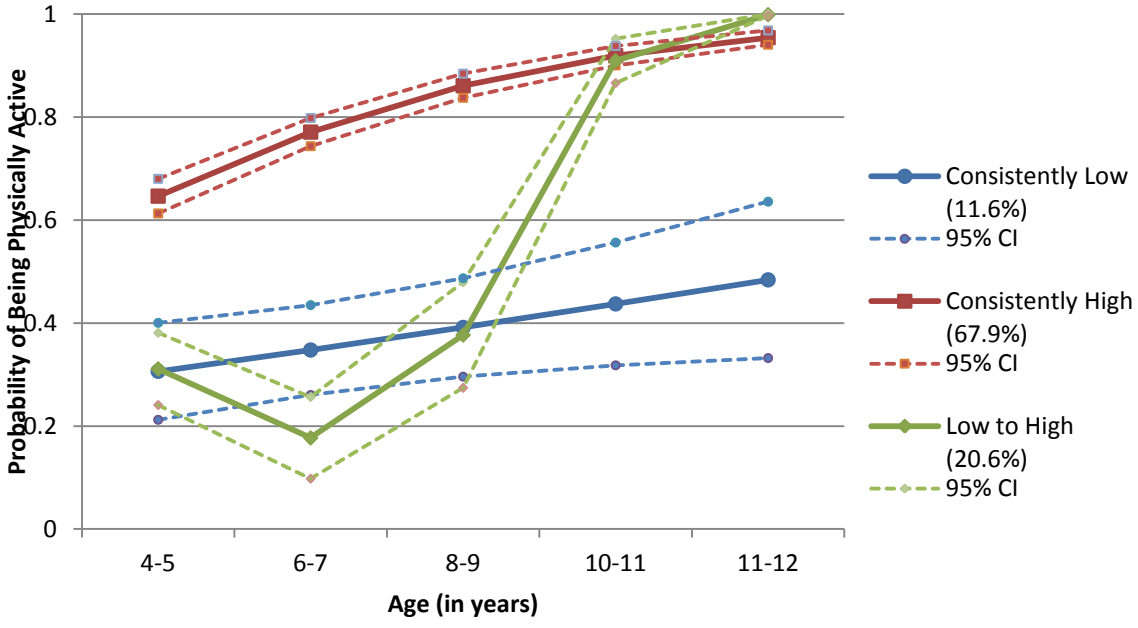


Figure 3.2 - Physical Activity Trajectories (95% CI), 3 Group Model



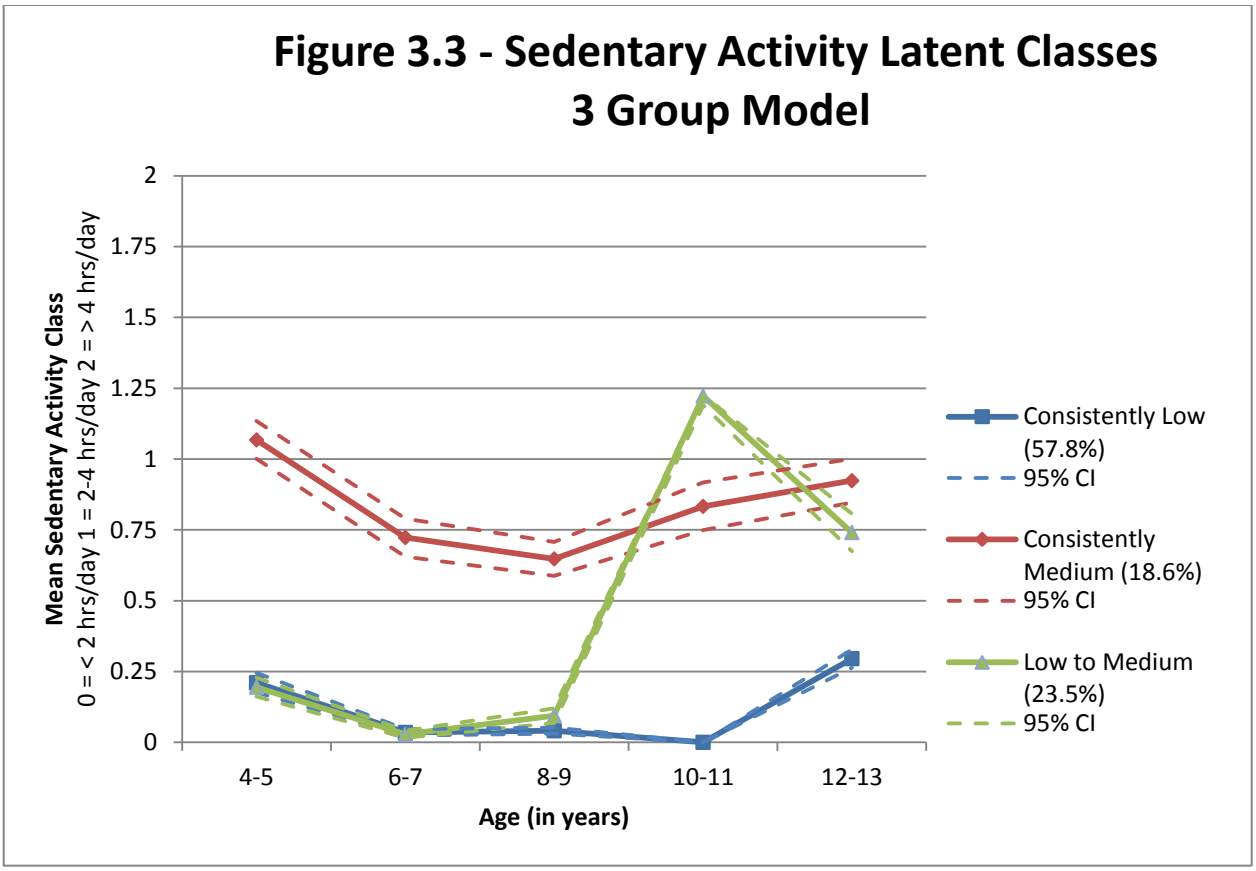


Figure 3.3 - Sedentary Activity Latent Classes
3 Group Model
Mean Sedentary Activity Class
0 = < 2 hrs/day 1 = 2-4 hrs/day 2 = > 4 hrs/day
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
4-5
6-7
8-9
10-11
12-13
Age (in years)
Consistently Low (57.8%)
95% CI
Consistently Medium (18.6%)
95% CI
Low to Medium (23.5%)
95% CI

Table 3.1: Weighted Proportion of Respondents by Depressive Symptom Category and Outcome/Covariates at Age 14-15[1]

	Depressive Symptom Category					χ^2 p-value
	Total	**None**	**Low**	**Medium**	**High**	
Total (unweighted n=5064)	100%	56.5%	20.7%	12.9%	10.0%	
Physical Activity Trajectory						0.116
Consistently Low	4.5%	3.2%	5.9%	5.5%	7.8%	
Consistently High	81.2%	82.8%	79.2%	81.4%	75.1%	
Low to High	14.4%	14.0%	14.9%	13.1%	17.1%	
Sedentary Activity Latent Class						0.486
Consistently Low	59.5%	59.9%	59.6%	54.9%	63.1%	
Consistently Medium	16.9%	17.3%	15.5%	16.9%	17.2%	
Low to Medium	23.6%	22.7%	24.9%	28.2%	19.7%	
Sex ***						< .001
Male	49.8%	58.4%	46.9%	31.9%	26.8%	
Female	50.2%	41.6%	53.1%	68.1%	73.2%	
Ethnicity						0.428
Caucasian	90.7%	91.8%	88.6%	90.8%	88.6%	
Non-Caucasian	8.0%	7.1%	10.3%	7.9%	8.5%	
Missing	1.3%	1.0%	1.1%	1.3%	2.9%	
PMK Education						--†
Less than Secondary	9.0%	8.4%	9.0%	12.7%	7.8%	
Secondary School	22.3%	22.0%	25.9%	20.9%	18.5%	
Some Post-Secondary	11.6%	11.5%	10.6%	10.3%	16.3%	
University/College Degree	56.3%	57.4%	23.5%	55.4%	56.9%	
Other	0.6%	0.6%	0.8%	0.6%	0.4%	
Missing	0.1%	0.1%	0.2%	0.2%	--†	
PMK Canadian Born						0.325
Yes	70.0%	12.8%	13.7%	15.7%	17.7%	
No	13.8%	72.2%	69.0%	66.7%	63.3%	
Missing	16.2%	15.0%	17.3%	17.6%	18.9%	
Presence of Chronic Condition						--†
Yes	31.5%	70.3%	68.2%	66.4%	60.7%	
No	68.4%	29.7%	31.8%	33.6%	39.3%	
Missing	--†	--†	--†	--†	--†	
Stressful Life Event						--†
Yes	33.7%	71.0%	61.9%	57.1%	58.8%	
No	66.3%	28.9%	38.0%	42.9%	41.2%	
Missing	--†	--†	--†	--†	--†	
Child Ever Smoked Tobacco ***						<.001
Yes	27.9%	76.2%	67.5%	60.7%	62.6%	
No	71.2%	23.1%	31.4%	37.7%	36.4%	
Missing	0.9%	0.7%	1.1%	1.5%	1.0%	
Child Ever Consumed Alcohol						0.721
Yes	75.0%	74.8%	72.8%	78.3%	77.3%	
No	23.3%	23.6%	25.5%	20.3%	21.0%	
Missing	1.6%	1.6%	1.7%	1.5%	1.7%	

[1]Some percentages may not add up to exactly 100% due to rounding.
Chi-Square: *** p < .001 ** p < .01 * p < .05 † Suppressed due to small cell count.

Table 3.2: Weighted Means and Standard Errors of Respondents by Depressive Symptom Category and Covariates at Age 14-15

	Depressive Symptom Category Mean (SE)				F-Test p-value
	None	Low	Medium	High	
Age	14.4 (0.020)	14.5 (0.023)	14.6 (0.030)	14.5 (0.037)	0.02*
LICO Ratio	2.8 (0.089)	2.5 (0.097)	2.5 (0.116)	2.5 (0.097)	0.16

* Statistically significant at α = 0.05.

Table 3.3: Comparison of Candidate Trajectory Models

		Model 1	Model 2
Number of Groups		2	3
Bayesian Information Criteria (BIC)		-16,397.43	-16,376.40
Group Distribution			
	Group 1	49.3%	11.6%
	Group 2	50.7%	67.9%
	Group 3	--	20.6%
Posterior Probability			
	Group 1	81.7%	76.4%
	Group 2	78.9%	80.5%
	Group 3	--	64.4%

Table 3.4a: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 1a – Unadjusted Physical Activity Trajectory (n = 5064)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	Medium vs None	High vs None
Physical Activity Trajectory			
Consistently High (Ref)	--	--	--
Low to High	1.11 (0.75, 1.65)	0.95 (0.62, 1.46)	1.34 (0.83, 2.17)
Consistently Low	1.95 (1.16, 3.27)*	1.76 (0.85, 3.66)	2.71 (1.40, 5.24)*

* Statistically significant at α = 0.05.

Table 3.4b: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 1b – Unadjusted Physical Activity Trajectory (n = 5064)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Trajectory			
Consistently High (Ref)	--	--	--
Low to High	1.14 (0.89, 1.44)	1.16 (0.87, 1.55)	1.71 (1.27, 2.31) *

* Statistically significant at $\alpha = 0.05$.

Table 3.4c: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 2a – Adjusted Physical Activity Trajectory (n = 5064)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Trajectory			
Consistently High (Ref)	--	--	--
Low to High	1.00 (0.70, 1.43)	0.78 (0.51, 1.20)	1.09 (0.70, 1.72)
Consistently Low	1.60 (0.97, 2.66)	1.40 (0.71, 2.77)	2.23 (1.14, 4.34)*
Sex			
Male (Ref)	--	--	--
Female	1.56 (1.23, 1.99)*	3.05 (2.28, 4.09)*	3.78 (2.72, 5.56)*
Age (per 1 year increase)	1.29 (1.01, 1.64)*	1.52 (1.16, 1.99)*	1.20 (0.86, 1.68)
LICO Ratio (per 1 unit increase)	0.95 (0.88, 1.02)	0.95 (0.88, 1.03)	0.94 (0.85, 1.04)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.57 (0.87, 2.85)	0.97 (0.43, 2.16)	0.95 (0.37, 2.44)
Missing	1.19 (0.49, 2.92)	1.43 (0.39, 5.27)	3.14 (0.71, 13.92)
PMK Education			
University/College Degree	--	--	--
Some Post-Secondary	0.89 (0.62, 1.29)	0.81 (0.52, 1.26)	1.19 (0.77, 1.84)
Secondary School	1.15 (0.83, 1.60)	0.90 (0.67, 1.22)	0.74 (0.48, 1.14)
Less than Secondary	0.95 (0.63, 1.42)	1.29 (0.80, 2.09)	0.74 (0.43, 1.27)
Other	†	†	†
Missing	†	†	†
PMK Canadian Born			
Yes (Ref)	--	--	--
No	1.01 (0.64, 1.58)	1.63 (1.07, 2.48)*	1.87 (0.91, 3.86)
Missing	1.01 (0.75, 1.37)	1.08 (0.76, 1.54)	1.12 (0.76, 1.63)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.10 (0.86, 1.39)	1.19 (0.91, 1.55)	1.65 (1.19, 2.29)*
Missing	†	†	†
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.46 (1.13, 1.90)*	1.69 (1.27, 2.25)*	1.50 (1.10, 2.06)*
Missing	†	†	†
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.52 (1.12, 2.07)*	1.85 (1.35, 2.52)*	1.88 (1.35, 2.62)*
Missing	1.89 (0.70, 5.10)	3.11 (0.88, 10.99)	2.07 (0.24, 17.99)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	0.78 (0.59, 1.04)	0.91 (0.64, 1.28)	0.95 (0.63, 1.45)
Missing	0.77 (0.37, 1.62)	0.68 (0.28, 1.64)	0.92 (0.33, 2.55)

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Table 3.4d: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 2b – Adjusted Physical Activity Trajectory (n = 5064)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Trajectory			
Consistently High (Ref)	--	--	--
Low to High	1.05 (0.84, 1.33)	1.11 (0.86, 1.43)	1.67 (1.26, 2.22) *
Remaining co-variates suppressed			

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Table 3.5a: Results of Bootstrapped Univariate Logistic Regression Modelling

Model 3 – Unadjusted Physical Activity Trajectory (n = 5067)

	Suicidal Ideation Unadjusted Odds Ratio (95% CI) (Weighted)
Physical Activity Trajectory	
Consistently High (Ref)	--
Low to High	1.06 (0.66, 1.71)
Consistently Low	1.17 (0.63, 2.16)

* Statistically significant at α = 0.05.

Table 3.5b: Results of Bootstrapped Univariate Logistic Regression Modelling

Model 3b – Unadjusted Physical Activity Trajectory (n = 5062)

	Suicide Attempt Unadjusted Odds Ratio (95% CI) (Weighted)
Physical Activity Trajectory	
Consistently High (Ref)	--
Low to High	1.02 (0.50, 2.08)
Consistently Low	0.69 (0.29, 1.67)

* Statistically significant at α = 0.05.

Table 3.6: Results of Bootstrapped Univariate Linear Regression Modelling

Model 4 – Unadjusted Physical Activity Trajectory (n = 2504)

	CESD Category		
	Low vs None	**Medium vs None**	**High vs None**
Physical Activity Trajectory			
Consistently High (Ref)	--	--	--
Low to High	1.14 (0.65, 2.01)	1.22 (0.71, 2.11)	1.21 (0.70, 2.11)
Consistently Low	1.25 (0.39, 3.97)	1.44 (0.44, 4.75)	1.41 (0.45, 4.45)

* Statistically significant at α = 0.05.

Table 3.7a: Results of Bootstrapped Univariate Multinomial Logistic Regression Modelling

Model 5 – Unadjusted Sedentary Activity Latent Class (n = 5062)

	Depressive Symptom Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Latent Class			
Consistently Low (Ref)	--	--	--
Consistently Medium	0.90 (0.67, 1.21)	1.07 (0.75, 1.52)	0.94 (0.62, 1.43)
Low to Medium	1.10 (0.81, 1.51)	1.36 (0.97, 1.89)	0.82 (0.53, 1.28)

* Statistically significant at α = 0.05.

Table 3.7b: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 6 – Adjusted Sedentary Activity Latent Class (n =5062)

	Depressive Symptom Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Latent Class			
Consistently Low (Ref)	--	--	--
Consistently Medium	0.84 (0.62, 1.12)	1.05 (0.75, 1.49)	0.95 (0.62, 1.45)
Low to Medium	1.07 (0.79, 1.46)	1.37 (0.98, 1.91)	0.87 (0.55, 1.36)
Sex			
Male (Ref)	--	--	--
Female	1.57 (1.23, 2.01) *	3.06 (2.31, 4.04) *	3.86 (2.74, 5.42) *
Age (per 1 year increase)	1.29 (1.01, 1.64) *	1.52 (1.15, 1.99) *	1.23 (0.89, 1.70)
LICO Ratio (per 1 unit increase)	0.94 (0.88, 1.02)	0.96 (0.88, 1.03)	0.93 (0.84, 1.03)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.65 (0.91, 2.96)	0.98 (0.44, 2.19)	1.03 (0.41, 2.19)
Missing	1.21 (0.49, 2.96)	1.38 (0.37, 5.11)	3.20 (0.73, 14.07)
PMK Education			
University/College Degree (Ref)	--	--	--
Some Post-Secondary	0.91 (0.63, 1.31)	0.82 (0.53, 1.27)	1.21 (0.77, 1.90)
Secondary School	1.17 (0.84, 1.63)	0.88 (0.65, 1.20)	0.76 (0.50, 1.17)
Less than Secondary	0.99 (0.66, 1.49)	1.31 (0.81, 2.12)	0.77 (0.45, 1.32)
Other	†	†	0.65 (0.01, 92.13)
Missing	†	†	†
PMK Canadian Born			
Yes (Ref)	--	--	--
No	1.00 (0.63, 1.57)	1.60 (1.04, 2.47) *	1.88 (0.92, 3.84)
Missing	1.04 (0.76, 1.41)	1.10 (0.77, 1.56)	1.18 (0.82, 1.69)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.09 (0.86, 1.38)	1.19 (0.91, 1.55)	1.64 (1.18, 2.27) *
Missing	†	†	†
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.45 (1.12, 1.88) *	1.66 (1.24, 2.22) *	1.49 (1.10, 2.02) *
Missing	†	†	†
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.54 (1.13, 2.10) *	1.83 (1.34, 2.48) *	1.93 (1.37, 2.70) *
Missing	1.90 (0.70, 5.15)	3.21 (0.88, 11.68)	2.03 (0.23, 17.60)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	0.77 (0.58, 1.02)	0.89 (0.63, 1.28)	0.93 (0.61, 1.41)
Missing	0.78 (0.38, 1.64)	0.69 (0.28, 1.68)	0.91 (0.32, 2.56)

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Table 3.8: Results of Bootstrapped Univariate Logistic Regression Modelling

Model 7 – Unadjusted Sedentary Activity Latent Class (n = 5065)

	Suicidal Ideation Unadjusted Odds Ratio (95% CI) (Weighted)
Sedentary Activity Latent Class	
Consistently Low (Ref)	--
Consistently Medium	0.88 (0.53, 1.49)
Low to Medium	0.81 (0.62, 1.09)

* Statistically significant at α = 0.05.

Table 3.9a: Results of Bootstrapped Univariate Linear Regression Modelling

Model 8a – Unadjusted Sedentary Activity Latent Class (n = 2503)

	CESD Category Unadjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Latent Class			
Consistently Low (Ref)	--	--	--
Consistently Medium	1.61 (1.00, 2.57) *,**	0.87 (0.57, 1.35)	1.170 (0.73, 1.88)
Low to Medium	1.39 (0.87, 2.23)	0.85 (0.53, 1.36)	1.56 (0.87, 2.74)

* Statistically significant at α = 0.05. ** p = 0.484

Table 3.9b: Results of Bootstrapped Multivariate Multinomial Logistic Regression Modelling

Model 8b – Adjusted Sedentary Activity Latent Class (n =2503)

	CESD Category Adjusted Odds Ratio (95% CI) (Weighted)		
	Low vs None	**Medium vs None**	**High vs None**
Sedentary Activity Latent Class			
Consistently Low (Ref)	--	--	--
Consistently Medium	1.54 (0.98, 2.44)	0.87 (0.54, 1.39)	1.21 (0.73, 1.41)
Low to Medium	1.34 (0.81, 2.21)	0.78 (0.48, 1.28)	1.56 (0.87, 2.85)
Sex			
Male (Ref)	--	--	--
Female	0.98 (0.69, 1.41)	1.82 (1.24, 2.68) *	2.36 (1.47, 3.79) *
Age (per 1 year increase)	0.86 (0.59, 1.24)	0.72 (0.49, 1.04)	1.20 (0.74, 1.94)
LICO Ratio (per 1 unit increase)	0.89 (0.78, 1.02)	0.98 (0.86, 1.09)	0.91 (0.79, 1.05)
Ethnicity			
Caucasian (Ref)	--	--	--
Non-Caucasian	1.83 (0.63, 5.27)	1.89 (0.66, 5.37)	1.17 (0.24, 5.69)
Missing	2.52 (0.22, 28.82)	†	†
PMK Education			
University/College Degree (Ref)	--	--	--
Some Post-Secondary	0.76 (0.41, 1.42)	1.06 (0.56, 2.02)	1.08 (0.55, 2.09)
Secondary School	0.73 (0.46, 1.17)	1.48 (0.85, 2.58)	0.72 (0.41, 1.26)
Less than Secondary	0.55 (0.29, 1.06)	0.83 (0.42, 1.65)	0.63 (0.31, 1.31)
Other	†	†	†
Missing	†	†	†
PMK Canadian Born			
Yes (Ref)	--	--	--
No	0.86 (0.46, 1.60)	0.92 (0.42, 2.01)	0.83 (0.28, 2.42)
Missing	0.84 (0.47, 1.50)	1.39 (0.77, 2.51)	1.12 (0.51, 2.46)
Presence of Chronic Condition			
No (Ref)	--	--	--
Yes	1.08 (0.73, 1.61)	1.14 (0.79, 1.64)	1.91 (1.18, 3.09) *
Missing	†	†	†
Stressful Life Event			
No (Ref)	--	--	--
Yes	1.67 (1.10, 2.51)	1.22 (0.81, 1.82)	1.20 (0.75, 1.93)
Missing	0.59 (0.25, 1.42)	†	1.03 (0.59, 1.78)
Child Ever Smoked Tobacco			
No (Ref)	--	--	--
Yes	1.41 (0.93, 2.16)	1.22 (0.76, 1.96)	2.17 (1.29, 3.67) *
Missing	0.70 (0.07, 7.13)	†	1.41 (0.93, 2.16)
Child Ever Consumed Alcohol			
No (Ref)	--	--	--
Yes	1.41 (0.83, 2.40)	1.53 (0.93, 2.51)	0.70 (0.34, 1.43)
Missing	1.20 (0.05, 29.92)	2.80 (0.26, 29.70)	†

* Statistically significant at $\alpha = 0.05$. † Suppressed due to small cell count.

Table3.10: Response Profile of Sedentary Activity Categories by Question Type (PMK or Self Report)		
	PMK Report (Age 2-9)	**Child Self-Report (Ages 10+)**
Not Sedentary	• None • Less than 30 minutes • 30 minutes to less than an hour • 1 hour to less than 2 hours	• I don't watch TV or videos, or play video games. • Less than 1 hour a day. • 1 or 2 hours a day
Moderately Sedentary	• 2 hours to less than 3 hours	• 3 or 4 hours a day
Sedentary	• 3 hours or more	• 5 or 6 hours a day • 7 or more hours a day

Discussion and Conclusions

This study sought to longitudinally examine the relationship between physical and sedentary activity and depressive symptom severity through the use of a depressive symptom category, physical activity trajectories, and sedentary activity latent classes.

Physical Activity

One of the primary findings of this study is that consistently low physical activity during childhood is significantly associated with the low and high levels of depression in unadjusted models. The inclusion of covariates attenuates this relationship, with the low depressive symptom level association falling out of significance, but the high depressive symptom level still having odds 2.23 times higher than those who remained consistently physically active in childhood. The addition of covariates attenuated the relationship between physical activity trajectory and depressive symptoms. Additionally, there was no statistically significant relationship between the low-to-high physical activity trajectory and any depressive symptoms. There were also no significant associations between physical activity trajectories and self-reported suicidal ideation or CESD category.

The lack of significance of the relationship between high depressive symptoms and low-to-high physical activity trajectory compared to the consistently high physical activity trajectory suggests that the depressive symptom outcomes between these two groups are not significantly different. Stated another way, this may suggest that early childhood physical activity and lack of physical inactivity is not as important as recent physical activity in the depression causal pathway. The significant result in the consistently low physical activity trajectory seems to support this assertion. Had the low-to-high trajectory had statistically significant results, the assertion would instead be that childhood physical inactivity was a predictor for adolescent depressive symptomatology. However since that relationship was not demonstrated in the results shown here, it lends weight to the suggestion that recent physical activity can help prevent depressive symptomatology. Given the symptom profile of depression as present in the DSM-IV[63], including lethargy, lack of pleasure or interest in activities, etc., we caution that is also plausible that those who are depressed are already pre-disposed to low physical activity. However, the trajectories were generated to age 12-13 and the outcome is measured at age 14-15, in order to help address that particular issue. These findings suggest that the physical activity is pre-dating the depressive symptom score, thus potentially having a causal effect on depressive symptoms.

The lack of significance between CESD and depressive symptoms is slightly concerning, however this can be explained by the smaller sample size (n=2,504 vs n=5065), and that the CESD score is an outcome at the 16-17 age group. If proximal physical activity is important in the prevention of depressive symptoms, it is reasonable to

assume that the relationship would attenuate towards insignificance over time, or in this case, that the effect would no longer be present four years past the end of the trajectory, as opposed to two years with the depressive symptoms.

A lack of any significant associations for suicidal ideation in any physical activity trajectory suggests that while depression and suicidal ideation are linked, and physical activity and depression are linked, it's likely there are other factors between depression and suicidal ideation that are more important in determining suicidal ideation.

It should be noted that increasing patterns of physical activity over time is unusual in adolescents. Previous studies have demonstrated that physical activity levels tend to reduce over time.[137] This increasing effect may be a result of the low threshold of physical activity used in this study, which is lower than Canadian recommended guidelines, which suggest 60 minutes of daily moderate to vigorous physical activity in children and youth aged 5-17.[138]

The results of this present study are consistent with the findings of Chapter 2, a cross-sectional study, which also found an association between physical activity and depressive symptoms, however this study expands on those findings by examining the longitudinal relationship to help further clarify directionality of causality and to provide a more nuanced understanding of that relationship.

A Norwegian longitudinal study[139] of the relationship between physical activity, body image and anthropometric measures and depressive symptom in children aged 13-19 showed that a relationship between increased physical activity and lower risk for

depressive symptoms was present, but when stratified by males and females, the effect was only present among males. Interestingly, body image in girls who perceived themselves as "very fat/ chubby" were at higher risk for depressive symptoms, whereas in boys it was only those who perceived themselves as "thin/very thin" which were at higher risk for depressive symptoms. The present study was unable to use measures of height and weight and derived indices like the body mass index (BMI) due to their unreliability in the NLSCY[125]. However, the above noted results regarding physical activity are somewhat consistent with the present study. This study included an interaction term between sex and physical activity trajectory in both unadjusted and adjusted models, but both were statistically insignificant. A similar study using the same sample but with all age groups conducted by Harvey et. al. found that participants who engaged in any leisure time physical activity were less likely to report depressive symptoms.[36]

A study by Birkeland et. al. found that physical activity inversely covaried with depression throughout adolescence at each time point, but that "baseline levels of leisure-time physical activity do not predict later changes in depressed mood, and baseline levels of depressed mood do not predict later changes in leisure-time physical activity".[71] These results are strongly consistent with the findings of this study and further bolster the assertion that proximal physical activity is associated with lower levels of depressive symptomatology.

With respect to suicidal ideation a study by Simon, Powell and Swann found that past-month involvement in physical activity was less likely in suicide attempters than in controls even after adjustment for covariates.[140] This is at odds with our finding, however,

the Simon study had more rigorous case ascertainment of suicidal ideation by using a form filled out by a psychiatric physician and then followed by in-person interviews, with matched controls. Additionally, the Simon study looked at suicide attempters, instead of suicidal ideation, which may suggest that severity of ideation and attempt may be an important factor, however this study failed to find any association between suicide attempt and physical activity.

A study by Taliaferro et. al. also suggests findings that involvement in sport and increased vigorous physical activity reduced suicidal ideation and feelings of hopelessness in boys and that a lack of vigorous physical activity increased the risk of suicidal ideation and feelings of hopelessness in girls.[141] While this result is also inconsistent with the present study, the Taliaferro et. al. study had a more rigorous definition of physical activity and was measured using ascertained by a question asking about the number of days that vigorous exercise of at least 20 minutes was engaged in in the past seven days. However, the Taliaferro study was also cross-sectional and did not address trajectories of physical activity which could explain the difference in results.

A study by Jacka et. al. found that low childhood physical activity was inversely associated with depression in adulthood, which would seem to contradict the results of the present study. However, that study had a smaller sample size (n = 2,152). Additionally, physical activity was measured retrospectively at study time, asking participants to ascertain their physical activity levels under the age of 15 in a four category response.[73] The present study uses a prospective design to ascertain physical activity, which may account for the differences between these two studies.

Sedentary Activity

This study did not find any link between depressive symptoms and sedentary activity latent class. Individuals who engage higher levels of sedentary activity, regardless whether in early childhood or later, were no more or less likely to have depressive symptom scores different than those who were engaged in lower levels of sedentary activities. The association between sedentary activity latent class and depressive symptom s was not modified by covariates, remaining very consistent between adjusted and unadjusted models, suggesting that sedentary activity may not be on the causal pathway towards depressive symptoms.

This finding is consistent with the previous chapter which demonstrated a similar finding, albeit cross-sectionally. This is important as it may suggest that future interventions targeted at physical activity to reduce the chance of developing depression need not worry about reducing sedentary activities, which could make a targeted intervention more palatable to children and their families. Increased leisure-time physical activity could be used as a reward to incentivize greater physical activity, though a properly evaluated, evidence-based intervention design is strongly recommended.

This study used the Canadian Sedentary Behaviour Guidelines for children and youth which recommend no more than two hours of sedentary activity[97], which is a very aggressive definition for sedentary behaviour. As mentioned in Chapter 2, this could suggest that the threshold for depressive symptomatology may be evident only at higher levels of sedentary activity than those seen in this study. However this study attempted to divide the outcome into three categories, instead of two like in the previous study, to allow

a more nuanced evaluation of sedentary activity. Despite this, however, no association was found between sedentary activity latent classes and depressive symptom scores.

It is interesting to note that the low-to-medium sedentary activity latent class's relationship with the medium symptoms did border on significance, with an OR (95% CI) of 1.36 (0.97, 1.89). This study has a large and well-defined sample, however may be lacking the power to detect this particular effect. This should be considered when future studies on this subject are undertaken.

With respect to other research, a study by Hume et al. also did not find any associates between sedentary activity time and depression using a longitudinal study design[122], though the Hume study had a much smaller sample than this study, so this may explain the lack of finding given the above concerns about power.

The study by Sund et. al. mentioned in the previous chapter demonstrated that higher levels of sedentary activity were associated with elevated depressive symptoms a year post-exposure[34], which was inconsistent with the previous chapter's results and is also inconsistent with the results demonstrated here, which look at exposure in a latent class and exposure two years post-exposure. However, the Sund study found the relationship between higher sedentary activity and increased risk of depressive symptoms in boys only, which this study does not stratify for. It is possible that the relationship between higher sedentary activity latent class and depressive symptom score is being lost due to the lack of stratification in this study by sex.

Strengths and Limitations

This study uses the National Longitudinal Survey of Children and Youth which is a large, nationally representative sample which is this study's primary strength. The large sample size granted the power to be able to detect smaller effects than in previous studies and to allow a more robust selection of covariates which lended further strength to the findings above by controlling for the number of confounders and effect modifiers present in psychiatric epidemiology.

The categorization of the exposure variables was a direct result of the structure of the questions in the NLSCY. Some of the inconsistency with other results may be accounted for by this means of quantifying exposure. A continuous variable, or more accurate logging techniques such as diaries or accelerometer (in the case of physical activity) may provide a more robust and nuanced analysis in the future.

As in the previous chapter, the use of self-reported physical activity measures is likely leading to some non-differential misclassification, as all individuals tend to overreport their physical activity levels, which would tend to bias these results to the null. Further research on whether differential misclassification between those who are more depressed and those who are less depressed on physical activity levels could be a promising area of research.

Body Mass Index (BMI) was not included in this analysis as the self-reported measures of height and weight used in the NLSCY show both inconsistent data across time, as well as high levels of bias and error. As a result, the derived BMI variables in the NLSCY are unreliable and would not contribute to the analysis. In addition, inconsistency in how questions were posed in earlier cycles versus later cycles for sedentary activity necessitated

the use of latent class analysis, rather than trajectory analysis. The rates of missingness for the outcome were relatively low (15.7%), and missingness in covariates was mitigated by the addition of a missing category in all categorical covariates, which helped retain sample size and keep power high, this meant that no respondents were lost in the multivariable adjusted models versus the univariate unadjusted models for physical and sedentary activity.

The longitudinal nature of this study has helped to better understand the causal pathway of the relationship between physical activity and depressive symptoms. However, having picked a weaker model for its greater explanatory power, it is recommended to interpret these results with some caution. Latent class analysis cannot provide us with a longitudinal understanding of the causal pathway, though the results from this study remain consistent with the previous fully-cross-sectional study in Chapter 2.

Conclusions

Recent physical activity appears to be significantly related to depressive symptomatology, suggesting that it is more important to be engaged in physical activity today rather than worry about physical activity in the past. The relationship between sedentary activity and depressive symptom score remains unclear, though this may be as a result improperly powered studies or measurement discrepancies.

Physical activity is an effective intervention for a number of physiological conditions, such as obesity and metabolic syndrome, insulin resistance, as well as promoting cardiovascular health and a host of other physical conditions.[114–116] It is also a very low-cost intervention which can easily be deployed into communities. The mounting

evidence for a clear link between increased recent physical activity and reduced depressive symptomatology as posited by this study suggests that physical activity may very well have additional mental health benefits to the already well-documented physical health effects. Further studies using advanced accelerometry will be able to provide more objective measures of physical activity and will be beneficial to more precisely understanding the relationship between physical activity and depressive symptoms. Additionally, more nuanced collection techniques with respect to sedentary activity may help more clearly understand the relationship, if any, of sedentary activity to depressive symptoms. For example, more objectively observed measures of physical and sedentary activity over a longer time would benefit these analyses. Also, survey questions on a greater variety of physical and sedentary activities would be very helpful for future research, as well as consistent question and answer formats.

Chapter 4: Discussion and Conclusion

Discussion

This thesis explores the relationship between physical and sedentary activity with the outcomes of depressive symptoms and suicidal ideation both cross-sectionally and longitudinally. This exploration was conducted through a secondary data analysis of Statistics Canada's National Longitudinal Survey of Children and Youth. The results of this thesis contribute incrementally to the growing body of evidence surrounding the links between physical activity, sedentary activity, depressive symptoms, and suicidal ideation in the early part of the life course. Initially, this thesis posed three goals with hypotheses (see below). Below, these goals and hypotheses are evaluated against the evidence acquired throughout this thesis and contrasted with current research.

1. **To examine, cross-sectionally, the relationship between physical activity, sedentary activity and depression in children and youth.**

   Hypothesis: Individuals who engage in less sedentary activity and more physical activity are less likely to demonstrate symptoms of depression, after controlling for confounding for a number of variables including demographic and socioeconomic variables.

The primary findings from the cross-sectional analysis (Chapter 2) found an association between low physical activity and depressive symptoms in adolescents., in both unadjusted and adjusted models. However, the analysis provided much less conclusive evidence for those who exhibited sedentary versus non-sedentary behaviours. In that case, sedentary behaviour was associated with moderate depression versus those who did not exhibnit

sedentary behaviour.. When examined jointly with physical activity, sedentary activity was no longer significantly associated with depression,. Therefore, the evidence from the findings in this study lead us to the following:

> *Conclusion:Individuals who engage in more physical activity may be less likely to demonstrate symptoms of depression, after controlling for confounding from a number of variables including demographic and socioeconomic variables. A significant relationship between sedentary activity and depression was not demonstrated in the present study and continues to remain unclear. An interaction between both physical and sedentary activity does not appear to exist.*

As this was a cross-sectional study, we cannot infer the directionality related to causality. It is equally plausible that children who are physically active are less likely to get depressed, or that children who are not depressed are more likely to be physically active. As reduced activity levels are in the list of presentations for depression according to the DSM-IV[117], this thesis cautions the reader about making assumptions about causality.

This thesis is largely consistent with other research in this field, such as the study by Sund et al. study which found a cross-sectional association between lowered physical activity levels and depression[34], as well as studies by Harvey et al.[36], and McKercher[118]. However, using more advanced methods of measuring physical activity such as accelerometry may yield different results, such as demonstrated by Parfitt et al, which found that physical activity was associated with lower anxiety and higher self-worth, but not with depressive scores.[120] Differences in measures of exposure and outcome may be contributing to the differences between studies. For example, this study did not account for structural physical activity, that is, physical activity that is structured as part of one's daily

life, such as walking to and from school, etc. Studies accounting for this may draw similar or different conclusions. This remains unclear.

2. To determine how trajectories of physical and sedentary activity in childhood are associated with the development of depression in adolescence.

Hypothesis: Physical activity in childhood and youth can both act as a protective factor for developing depression later in life and that early childhood sedentary activity can be a risk factor for the development of depression later in life. (See Figure 1.1).

Chapter 3 of this thesis examined the longitudinal association of physical and sedentary activity and depressive symptoms. Primary findings included recent physical activity was more predictive of reduced depressive symptomatology than early measures of childhood physical activity, in both unadjusted and adjusted models. This finding was especially strong in the adjusted models, which suggested that for those who engaged in consistently low physical activity had a higher risk of having severe depression symptoms compared to those who had consistently high levels of physical activity or those with increasing physical activity trajectories. A sex and physical activity trajectory interaction was not statistically insignificant, suggesting that there were no differences between males and females in the relationship between physical activity and depression.

No association was found between sedentary activity latent classes and depressive symptom category either in unadjusted or adjusted models, lending further evidence to the finding in Chapter 2 that it is unlikely that sedentary activity is related to depressive symptoms cross-sectionally and longitudinally. A sex and physical activity trajectory

interaction was statistically insignificant, suggesting that there were no differences between males and females in the relationship between sedentary activity and depression.

Conclusion: Lower physical activity in early childhood was not associated with depression in adolescence. However, those who had physical activity levels that increased over childhood were less likely to be severely depressed in adolescence, with no differences in outcomes between males and females. Sedentary activity patterns in childhood were not associated with increased odds of depression in adolescence. (See Figure 4.1)

This study was also largely consistent with the literature, however, a Norwegian study conducted by Flotnes et. al. found that an effect of physical activity on depression was only present in males and not females.[139] This thesis did not find such a sex interaction. Both the Flotnes study and this study were well-powered, longitudinal designs, however the Flotnes study had a smaller sample (n=2000 vs n=5064), was regionally based (a single county in Norway versus a nationally representative sample of Canada for this thesis), and had different measures of physical activity and depression anxiety which may contribute to the differences found. However, other studies such as by Birkeland et. al.[71] and Harvey et. al.[36] were consistent with the findings of this thesis as they showed that those engaged in physical activity were less likely to be depressed.

3. **To longitudinally examine the association between sedentary and physical activity and suicidal ideation.**

Hypothesis: Children and youth who are more physically active and engage in less sedentary behaviour are less likely to be having suicidal thoughts than kids who are less physically active and engage in more sedentary behaviour, after controlling for confounding for a number of variables including demographic and socioeconomic variables.

Finally, this study looked at the association between physical and sedentary activity and suicidal ideation and attempt as an outcome. However, neither physical activity nor sedentary activity was statistically significantly associated with suicidal ideation and physical activity was not statistically significantly associated with suicide attempt. A study by Simon, Powell and Swann did find that recent physical activity was associated with lower physical activity levels in suicide attempters compared to controls.[140] The present study found no link between suicidal ideation and either physical or sedentary activity, and also found no association between suicide attempters and physical activity. The conclusion is thus:

> *Conclusion: There was no association between physical or sedentary activity and suicidal ideation and no association between physical activity and suicide attempt.*

On Causality

Bradford Hill suggested 9 criteria in his landmark work to help evaluate the strength of evidence to support causal inferences.[142] Understanding the results and evidence presented in this thesis within that context will be helpful in determining whether the effects of physical activity found are merely *associations*, or whether there is some true causal relationship at play here. However, as cautioned by Rothman and Greenland,[143] this is being undertaken as a conceptual exercise, rather than making definitive statements about causality. The nine criteria are outlined below:

Strength

Bradford Hill posits that the size of an effect in a relationship be indicative of a causal association, suggesting that larger effects are more likely to be causal than

not. In the cross-sectional analysis, respondents medium and high symptoms had odds (95%CI) 1.43 (1.12, 1.84) and 1.88 (1.45, 2.44) times higher, respectively, which are suggestive of relatively robust effects. Longitudinally, low physical activity was only statistically significantly associated with high depressive symptoms, but the effect was also large, with odds (95% CI) 2.23 times (1.14, 4.34) higher than a consistently physically active reference group, again suggesting that the strength of this relationship may be indicative of some causal mechanism.

Consistency

The results of this thesis are largely consistent with other epidemiological evidence in both cross-sectional and longitudinal analyses. To begin with, the cross-sectional and longitudinal studies present in this thesis are consistent with one another in terms of the direction and the strength of the association between physical activity and depression. The studies presented here are also consistent with other studies in the field which point to similar effects.

For example, the study by Harvey et. al. concluded that people participating in leisure time physical activity were less likely to be depressed. This study was comprised of 40,401 residents of Norway, with a mean (SD) age of 45.9 (16.2) that were largely married (58.8%) and had completed at least secondary school (69.5%). Results of modelling adjusted for age, gender, and a variety of covariates including but not limited to "family history of mental illness, current social class, education, marriage status", substance use and "subjective impairment owing to physical illness" indicated that those who participated in less than 3 hours of light leisure activity had statistically significant odds ranging from 1.33 to 2.04 times higher for

depression alone compared to those who engaged in 3 hours of light leisure activity per week. Those who participated in less than 1 hour per week or no hours per week of intense leisure activity per week had statistically significant odds of 1.61 and 1.98 times higher than those engaging in 3 or more hours per week of intense leisure activity.[36]

A study by Flotnes et. al. using the same base population as the Harvey study, but with a subsample of children aged 13-19, which is more consistent with the population of interest in this thesis, also demonstrated an inverse relationship between physical activity and depressive symptoms, with adjusted relative risks ranging from 1.4-2.1 among boys.[139] This previous study by Flotnes et. al. as mentioned above did have inconsistent results especially when presenting sex-stratified results,[139] however that may be accounted for by largely different sampling frames (national versus local), sample sizes, and other such concerns as noted above.

Birkeland et. al. also demonstrated that increased physical activity was proximally associated with lower levels of depression. This was another Norwegian study, using the Norwegian Longitudinal Health Behaviour Study, a prospective 10-year longitudinal study. This study concluded that "leisure-time physical activity and depressed mood covary, but are inconclusive regarding which comes first."[71]

Cross-sectional studies, such as that by Wiles et. al. also demonstrated that adolescents who are more physically active have lower odds of being depressed. Wiles' study was based on 2,951 adolescents from the Avon Longitudinal Study of Parents and Children (ALSPAC), a British cohort based in Bristol. Physical activity

was protective against depression, with odds ratios ranging from 0.69-0.82 (statistically significant) for all physical activity, and 0.92 (95% CI: 0.86, 0.98) for "moderate and vigorous physical activity". [68] Even studies looking at other age groups have shown that meeting minimum U.S.-based physical activity guidelines, for example, has demonstrated lower odds of depressive symptoms in men aged 20-87.[69]

Taken together, there appears to be a large body of evidence to suggest the consistency of the findings of this thesis with other epidemiological research on this subject.

Specificity

Specificity is difficult to establish in the case of depression as it is relatively poorly understood and there are many putative causes to depression explored in the literature and lack of physical activity may only be one of the contributing factors to the development of the disease. However, Bradford Hill himself notes that a lack of specificity does not *eo ipso* imply a lack of causation.[d]

Temporality

Perhaps one of the more important criteria, *in hoc opinionem studiosum scriptor*, that Bradford Hill posited was the need for a cause to occur before an effect. While the cross-sectional analysis in this paper provides compelling evidence for an association, it cannot speak to the temporality of the association, as effects and

[d] Ego tristis defectus in linguam Latinam sive in academicum litterarum.

outcomes were measured in the same time frame. However, the longitudinal analysis does allow us to comment on causality, with the effects being measured prior to the outcomes, with a two year separation between the two. Even with this separation of postulated cause and effect, a strong effect still exists, which suggests that there is a temporal component to this association, lending strength to the argument for causality. One caveat is that this study examined outcomes at ages 14-15, but some respondents may have had internalizing issues in early childhood. Additionally, reverse-causation is also a possibility. As mentioned previously in the paper, one of the symptoms of depression is a loss of interest in activity. It remains difficult to determine whether physical inactivity is leading to depression, or vice versa.

Biological Gradient

The existent of a dose-response effect was one of the criteria that Bradford Hill asserts can lead to the credibility of the causal assertion. This analysis dichotomized the physical activity exposure, denying any nuance in the determination of dose-response effect. However, given this, the effect of increasing physical activity over time was statistically no different than consistently high physical activity over time, this supports the case for a short-term causal mechanism for physical activity's effect on depression, versus a long-term causal mechanism.

Plausibility

If a plausible mechanism between the exposure and the outcome can be proposed, it would strengthen the case for causality. In the case of physical activity and depression, a great deal of literature has examined some of the many potential social and physiological mechanisms which may be at play. For example, physical activity may be acting as a psychosocial buffer, as demonstrated by an Icelandic study as part of the Youth in Iceland survey. This study of 7,430 participants noted that while depressed mood can be elevated in boys and girls when family conflict is elevated, that physical activity significantly buffers this effect by reducing the likelihood of depressed mood in adolescents.[51] Social support and self-esteem have been noted as acting as mediators in the relationship between sports participation, depression, and suicidal ideation, as in the study by Babiss et. al. based on the National Longitudinal Study of Adolescent Health (Add Health) study in the United States.[52] A recent trial by Wipfli et. al. based in the United States has demonstrated that vigorous exercise, versus stretching only, for example, has been linked to lower blood serotonin levels, which is an effect similar to that of a class of drugs used to treat depression, SSRIs. The sample for this study was 65, with a mean age (SD) of 20.7 (2.1) years, ranged 18-30 years old.[55]

Studies have also examined how physical activity affects cortisol (the "stress" hormone) levels. For example, a Taiwanese study of 232 subects demonstrated that higher levels of self-reported physical activity was associated with more positive night-time cortisol patterns.[61] Beyond depression, physical activity has also been demonstrated to reduce the sensations of fear associated with panic disorders,

which are not explained by "established risk factors of CO2 challenge reactivity" as noted in a study of 92 participants aged 17-24[58], and that the intensity of exercise can change the strength of this effect.[59]

These are only a few of the potential plausible mechanisms by which physical activity could be affected depression outcomes. The fact that these potential mechanisms exists and a body of research supports their links to depression outcomes lends strength to the plausibility of the causal relationship between physical activity and depression.

Coherence

Some complications arise when considering the coherence between the suggested causal relationship and the "natural history and biology"[142] of depression. As noted before, reduced physical activity, increased lethargy, and loss of interest in previously enjoyable activities are noted as presentations of depression.[117] This complicates the inference of a causal relationship between physical activity and depression. However, the use of measures of exposure and outcome taken two years apart in the longitudinal analysis may help to contextualize the coherence in this case.

Experiment

A lack of double-blinded, placebo-controlled clinical trials examining the use of physical activity as a tool for the prevention of depression continues to limit the ability to draw causal inferences. This study does not contribute this lack of experimental evidence. However, its large, longitudinal nature does help to

continue to strengthen the epidemiological relationship between physical activity and depression.

However, studies have demonstrated that physical activity is effective as a treatment for mental illness, both alone and as a complement to other therapies. A small pilot study demonstrated that both aerobic exercise and regular stretching were associated with improved outcomes in depressed patients.[144] A randomized controlled trial demonstrated that participants engaged in aerobic exercise had lower blood-serotonin levels and improved depression outcomes, an effect similar to the use of SSRIs, the current gold standard in the treatment of depression.[55] This experimental result suggests a causal link between physical activity and depression. A meta-analysis of physical activity randomized controlled trials and anxiety outcomes provide tangential but added experimental strength to the causal relationship between physical activity and mental health outcomes.[145]

Analogy

Bradford Hill states that "in some circumstances it would be fair to judge by analogy."[142] However, in this case, it is likely that analogy is not needed given the responses to the above criteria.

Conclusions on Causality

Given the considerations and the relative strength of the responses to most of the criteria above, it is likely that a causal relationship between physical activity and depression exists, and as such a further examination into the specific mechanisms at play would likely be warranted to better understand that relationship. Additionally, since increased physical activity is a low-risk, low-cost intervention, there is no

reason why physical activity interventions couldn't be designed and implemented concurrently with additional research aimed at more closely understanding the causal relationship.

Updating the Model

In Chapter 1, a model was suggested to explain the relationship between physical and sedentary activity and its role in the depression/suicidal ideation pathway. Originally it was suggested that physical activity and sedentary activity were opposing forces that could push an individual further along the depression pathway (sedentary activity), or back towards a healthy state (physical activity). However, given the analysis conducted in this thesis, a revised model is proposed (see figure 4.1). In this model, physical activity only acts on the left-most portion of the pathway, acting from depression back to healthy state, through a number of potential mechanisms indicated on the right side of the physical activity arrow, which are not within the scope of this thesis. This revised model has removed sedentary activity entirely, and limits the physical activity force to what evidence was found as part of this study. While this model may be less robust than the original model posited, it is certainly more parsimonious.

This model is based both on the empirical evidence gathered in this study, but also on the evidence presented by other researchers in the field synthesized in various parts of this overall thesis. The inferences on causality drawn above using Bradford Hill's criteria lend strength to this model suggesting physical activity as a causal mechanism in improving mental health outcomes and in the prevention of depression.

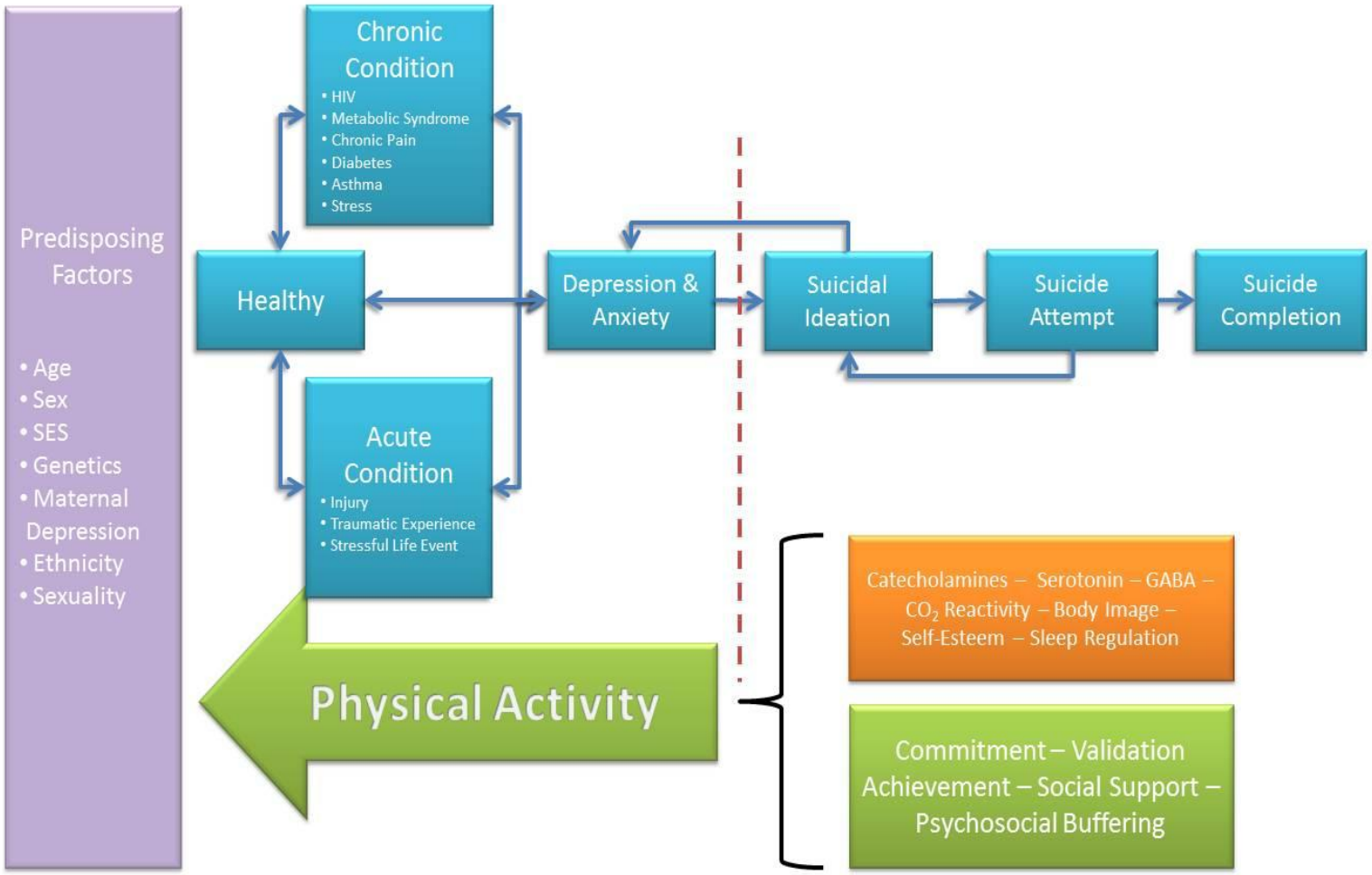


Figure 4.1 – **A revised model for the longitudinal relationship between sedentary activity and physical activity on depression health outcomes in children and youth.**

Strengths and Limitations

This thesis has many strengths and limitations to consider when evaluating its overall contribution to the field of study. The National Longitudinal Survey of Children and Youth, a large, nationally representative sample is this study's main strength. The large sample size has provided the power to detect smaller and more nuanced effects than many other studies in this area of research and to allow for more robust model generation by providing the flexibility to control for many confounding and effect-modifying variables which are closely related to depression as an outcome. Additionally, the cross-sectional design leading to the longitudinal analysis allowed this thesis to better disentangle the causal pathway between physical and sedentary activity and depression. Trajectory and latent class analysis was conducted in a rigorous manner to select the best trajectory or latent classes for the question at hand, and while some compromises had to be made with trajectory generation, this thesis demonstrated that while a 3-group model was perhaps less methodologically rigorous, given the 2-group results, it has adequately demonstrated the rationale for the use of a 3-group model.

The use of advanced statistical techniques such as bootstrap weighting, multinomial logistic regression and trajectory analysis and latent class analysis ensured a rigorous analysis of the data at hand. Additionally, having prospective repeated measures of numerous covariates and outcomes in the NLSCY provided some flexibility in choosing the most relevant time points for this analysis.

However, a number of limitations prevented this study from going further with its inferences. The measures of physical activity were imprecise. Measures of physical

activity with greater numbers of categories, or advanced methods of data collection such as actigraphy could lead to a more nuanced analysis of the relationship between physical and sedentary activity and depression. While the OCS Depressive Symptom Score which was used to generate the depressive symptom category at age 14-15 is a reliable score, and the CES-D that was used for depressive symptom category generation at age 16-17 is also a reliable scale, a much smaller sample in the CES-D scale led to questions about whether the lack of effect seen was due to smaller sample size, or due to a true proximal temporal effect of physical activity on depression.

Originally, this thesis intended to generate trajectory models for sedentary activity in addition to physical activity trajectories. However, due to changes in how the survey ascertained sedentary activity in different cycles, we were unable to use that method and had to compromise with latent class analysis for sedentary activity. Unfortunately, latent class analysis does not allow this thesis to make inferences about the longitudinality of the relationship between sedentary activity and depression, leading to continued murkiness in this relationship, as suggested in the cross-sectional analysis.

This study examines outcomes at the age of 14-15, however some respondents may have experienced internalizing disorders at an earlier age. The NLSCY does contain earlier measurements of depressive symptoms but this study design does not account for them. A different study design and analytical technique would have to be used in order to investigate repeated measures of internalizing effects but is beyond the scope of this thesis.

Additional consideration should also be given to the self-reported or PMK-reported nature of the data in the NLSCY. While sedentary measures were validated in the NLSCY with a 7-day viewing diary (see page 25) with acceptable reliability scores, this data remains self-report and may be biasing results similarly to physical activity data (under-reporting sedentary behaviour). Covariate data is similarly self-reported and can be very sensitive such as those about tobacco and alcohol use, or questions regarding stressful life events, which may also be biasing these results. Any inferences and generalizations to be drawn from this survey must be made within a clear understanding of the context of the data available.

Policy Implications

Since physical activity is already recommended as a means to both prevent and mitigate the effects of cardiovascular and metabolic diseases[114–116], such as heart disease, diabetes, obesity, etc., adding mental health outcomes to this inexpensive and easily modifiable intervention has many far-reaching implications. In addition, since sedentary activity does not appear to be related to depression based on this study, and if this holds true in future studies, interventions would only have to target physical activity and not necessarily seek to reduce overall sedentary activity. In children and youth, this could have some very powerful incentivizing factors, as sedentary activity such as reading, video games, and television viewing could be used as a reward for successfully reaching physical activity goals. In addition, the introduction of physical activity could be done by addressing structural sedentary activity, instead of leisure-time intentional sedentary

activity. Examples of this could include walking to school instead of getting a ride (if safe and feasible), spending more play time outside at recess, or using stairs instead of elevators (when safe to do so).

Safe and Effective Interventions

Many interventions exist both in and out of schools to promote physical activity. One of the most basic is the physical activity curriculum in schools. However, in recent years, physical fitness funding in schools has been clawed back.[146] It is widely reported in the media that cutbacks in physical education are leading to poorer health outcomes in children[147–149]. Some recent research on the subject suggest that physical activity programming in schools can reduce body weight in 5th graders, for example, but that the effect tends to be present only in boys.[150] A study by Harris et. al. similarly concluded that school-based physical activity did not have an impact on participants' BMI.[151]

The World Health Organization released a report in 2009 outlining a series of diet and physical activity interventions that were evidence-based and evaluated in a report titled "Interventions on Diet and Physical Activity: What Works".[152] The report concludes that the most successful programs were "multi-component and adapted to the local context."[152] However, the WHO report notes that much of the research on diet and physical activity interventions "are a result of short term studies", noting additionally that some outcomes such as psychosocial ones may be evident as part of those studies, but that additional long-term research is needed to properly determine "behavioural, physical and clinical outcomes."[152]

A report by the Cochrane Heart Group noted that while physical activity interventions in adults 16 years and older did increase physical activity outcomes "moderately", that methodological issues and study heterogeneity limited the scope of the conclusions.[153]

An early systematic review on internet-based interventions show some promise, suggesting that internet based program especially when using objective measurements such as through an activity monitor, may improve physical activity outcomes.[154]

Canadian Context

Unfortunately, sport and exercise funding has seen great declines over the decades in Canada as programs were cut back or cancelled outright due to greater fiscal restraints when faced with large spending deficits. One of Canada's best known fitness programs, ParticipACTION, was cancelled in 2001. In 2007, the program was restarted again, but then faced clawbacks of 55% of its federal funding in 2014.[155] Some research on ParticipACTION suggested that its media campaigns improved attitudes towards physical activity in sedentary individuals and increased the intention of individuals to participate in physical activity in the future.[156]

Despite consistent messaging from the federal government about the need to improve the physical activity and health outcomes of Canadians, and Canadian children in particular, the federal government continues to reduce funding to programs like ParticipACTION. The current Conservative government has preferred to implement a series of tax credit schemes such as the Children's Fitness Tax Credit as a policy lever to encourage Canadian families to get their children involved in physical activity. The

Children's Fitness Tax Credit, introduced in 2006 hoped to provide parents of children enrolled in sports and fitness activities a tax credit of $500 per child (and an additional $500 if a child is eligible for the Disability Tax Credit) to defray the costs of sports and fitness program enrollment. In 2014, a proposal was put forward to make the Children's Fitness Tax Credit a refundable tax credit, however this proposal has yet to receive parliamentary approval as of the writing of this document.[157]

Tax credits, however, are often seen as regressive tax measures, as they tend to favour those who are economically well-off, and those who are economically disadvantaged may not reap their benefits.

A study in the Canadian Tax Journal noted that the Children's Fitness Tax Credit represents between $90 million and $115 million in lost tax revenue per year, noting that it is a "substantial investment of public funds".[158] Despite this, the study notes, only 36% of households claimed the credit in 2009, and the families that claimed the tax credit tended to be dual-parent households (39.5%), and that the average annual income of credit claimers was $115,000.[158] An additional interesting finding of this study found that "families living in the Far North were significantly less likely to claim the [Children's Fitness Tax Credit]."[158] Another consideration was that having a male child statistically increased the odds of claiming the tax credit versus households with no male children (OR: 1.13, $p<0.01$).[158] A study by Spence et. al. also supports the assertion that wealthier families are more likely to benefit from the tax credit.[159]

A commentary by Spence, et. al. in the Canadian Journal of Public Health reinforced this message, saying that non-refundable tax credits only benefit those who incur a tax liability, and those who are in low income brackets do not tend to do so.[160] Additionally, the defunding of public fitness programs, and rising costs of sports activities tend to make sport and physical activity programs inaccessible to those who are economically disadvantaged. This is concerning as lower income levels is often predictive of higher rates of childhood obesity and diabetes.[161]

As suggested by Spence et. al., in order to provide more equitable access to sport and fitness programming for children and youth, a combination of refundable tax credits and "subsidized programming for low-income children" should be implemented.[160]

Given the evidence proposed in this thesis and the evidence generated by previous studies in this field, it is feasible to suggest that including mental health outcomes, especially depression, as key indicators of the success of physical activity interventions would be timely. Given the increased focus on mental health in recent years, especially in the light of several high profile suicides and the release of several mental health strategies, at the provincial and federal levels, bringing physical activity as a safe, costly and effective intervention for mental health outcomes, in addition to the other well-documented and well-studied physiological outcomes is timely.

Research Implications

Future studies should continue to use large, well-powered studies and advanced data collection techniques to better ascertain the exact nature of the relationship between physical activity and sedentary activity. Large, longitudinal and representative samples

will continue to lend additional credence to other smaller epidemiological studies which have found similar effects and help to clarify the causal pathway between physical activity and depression. Additionally, such a study would also perhaps more conclusively fail to find evidence of a lack of relationship between sedentary activity and depression.

In this context, more direct collection of outcome and exposure measures would be favourable such as those collected by the Canadian Health and Measures Survey. For example, instead of self-reported depression scales, future studies could use the services of trained psychologists or psychiatrists to better ascertain the true depressive severity of sample participants. In addition, instead of relying on parental-reports or self-reports of physical activity, more direct methods of data collection such as accelerometry or actigraphy using a variety of sensors such as accelerometers, heart rate monitors, etc., could yield a more accurate and precise measure of a participant's true physical activity over time. When ascertaining sedentary activity, monitoring tools such as computer software which logs individual's computer time, smart devices which monitor television watching time, and logs which record book reading, in addition to accelerometry and actigraphy could more accurately ascertain not only the amount of sedentary activity being engaged in, but to further ascertain the type of sedentary activity being engaged in, which could provide a more nuanced approach to analysis.

Further research on the amount of physical activity needed to improve mental health outcomes is needed, as well as further research in other outcomes, such as anxiety, phobias, and other mental health conditions. Despite this, however, this is a very promising intervention point to help reduce the burden of mental illness especially in

adolescents, and due to the proximal relationship between physical activity and depression posited by this thesis, a further message could include something such as, "It doesn't matter if you've never been physically active a day in your life. Starting today can help reap benefits to you right away." This could be a very powerful motivating message to help those who may feel helpless because they've never been physically active before.

Conclusion

While this thesis has not conclusively answered the question of whether physical activity is protective against depression and whether sedentary activity puts one at risk for depression, the evidence gained from the analyses within suggest that physical activity may play an important role in the prevention and treatment of depression, along with a host of other physical conditions such as diabetes, cardiovascular disease, etc. In addition, this study suggests that a link between sedentary activity and depression may not exist, which could help determine the way physical activity interventions are structured.

An examination of the results of this thesis against the Bradford Hill criteria provides compelling evidence for the causal assertion that low levels of physical activity can lead to higher levels of depression. This thesis has demonstrated a strong case for temporality, is consistent with the growing body of epidemiological research surrounding physical activity and depression, has many plausible physiological mechanisms that may underlie the relationship supported by experimental evidence.

This compelling evidence for the assertion that lower levels of physical activity can lead to higher levels of depression has important implications for policy makers. Because the implementation of physical activity programs has relatively low costs, very low risk and a number of benefits across physiological and now mental health, policy makers would

be well served to look at the variety of programs available and implement them with strong, structured evaluation components to ensure proper cost-benefit ratios and positive outcome indicators.

The potential causality discussed earlier lends additional strength to the use of physical activity as an effective, timely and cost-effective intervention for the prevention and treatment of depression and other physiological conditions. The implementation of school-based physical activity, the expansion of subsidized physical activity programs, in combination with other incentives to support the development of healthy patterns of physical activity in adolescents could be a boon to the overall health, both physical and mental, of adolescents.

Further research is needed to help further clarify these relationships, but at this time, physical activity remains a promising and timely activity to protect against depression in adolescence.

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