MENTAL HEALTH AND PHYSICAL ACTIVITY IN CANADIAN ADOLESCENTS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

by

Mariam Bakshi

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Queen’s University
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Abstract

Background: Adolescents with attention deficit hyperactivity disorder (ADHD) are at a heightened risk for poor mental health. Limitations of medication use for the treatment of ADHD include non-response and adverse side effects. Physical activity has shown promise for such treatments through the alleviation of the direct symptoms of ADHD, as well as the fostering of positive mental health. However, the contexts in which physical activity occurs in youth with ADHD and impacts upon their mental health have not been thoroughly explored.

Objectives: The objectives of this thesis are to: 1) describe the prevalence of positive and negative mental health indicators in Canadian youth with ADHD and compare the prevalence of these indicators to Canadian youth without ADHD, 2) estimate the strength and statistical significance of associations between different types of physical activity and mental health indicators in adolescents with ADHD, and; 3) examine the potential influence of biological sex and age in these relationships.

Methods: Data from the 7th cycle of the Health Behaviour in School-aged Children (HBSC) study was used. Prevalence estimates were calculated for each mental health indicator by ADHD status. Rao-Scott chi-square tests were conducted to examine group differences. Multi-level log binomial regression models were developed to explore the associations of interest.

Results: Canadian adolescents with ADHD reported poorer mental health than Canadian adolescents without ADHD. Within the ADHD population, females reported a higher prevalence of negative mental health indicators than males. Inconsistent patterns were found between engagement in different types of physical activities and mental health in youth with ADHD. The main potential etiological finding was that engagement in physical activity in certain contexts was associated with high prosocial behaviour in adolescents with ADHD.

Conclusions: Identification of different mental health patterns in males and females in the ADHD population suggests the possibility of differential diagnoses of ADHD by biological sex. Physical activity in different contexts may have differential effects on the mental health of young
people with ADHD. Understanding of these relationships could help inform public health to
develop physical activity interventions that are the most effective in this subpopulation of youth.
Co-Authorship

This thesis is the work of Mariam Bakshi, in collaboration with her supervisor Dr. William Pickett.

**Manuscript 1:** *The Mental Health Status of Canadian Adolescents with ADHD.* The idea to study the mental health of adolescents with ADHD was Dr. Pickett’s. Mariam Bakshi and Dr. Pickett collectively outlined the mental health indicators used to measure mental health, based on previous conceptual framework from the HBSC. The statistical analyses, interpretation of results and writing of the manuscript were performed by Mariam Bakshi with feedback and guidance from Dr. Pickett.

**Manuscript 2:** *Protective Effects of Physical Activity on the Mental Health of Canadian Adolescents with ADHD.* The idea to examine the associations between physical activity and mental health in youth with ADHD was Dr. Pickett’s. Dr. Janssen helped conceptualize the different types of physical activities during the proposal stage. The statistical analyses, interpretation of results, and writing of the manuscript were performed by Mariam Bakshi with feedback and guidance from Dr. Pickett.
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List of Abbreviations

**ADHD**  Attention deficit hyperactivity disorder

**APA**  American Psychiatric Association

**HBSC**  Health Behaviour in School-aged Children Study

**DSM-IV**  Diagnostic and Statistical Manual of Mental Disorders

**ART**  Attention restoration theory

**ICC**  Intraclass Correlation

**SES**  Socioeconomic status

**RR**  Relative risk
Chapter 1

Introduction

1.1 General Background

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects approximately 1 in 20 children, with prevalence levels estimated at 3.3 to 8.9% in Canada (American Psychiatric Association, 2013; Faraone, Sergeant, Gillberg, & Biederman, 2003; Polanczyk, 2007). The disorder is characterized by pervasive and impairing symptoms of inattention, hyperactivity and impulsivity (American Psychiatric Association, 2013).

ADHD can be a challenging disorder for young people. It is associated with a diverse array of negative outcomes including academic failure, low self-esteem, poor peer relationships, parental conflict, delinquency, depression, anxiety and anti-social behaviour (Biederman, 2005; Brinkman, Epstein, Auinger, Tamm, & Froehlich, 2015; Hurtig et al., 2007; Klassen, Miller, & Fine, 2004; Lundervold, Hinshaw, Sørensen, & Posserud, 2016; Molina & Pelham, 2003). Up to 80% of children with ADHD continue to experience its effects throughout adolescence and then adulthood (Faraone et al., 2003). ADHD also poses a major public health burden on society with families and communities both affected (Polanczyk, 2007). Birnbaum et. al., (2006) estimated that the yearly indirect and direct costs of American families with children who have ADHD was approximately $6.78 billion collectively for the U.S. population, with collective costs being slightly lower in Canada.

Although pharmacological approaches such as the use of medications like Ritalin have been the main method of treatment for ADHD, these can have many adverse side effects (Hinshaw, Henker, Whalen, Erhardt, & Dunnington, 1989; Wigal, 2009). Up to 30% of individuals with ADHD do not respond to medications such as stimulants (Wigal, 2009). Engagement in physical activity is an alternative therapeutic approach. While animal studies and studies with young children have shown a link between physical activity and the reduction of behavioural symptoms, most of these studies have involved small samples and have not taken into account the natural settings in which physical activity typically occurs in children and youth (Bahrke & Morgan, 1978; Cho, Baek, & Baek, 2014; Hoza et al., 2015; Jeong et al., 2014; Kiluk, Weden, & Culotta, 2009; Lufi & Parish-Plass, 2011; Robinson, Buttolph, Green, & Bucci, 2015). The types of physical activity that young people engage in are also significantly different than
those of adults (Brodersen, Steptoe, Williamson, & Wardle, 2005). While introduction of adult-based physical activity interventions to young people with ADHD has shown promise, more youth-centered physical activity interventions require implementation and evaluation. Moreover, in general populations of young people, physical activity has shown to foster positive aspects of mental health (Ahn & Fedewa, 2011; Howie, Lukacs, Pastor, Reuben, & Mendola, 2010; King et al., 2005; Pate, Trost, Levin, & Dowda, 2000; Synder et al., 2010). This finding is also important for adolescents with ADHD, as physical activity may not only help alleviate symptoms, but also protect against adverse mental health outcomes.

Mental health is an integral component of population health and well-being and includes both negative and positive aspects (Keyes, Dhingra, & Simoes, 2010). Population-based studies of mental health have focused both on the reduction of symptoms of illness and the improvement of positive aspects of mental health (Hatch, Harvey, & Maughan, 2010; Keyes, Dhingra, & Simoes, 2010; Trompetter, Lamers, Westerhof, Fledderus, & Bohlmeijer, 2017). Similarly, the positive youth development approach focuses on the promotion of factors that increase positive youth behaviour, rather than exclusively focusing on problem youth behaviour (Lerner, 2005).

In addition, existing psychopathological theory surrounding children and youth suggests that mental health is best modeled in two factors consisting of internalizing and externalizing behaviours (Achenbach, & Edelbrock, 1978; Krueger, Chentsova-Dutton, Markon, Goldberg, & Ormel, 2003). While the majority of related adolescent studies have focused on one of these two domains, there is a need for holistic studies that consider both positive and negative aspects of mental health (Brinkman et al., 2015). In my thesis I will therefore examine mental health in four related constructs including internalizing-negative (psychosomatic symptoms), externalizing-negative (risk behaviour), internalizing-positive (emotional well-being), externalizing-positive (prosocial behaviour) components (Freeman et al., 2011).

My study aims to provide a descriptive, epidemiological overview of the mental health of Canadian adolescents with ADHD on a national scale. Moreover, I will explore relationships between the different types of physical activity and the above indicators of mental health status among young people with ADHD. These types of physical activity include curriculum time physical activity, outdoor active play, active travel as well as engagement in sports. I will consider both negative and positive mental health indicators of adolescent mental health.

I believe that this study represents a novel contribution to the field of mental health epidemiology, and my hope is that its findings will be important for clinical and health promotion practice.
1.2 Objectives

This thesis is based on the theme of mental health of young people in Canada with ADHD. I will start by describing a number of mental health indicators among Canadian adolescents with ADHD. Next, based on identified gaps in knowledge, I will study relationships between different types of physical activity and the mental health of young Canadians with ADHD.

1.2.1 Manuscript 1:

The objective of the first manuscript will be to describe a range of negative and positive mental health indicators among a contemporary national sample of Canadian adolescents with ADHD. Prevalence levels of these indicators will be compared to those of Canadian adolescents without ADHD. It is hypothesized that Canadian adolescents with ADHD will report lower prevalence levels of positive mental health indicators and higher prevalence levels of negative mental health indicators, compared to their non-ADHD counterparts.

1.2.2 Manuscript 2:

The objective of the second manuscript will be to estimate the strength and statistical significance of relationships between engagement in different types of physical activity and the various mental health indicators. Both biological sex and age will be considered as effect modifiers, consistent with gender/sex and developmental theories. It is hypothesized that Canadian adolescents with ADHD who engage in greater amounts of physical activity will have better indications of mental health status than young people who are physically inactive, and that the context of this physical activity will influence the strength and significance of these associations.

1.3 Thesis Organization

The following thesis conforms to the Queen’s University School of Graduate Studies and Research Guideline “General Forms of Theses” (School of Graduate Studies Queen’s University, 2016). The second chapter consists of a literature review that focuses on: (1) mental health in adolescents with ADHD, as well as (2) the relationship between physical activity and mental health in adolescents with ADHD. The third chapter (Manuscript 1) examines the mental health status of Canadian adolescents with ADHD. The fourth chapter (Manuscript 2) examines
relationships between various types of physical activity and four standard indicators of mental health status. Both of these manuscripts have been developed for publication in the *Journal of Attention Disorders*. The final chapter provides an integrative discussion from the findings of the manuscripts, and summarizes the strengths and limitations of the thesis. Future research needs in this specific field are also identified.
1.4 References


Chapter 2

Literature Review

2.1 Introduction

In the following chapter, we will briefly describe attention deficit hyperactivity disorder (ADHD), how it is diagnosed and the known causes of the disorder. We will review the past literature on the cognitive, internalizing and externalizing impairments that ADHD is related to. Additionally, the common therapies used for the treatment of ADHD will be discussed, with our primary focus on physical activity as a mode of treatment. Physiological and psychological theories that describe the effects of physical activity on mental health will be outlined. We will then review evidence from key studies that have looked at the effects of physical activity on the cognitive, internalizing and externalizing aspects of mental health. Finally, we will present our proposed conceptual model along with the study rationale.

2.2 Attention Deficit Hyperactivity Disorder

ADHD is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity and impulsivity (American Psychiatric Association, 2013). The APA (2013) describes the symptoms of ADHD as the inability to sustain attention for a period of time, difficulty organizing and completing tasks, making careless mistakes and being forgetful. Symptoms of hyperactivity include being fidgety, excessive motor movement, difficulty inhibiting responses or movement, and restlessness. The APA also states that impulsivity is commonly exhibited through committing thoughtless actions, which may potentially cause harm. ADHD affects approximately 5-10% of children worldwide, with prevalence levels estimated at 3.3 to 8.9% in Canada (Biederman, 2005; Faraone et al., 2003; Polanczyk, 2007).

In Canada, a diagnosis of ADHD in youth is typically made by a paediatrician or family physician (Hinshaw et al., 2011). Criteria for diagnosis are taken from the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), which was compiled and released by the American Psychiatric Association in 2013. The APA (2013) identifies that for ADHD diagnoses in youth below the age of 16, six or more symptoms of inattention, hyperactivity or impulsivity must be present for at least 6 months, and these must cause significant impairment in more than one setting. Moreover, the APA states that the symptoms must be present before the age of 12 for youth with ADHD. Lastly, these symptoms must not be
better explained by any other psychiatric or psychotic disorders and should cause significant disruptions in social, academic and occupational functioning.

The causes of ADHD are multifactorial and attributable to a combination of genetic and environmental factors (Biederman, 2005). The children of adults with ADHD are 50% more likely to also develop ADHD (Barkley, 1998). Twin studies suggest that a twin is 11 to 18 times more likely to have ADHD when their identical twin has ADHD (Barkley, 1998). Several gene association studies of ADHD have found potential risk genes, including risk alleles of dopaminergic and serotonergic genes (Gizer, Ficks, & Waldman, 2009; Smith, 2010). Environmental factors implicated in the etiology of ADHD include lead contamination, food additives and alcohol exposure during pregnancy (Biederman, 2005). Maternal smoking and stress during pregnancy have also been strongly correlated to ADHD in offspring (Grizenko, Shayan, Polotskaia, Ter-Stepanian, & Joober, 2008; Langley, Rice, van den Bree, & Thapar, 2005). Psychosocial adversity such as family adversity, hostile relationships with parents and severe early deprivation have also been linked to the onset of ADHD, though it is unclear whether these factors lead to ADHD through secondary adverse consequences (Langley, Heron, O’Donovan, Owen, & Thapar, 2010; Pheula, Rohde, & Schmitz, 2011). Moreover, many of the environmental risk factors identified have been correlated to ADHD status although this does not necessarily imply causation. Although the direct causes of ADHD are unclear, the genetic and environmental underpinnings of ADHD are more established and considered to be strong (Thapar, Cooper, Eyre, & Langley, 2013).

2.3 Impairments in Individuals with ADHD

2.3.1 Cognitive Impairments Associated with ADHD

Individuals with ADHD have impairments in response inhibition as they have longer reaction times when inhibiting irrelevant information, due to the impairment of the executive functioning system (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Seidman, 2006). Individuals with ADHD also have working memory deficits, with the greatest deficiencies in the spatial working memory (Castellanos et al., 2006). Due to impairment in executive functioning, other processes such as planning, vigilance, organizing, complex problem solving and shifting attention can also be impaired (Castellanos et al., 2006; Seidman, 2006). As a result of such impairments, goal-oriented tasks are more difficult to complete in comparison to peers without ADHD (Seidman, 2006). Weyandt and Willis (1994) found that school-aged children with
ADHD score significantly less on executive functioning tasks than non-ADHD children, (M=27 vs. M=33, p<0.05) as well as commit a higher amount of errors during the tasks (M=18 vs. M=13, p<0.05). Hence, individuals with ADHD experience moderate to severe cognitive impairments primarily due to the impairment of the executive functioning system.

2.3.2 Internalizing Problems Associated with ADHD

Internalizing behaviours are defined as behaviours in which the negativity is focused inwards, resulting in internalizing disorders such as depression, anxiety, withdrawal and eating disorders (Leadbeater, Kupermine, Blatt, & Hertzog, 1999). Compared to their peers, adolescents with ADHD are more likely to experience internalizing problems. In Finnish youth, Hurtig et al. (2007) found that a diagnosis of ADHD was associated with greater odds of having a mood disorder (OR=2.92, 95% CI: 1.4-6.2), anxiety (OR=2.39, 95% CI: 1.4-4.2) and major depressive disorder (OR=2.48, 95% CI: 1.2-4.9) when compared with non-ADHD peers. In particular, youth with higher ADHD severity are at a heightened risk of internalizing disorders, as higher ADHD symptoms are correlated with an increase in reported depressive symptoms (B = 1.62, p<0.001) (Lundervold et al., 2016), and significantly lower quality of life, self-esteem and psychosocial health (Spearman’s correlation = -0.31, p<0.01; Spearman’s correlation = -0.21, p<0.05; Spearman’s correlation = -0.48, p<0.01) (Klassen et al., 2004). Thus, internalizing problems are highly prevalent in adolescents with ADHD, in isolation as well as compared to the non-ADHD youth population.

2.3.3 Externalizing Problems Associated with ADHD

Externalizing behaviours arise from disruptive behaviours that are focused outside oneself such as aggression, delinquency and substance abuse (Leadbeater et al., 1999). Youth with ADHD are more likely to engage in high risk behaviour than their peers. Large epidemiological studies based on U.S. youth, both cross-sectional and longitudinal in design, found that youth with ADHD had greater odds of engaging in tobacco, alcohol and illicit drug use than their non-ADHD peers (OR = 2.30, p=0.008; OR = 2.20, p = 0.02; OR = 2.40, p=0.083) (Brinkman, Epstein, Auinger, Tamm, & Froehlich, 2015; Burke, Loeber, & Lahey, 2001). Childhood ADHD diagnoses also predict future sexual behaviour, as men with a childhood diagnosis of ADHD had a greater odds of engaging in casual sex and infrequent condom use than men without ADHD (OR=2.91, p<0.05; OR=5.14, p<0.05) (Flory, Malone, & Lamis, 2011). Moreover, youth with ADHD are more likely to display aggression and act disruptively in social
interactions, due to poor self-regulation of emotions (Buhrmester, Whalen, Henker, MacDonald, & Hinshaw, 1992). A Taiwanese study found that both inattention and hyperactivity-impulsivity were significantly correlated to prosocial behaviour, with a higher score of ADHD symptoms linked to lower prosocial behaviour ($r = -0.27, p<0.001; r = -0.20, p<0.001$) (Tseng et al., 2012).

2.4 The Treatment of ADHD

2.4.1 Pharmacological Approaches

Stimulants such as amphetamines and methylphenidate are the main method of treatment for ADHD (Wigal, 2009). However, only 70% of individuals with ADHD respond to stimulants and such treatments have side effects (Wigal, 2009). The risk of insomnia is reported to double in frequency with the use of stimulants (Wigal, 2009). Other side effects include decreased appetite, weight loss and emotional disturbance (Wigal, 2009). As a result, there is a high rate of discontinuation of medication among those with ADHD (Wigal, 2009).

Medicated adolescents often experience dysphoria resulting in less social engagement and positive affect, leading them to being more withdrawn, nervous, sad and depressed (Buhrmester et al., 1992). Moderate dosages of methylphenidate over a 3-week period administered to boys aged 6 to 12 years old with ADHD led to decreases in aggressive and noncompliant behaviour, however these drug regimens failed to increase prosocial behaviour (Hinshaw et al., 1989). Although medication such as methylphenidate (Ritalin) decreases aversive behaviour such as aggression and other negative behaviours, effects of methylphenidate on other domains of mental health such as prosocial behaviour remain unestablished (Buhrmester et al., 1992). Hence, alternative and complementary therapies need to be further explored for youth with ADHD.

2.4.2 Complementary and Alternative Therapies

Complementary and alternative therapies are now being more widely used for children and adolescents with ADHD (Bader & Adesman, 2012; Wigal, 2009). Behavioural therapy, psychosocial therapy and physical activity have proven long-term efficacy with regards to ADHD symptom alleviation, with such effects comparable to medication use (Arnold, Hodgkins, Caci, Kahle, & Young, 2015; Wigal, 2009). A systemic review by Arnold et al. (2015), assessed whether the long-term benefits of motor, social and emotional functioning in children and adolescents with ADHD differed based on treatment modalities, including the pharmacological
approach, non-pharmacological approach and a combination of both. Among the 51 studies included, 50% of studies with only pharmacological treatment, 65% of studies with only non-pharmacological treatment and 83% of combination studies reported long-term improvements. The effects of all three treatment modalities were comparable with regards to motor coordination, while the non-pharmacological and combination treatments improved long-term social functioning considerably more than the pharmacological treatment only, 83% and 86% respectively, compared to 67% (Arnold et al., 2015). Long-term improvements in self-esteem, social functioning, academic, and antisocial behavior outcomes were more likely to follow with combination treatment compared to pharmacological and non-pharmacological treatment (Arnold et al., 2015). Moreover, the Multimodal Treatment Study of Children with ADHD (MTA) Cooperative Group (1999) found similar results as children with ADHD had significantly decreased symptoms of inattention and hyperactivity over a 14-month period with combination treatment. Combination treatment had the greatest effect compared to the other modes of treatment such as medication use only, especially for females ($F=2.8$, $p=0.04$, $\beta = -0.172$).

2.5 Effects of Physical Activity

2.5.1 Physiological Mechanisms

There is an extensive amount of research on the biological pathways in which physical activity affects individuals with ADHD and alleviates its symptoms. Compared to typically developing youth, adolescents with ADHD may have especially lower levels of critical neurotransmitters (Ahn & Fedewa, 2011). The dysfunction of the dopaminergic system is implicated as one of the causes of ADHD and dopamine is a critical neurotransmitter that regulates emotion, motor control, cognition and event prediction (Caspersen et al., 1985). Animal studies have shown that physical activity alleviates behavioural symptoms by increasing the dopamine availability in the substantia nigra and striatum (Cho et al., 2014). ADHD positive rats who ran 30 minutes a day on treadmills for 28 consecutive days had significantly decreased symptoms of hyperactivity, inattention and impulsivity, comparable to ADHD positive rats who were administered methylphenidate (Cho et al., 2014). Moreover, Robinson et al. (2015), found that rats with ADHD, had greater attention spans after physical activity through increases in norepinephrine in the prefrontal cortex (Robinson et al., 2015). Jeong et al. (2014), suggests that brain derived neurotrophic factor (BDNF; a neurotrophin that plays a critical role in the growth and differentiation of neurons) is lower in individuals with ADHD. Rats with ADHD that
underwent 30 and 60 minutes of treadmill exercise per day had increased BDNF levels and thus also displayed greater spatial learning ability compared to rats with ADHD who did not undergo physical activity (Jeong et al., 2014).

Furthermore, in the otherwise healthy population, physical activity is linked to positive mood and is protective against depression through the monoamine hypothesis and release of hormones such as endorphins. Primary monoamines in the brain such as norepinephrine, dopamine and serotonin affect mood and are implicated in mood disorders such as depression (Dunn, & Dishman, 1991; Nicoloff, & Schwenk, 1995; Sachar et al., 1980). Physical activity appears to elevate mood in individuals through aminergic transmission, which reduces the impairments in the production, transmission, reuptake and metabolism of these monoamines (Dunn, & Dishman, 1991; Nicoloff, & Schwenk, 1995; Sachar et al., 1980). Furthermore, increased duration of physical activity and intensity is implicated in the secretion of endorphins, which is linked to positive mood (Morgan et al., 1988; North, McCullagh, & Tran, 1990).

2.5.2 Psychological Mechanisms

Several theories have been postulated surrounding the psychological effects of physical activity on the mental health of youth with ADHD. Bandura (1977) suggests that physical activity increases self-efficacy, which is the notion of one’s own perceived ability, through engagement in “performance accomplishments” such as participating in sports, team work and achieving the team’s or one’s own goals. Similarly, Mellion (1985) explains that physical activity increases self-mastery in individuals, by engaging in tasks that are challenging and gaining a sense of success when complete. Furthermore, the attention restoration theory (ART) helps explain the effects of physical activity on children diagnosed with ADHD, especially those activities that take place in outdoor environments. Youth with ADHD have more difficulty in sustaining directed attention and are more likely to experience mental fatigue as a result (Kaplan, 1995). Thus, physical activity in restorative environments such as the outdoors help youth with ADHD who are more susceptible to mental fatigue (Kaplan, 1995). Other ways that physical activity fosters mental health include the social interaction theory, which postulates that physical activity is a means by which individuals can access support and social interaction (Ransford, 1982).

Moreover, from the health perspective view, adolescents who engage in sports are less likely to engage in antisocial behaviour, such as substance use, drinking and deviant behaviour. This is attributed to a lack of time for engagement in potentially deviant activities, increased adult
supervision and youth being more motivated to be in the best shape for optimal performance (Duncan, Duncan, Strycker, & Chaumeton, 2002).

2.6 Benefits of Physical Activity

2.6.1 Cognitive Benefits

Few studies have examined the effects of different types of physical activity on the behavioural symptoms of ADHD. Kuo conducted a randomized controlled trial in 2008 with youth diagnosed with ADHD. He found that youth who underwent 20 minutes of walking in a park exhibited a higher attention span compared to walking in an urban and residential area, with statistically significant differences of Cohen’s d=0.71, p=0.007. A national U.S. based study found that mothers with children with ADHD reported better behaviour and decreased behavioural symptoms after physical activity was conducted in greenspace compared to other settings (Kuo & Faber Taylor, 2004). Thus, physical activity conducted in natural settings compared to settings that are busier and man-made could decrease the inattention component of ADHD.

2.6.2 Relationship between Physical Activity and Internalizing Problems

Although less research has been done on the effects of physical activity on the internalizing behaviour of individuals with ADHD, physical activity appears to be protective. Kiluk et al. (2009), found that youth who on average played 3 or more sports displayed fewer symptoms of anxiety and depression compared to other children with ADHD. A randomized controlled trial found similar results with adolescent males with ADHD who engaged in 20 weeks of sports and had significantly less emotional problems than other ADHD males (Lufi & Parish-Plass, 2011). The effect was seen post one year follow up as well, especially in the domain of anxiety (Lufi & Parish-Plass, 2011). Other types of physical activity such as aerobic physical activity has also shown promise, as Hoza et al. (2015) found that children with ADHD had significantly decreased moodiness compared to typically developing children after the 12-week intervention (Cohen’s d=0.40, p<0.05).

Even in adults without mental disorders such as ADHD, the effects of acute vigorous exercise have led to significant decreases in anxiety (F=48.9 p<0.05) (Bahrke & Morgan, 1978). A meta-analysis study that pooled the results of 182 randomized controlled trials of the effects of physical activity on typically developing school-aged children, found that depression (d = -0.41,
p<0.01) and anxiety (d= -0.35, p<0.05) decreased after physical activity more substantially in the experimental group compared to the control group, while self-esteem (d = 0.29, p<0.01) and self-concept (d = 0.16, p<0.01) increased (Ahn & Fedewa, 2011).

2.6.3 Relationship between Physical Activity and Externalizing Problems

There has been conflicting evidence with regards to the effects of physical activity on engagement in risk behaviour in the adolescent population. A large epidemiological study on the U.S. youth population found that typically developing youth who participated in sports outside and during school, had lower odds of cigarette smoking (OR=0.64, 95% CI of 0.53-0.77), marijuana use (OR=0.63, 95% CI of 0.41-0.96), cocaine use (OR=0.19, 95% CI of 0.06-0.66), use of other illegal drugs (OR=0.48, 95% CI of 0.36-0.65) and sexual intercourse (OR=0.57, 95% CI of 0.45-0.74) compared to those who did not (Russell R Pate et al., 2000). However, Smith and Caldwell (1994) found contradictory evidence. Both male and female adolescents who participated in sports reported higher engagement in sexual activity than their non-participant peers (51% vs. 36%, p<0.001 and 66% vs. 52%, p<0.002).

To our knowledge, no studies have been conducted yet on the effects of physical activity on prosocial behaviour in adolescents with ADHD. Prosocial behaviour consists of actions which benefit other people than oneself, including sharing, cooperating and comforting (Batson, & Powell, 2003). Prosocial behaviour is especially important for youth with ADHD as it fosters positive peer interactions and leads to more satisfying relationships with peers (Hinshaw et al., 1989). Decreases in negative behaviour without increasing prosocial behaviour do not necessarily result in increases of positive peer interactions and relationships (Buhrmester et al., 1992). The National Longitudinal Survey of Children and Youth in Canada in 1994-1995, found that in approximately 22,000 children aged 6 to 11 years old, recreational participation in sports and activities was significantly correlated to prosocial behaviour (r = 0.21, p<0.01) (King et al., 2005).
2.7 Conceptual Model Depicting the Relationship between Different Types of Physical Activity and Specific Indicators of Mental Health

Exposures:
1) Curriculum Time Physical Activity  
2) Outdoor Active Play  
3) Active Travel  
4) Engagement in Sports

Effect Modifiers:  
Sex  
Age

Outcomes:  
1) Psychosomatic Symptoms  
2) Emotional Well-being  
3) Prosocial Behaviour  
4) Risk Behaviour

Potential Confounders:  
Sex  
Age  
Socioeconomic Status  
Ethnicity  
ADHD Severity  
Other Comorbidities  
Immigration Status  
Family Structure  
Family Communication  
School Climate  
Neighbourhood Environment

2.8 The Context of Physical Activity

To our knowledge, there are no previous studies in the ADHD youth population, that have examined how physical activity in different contexts affects these youths’ mental health. Yet, there is evidence that suggests that the different contexts in which physical activity occur may be important in terms of their potential influence on mental health. For instance, unstructured play in restorative environments such as the outdoors may be more beneficial for youth with ADHD (Buhrmester et al., 1992; Kaplan, 1995). Team sports seem to have negative effects on youth with ADHD due to the competitive nature of the sports and low emotional regulation of some of these youth (Johnson, & Rosen, 2000). Lastly, the effects of other types of physical activity that youth engage in on a daily basis, such as active travel, have not been explored in this subset of youth. In our study we had the opportunity to explore the potential differential effects of physical activity in various contexts, including curriculum time physical activity, outdoor active play, active travel and sports participation, on the mental health of youth with ADHD.

2.9 Mental Health

Adolescents with ADHD are at a heightened risk for poor mental health compared to adolescents without ADHD due to the nature and secondary consequences of the disorder (Biederman, 2005; Wehmeier, Schacht, & Barkley, 2010). While numerous past studies on the
effects of physical activity have focused on one domain of mental health, there is a need for studies that examine mental health in a more holistic manner. Mental health is no longer seen as the absence of symptoms of illness, and consists of positive aspects as well (Keyes, Dhingra, & Simoes, 2010; Strauss, 2007). Moreover in youth, mental health tends to be modelled best in two factors, consisting of internalizing and externalizing behaviours (Achenbach, & Edelbrock, 1978; Krueger, Chentsova-Dutton, Markon, Goldberg, & Ormel, 2003). Thus, for the purpose of our study we analyzed mental health in four domains, comprised of negative-internalizing (psychosomatic symptoms), negative-externalizing (risk behaviour), positive-internalizing (emotional well-being) and positive-externalizing (prosocial behaviour).

2.10 Potential Effect Modifiers and Confounders

The following were considered as potential confounders, with the exception of biological sex and age that were considered as both effect modifiers and confounders.

*Biological sex and age* may have differential effects on adolescents with ADHD with regards to mental health outcomes and physical activity levels (Steptoe & Butler, 1996). Male adolescents are on average more physically active than female adolescents (Kaltiala-Heino, Marttunen, Rantanen, & Rimpel, 2003). Female youth with ADHD have reported more internalizing problems than male youth with ADHD (Estabrooks, Lee, & Gyurcsik, 2003). There is also evidence that indicates physical activity levels decline with age as adolescents grow older (Kaltiala-Heino et al., 2003). Increases in mental health problems are associated with increasing age in adolescence, and later decline in late adolescence, attributable to pubertal changes in both females and males (Hanson & Chen, 2007).

*Socioeconomic Status*. Adolescents who belong to lower socioeconomic status groups are more likely to have lower levels of physical activity (Gaub & Carlson, 1997; Trost et al., 2002). Furthermore, adolescents of lower socioeconomic status are also more likely to have poorer mental health outcomes, and hence such factors could confound the relationships of interest (Gaub & Carlson, 1997).

*Ethnicity*. Caucasian youth are more likely to suffer from mental health problems compared to African American and Hispanic adolescents; however the mental health problems may vary due to cultural constructs rather than real differences (Jellinek, Biederman, & Lock, 1996). Moreover, Caucasian adolescents report higher levels of physical activity compared to their Asian and African peers (Sallis, Prochaska, & Taylor, 2001).
Comorbid Conditions. Individuals with ADHD and other comorbid conditions are more likely to have poorer mental health outcomes and lower physical activity levels than those only diagnosed with ADHD (Missiuna et al., 2014). ADHD Severity was also considered as a confounder as adolescents with relatively severe forms of ADHD are more likely to experience higher motor, social and emotional impairments, hindering them from participating in physical activity and increasing their risk for mental health problems (Khalife et al., 2014).

Immigration Status. The length of time an individual has lived in a country that is not native to them may also affect their risk to mental health problems as well as physical activity levels (Dawson, Sundquist, Johansson, Dawson, & Sundquist, 2016; Harker, 2011).

Family Structure was considered as a confounder as the familial influences on physical activity in adolescents are strong and the family structure may also affect the relationship dynamics with the adolescents, subsequently affecting the mental health of the adolescents as well (Sallis, Prochaska, & Taylor, 2001; Steinhausen & Metzke, 2001).

Family Environments. A supportive and trusting family environment is linked to better mental health outcomes and higher levels of physical activity in adolescents (Sallis, Prochaska, & Taylor, 2001; Steinhausen & Metzke, 2001).

School Climate was considered as a confounder as adolescents who feel secure in their school environment and have supportive relationships with teachers are more likely to engage in physical activity and have better mental health outcomes (Sallis, Prochaska, & Taylor, 2001; Steinhausen & Metzke, 2001).

Lastly, neighbourhood environment was considered as a confounder because neighbourhoods that are not viewed as safe and that have high crime levels are associated with higher levels of physical inactivity in adolescents (Gordon-larsen et al., 2000). Moreover, neighbourhoods that are perceived as threatening are associated with more externalizing and internalizing behaviour from adolescents in the community (Aneshensel, 2016).

2.11 Study Rationale

ADHD is a common neurodevelopmental disorder among children and about 80% of adolescents and adults continue to have ADHD from childhood (Faraone et al., 2003). Due to the adverse side effects of medication use and potential of non-response, alternative therapies for ADHD should be further explored. To our knowledge, epidemiological studies on the national level have not been conducted yet on the mental health status of Canadian youth with ADHD. The majority of the research in the field has been based on U.S. populations, however there may
be differences in Canada due to variations in identification and treatment of young people with ADHD (Faraone et al., 2003). In our study we have the opportunity to describe the current mental health status of Canadian youth with ADHD at the national level, which is important for prevention efforts specifically designed for Canadian populations.

In addition, while physical activity has been linked to positive mental health outcomes in youth with ADHD, there has been little research on the contextual effects of physical activity on specific aspects of mental health (Hoza et al., 2015; Kiluk et al., 2009; Lufi & Parish-Plass, 2011). This is an important research gap, as the contexts in which physical activity occurs in youth could have differential effects on the mental health of youth with ADHD. Our study will address this gap in literature, by exploring the associations between the different types of physical activities and various indicators of mental health, both positive and negative, in youth with ADHD. By understanding the relationships between the different types of physical activities, youth with ADHD typically engage in on a daily basis, and their mental health, we could inform potential intervention as to which types of physical activities are the most beneficial. Lastly, by determining whether biological sex and age modify the relationships between physical activity and mental health in youth with ADHD, we can provide informed evidence based on sex and age for public health interventions.
2.12 References


Chapter 3

The Mental Health Status of Canadian Adolescents with ADHD
3.1 Abstract

**Objectives:** To: (1) describe the prevalence of selected positive and negative mental health indicators among Canadian adolescents with ADHD, and (2) compare the prevalence of these indicators with those of Canadian adolescents without ADHD.

**Methods:** We analyzed data from Cycle 7 (2013/2014) of the Canadian Health Behaviour in School-aged Children study in a cross-sectional analysis. A diagnosis of ADHD was reported by 1,225 (4.1%) of the 29,784 participating adolescents aged 11-15 years from 215 Canadian schools. Analyses were descriptive, and comparisons accounted for both the clustered nature of data collection (children nested within schools) and incorporated standardized weights to ensure representativeness by age, sex and province/territory.

**Results:** Compared with youth not reporting ADHD, those with ADHD more frequently reported negative health outcomes, both internalizing and externalizing, as expressed through higher psychosomatic symptoms (45% vs. 28%; p<0.001) and high levels of risk-taking (54% vs. 41%; p<0.001). Those with ADHD also less frequently reported positive health outcomes: high emotional well-being (38% vs. 56%; p<0.001) and high prosocial behaviour (71% vs. 77%; p<0.004) than youth without ADHD. Females with ADHD reported higher prevalence levels of specific risk behaviours including tobacco use, alcohol consumption, drug misuse, and sexual behaviour.

**Conclusion:** Youth with ADHD report higher levels of behaviours and symptoms consistent with negative internalizing and externalizing problems. Observed risk-taking patterns also suggest the possibility of differential diagnoses of ADHD by biological sex.

**Keywords:** adolescence, ADHD, attention deficit hyperactivity disorder, biological sex, epidemiology, mental health
3.2 Introduction

Attention deficit hyperactivity disorder (ADHD) is diagnosed in up to 1 in 20 children worldwide (Biederman, 2005; Faraone et al., 2003). It is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity and impulsivity (American Psychiatric Association, 2013). Adolescents with ADHD experience more adverse mental health outcomes than their peers (Biederman, 2005). ADHD is highly correlated to emotional difficulties including poor self-regulation of emotion, excessive emotional expression, reduced empathy, anxiety and depression (Wehmeier et al., 2010). Adolescents with ADHD also engage in higher levels of risk-taking behaviour than their peers; the latter include risky sexual behaviour and the misuse of tobacco, alcohol and illicit drugs (Brinkman et al., 2015; Burke et al., 2001; Eck, Flory, & Willis, 2015). Although ADHD typically is first diagnosed during early childhood, approximately 80% of children with ADHD continue to experience its effects throughout adolescence and into their adult years (Faraone et al., 2003).

Impacts of ADHD on health during adulthood can be detrimental. Diagnoses of ADHD are associated with greater difficulties in the workforce, more challenging interpersonal relationships, and substance abuse issues (Harpin, 2005). Yet there has been no large-scale and contemporary epidemiological study that describes the potential mental health impact of ADHD on adolescent health in Canada. This gap in knowledge is important as Canada may be unique in terms of diagnostic and treatment patterns (Faraone et al., 2003). Moreover, understanding factors associated with poorer mental health at this critical stage of the life course provides a foundation for potential prevention efforts.

Mental health is a multifaceted construct and includes the presence of positive and negative aspects (Keyes, Dhingra, & Simoes, 2010; Strauss, 2007). Psychologists have traditionally categorized mental health as having two domains, these being externalizing and internalizing symptoms (Hopwood & Grilo, 2010; Krueger & Markon, 2011). When examined together, mental health can therefore be described using four constructs that include internalizing-negative (psychosomatic symptoms), externalizing-negative (risk taking behaviour), internalizing-positive (emotional well-being), and externalizing-positive (prosocial behaviour) aspects (Freeman et al., 2011).

We had a unique opportunity to study the mental health of a large and nationally representative sample of young Canadians. Our objectives were to describe the prevalence of selected mental health indicators among Canadian adolescents with ADHD, and compare the prevalence of these indicators to those of Canadian adolescents without ADHD. In doing so, we
focused on four domains of mental health, described above. Our hope was that findings from this national study could inform the content and targeting of interventions aimed at optimizing health in populations of children with ADHD.

3.3 Methods

3.3.1 Study Sample

This study is based on the data from the Canadian Health Behaviour in School-aged Children (HBSC) study (Freeman et al., 2011). HBSC is conducted in collaboration with the World Health Organization, and involves administration of a cross-sectional general health survey every four years to adolescents aged 11-15 years (Inchley et al., 2016). Our study used data from the 7th Cycle of the HBSC in Canada, collected in the 2013-2014 academic years from 377 schools across Canada. HBSC employs a multi-level cluster sampling method. School jurisdictions were identified within each province and territory and a sampling list was created based on school size, public or Roman Catholic designation, community size and main language of instruction. Random schools were selected from the sampling list and entire classes within the schools were asked to participate. Data from each province and territory were also weighted by age group (grade) and sex in proportion to the Canadian student population (Freeman et al., 2011).

3.3.2 Indicators of Mental Health

Four summary indicators of mental health were considered, including scales describing negative (high psychosomatic symptoms, high risk-taking behaviour) and positive indicators (high emotional well-being, high prosocial behaviour) (Freeman et al., 2011).

Negative Indicators. The HBSC psychosomatic symptoms scale (Cronbach’s alpha = 0.84) measures the internalizing-negative aspect of mental health and consists of the question, “In the last 6 months how often have you had the following...?” The scale consists of 8 items, ranging from somatic symptoms such as headaches to psychological symptoms such as feeling depressed (Haugland, Wold, Stevenson, Aaroe, & Woynarowska, 2001). Adolescents who expressed 4 or more psychosomatic symptoms once a week or more were categorized as having “high psychosomatic symptoms,” based on precedent (Kinnunen, Laukkanen, & Kylma, 2010).

An HBSC risk taking scale measures the externalizing-negative aspect of mental health. Domains included questions about tobacco use, alcohol and other illicit substance use, sexual
behaviours (grade 9 and older only), aggressive behaviour and unhealthy dietary patterns (Kwong, 2015). Adolescents who engaged in at least one risk taking behaviour frequently were categorized as “high risk-taking behaviour,” based on previous research on adolescent risk behaviour (Bry, McKeon, & Pandina, 1982; Newcomb & Felix-Ortiz, 1992).

**Positive Indicators.** The emotional well-being scale measures the internalizing-positive aspect of mental health. The adapted version of the Cantril Ladder for adolescents was used; this is a good measure of subjective well-being with a test-retest reliability (Pearson’s r coefficient of 0.58 – 0.70) and convergent validity (Spearman’s r coefficient of 0.58 – 0.62) (Currie, 2014). The scale ranges from 0 to 10, with 0 indicating worst possible life and 10 indicating best possible life. “High emotional well-being” was indicated by a score of 8 or more, based on established precedent (Boyle, King, & Roche, 2008; Levin, & Currie, 2014).

A prosocial behaviour scale (Cronbach’s alpha of 0.85) was used to measure the externalizing-positive aspect of mental health (Freeman et al., 2011). The 5-item scale asks about prosocial acts, and adolescents can choose six options ranging from the two extremes of “definitely not like me” to “definitely like me”. Scores ranged from 5 (lowest prosocial behaviour) to 30 (highest) with those who scored 16 or more categorized as having “high prosocial behaviour”, based on previous research (King et al., 2005; Tremblay, Vitaro, Gagnon, Piché, & Royer, 1992).

### 3.3.3 Sociodemographic Characteristics

Biological sex was assessed using the question, “Are you male or female?” Age was estimated from the month and year of birth indicated relative to the survey date. Ethnicity was measured using the question, “People living in Canada come from many different cultural and racial backgrounds. How do you describe yourself?” Ethnic categories were formed based on the 2006 Canadian Census of Population (Statistics Canada, 2010). Immigration status was measured from the question, “How many years have you lived in Canada?” Children as young as 11 years old can provide accurate immigrant status based on this question, with over 97% agreement with parental reports (Nordahl, Krolner, Páll, Currie, & Andersen, 2011). Family structure was inferred from the person that adolescents identified as living with most of the time: “both parents,” “single parent,” and “other” (Blum et al., 2000). Socioeconomic status was measured from the question, “How well do you think your family is?” Responses were grouped into “well-off”, “average” and “not well-off”. This item has strong test-retest reliability and has been shown
to correlate to household income as well as parental education (Goodman et al., 2001; Goodman, Huang, Schafer-Kalkhoff, & Adler, 2007).

### 3.3.4 Statistical Analyses

Descriptive analyses were performed to profile the sample socio-demographically. Prevalence estimates were generated for each mental health indicator among the sub-population with ADHD and those without ADHD. Intraclass correlations (ICC) were calculated to determine the extent of variation in the different outcomes at the cluster (school or classroom) levels. To test for differences in the ADHD and non-ADHD group, Rao-Scott chi-square tests were conducted which took into account clustering at the classroom level (Rao & Scott, 1987). All analyses were weighted.

We employed the following philosophical approach to the interpretation of possible observed differences. Evidence that was used to infer important group differences included: (1) the size and direction of any observed differences, and whether this coincided with pre-existing theory; (2) the width and nature of any skewness of the confidence intervals that surrounded any observed differences; (3) the consistency of direction of the observed differences indicating a general or inconsistent pattern across multiple indicators, irrespective of statistical significance; (4) the potential gradient of differences across multiple indicators indicating an important pattern; (5) the level of statistical significance achieved, given available study sample size and power to identify group differences. Evidence of important differences included strong and consistent relationships in an expected direction. While the statistical significance of the observed differences was also considered, it was not done in a binary fashion (significant, not significant) but rather using a scale to make decisions about the p-values found, consisting of $1.0 \leq p \leq 0.1$ indicating the weakest evidence, $0.1 < p \leq 0.001$ indicating increasing evidence and lastly $0.001 < p \leq 0.0001$ indicating strong evidence against the null hypothesis (Sterne & Smith, 2001).

### 3.4 Results

#### 3.4.1 Sociodemographic Characteristics

This study used data from 29,784 participants, of which 1,225 (4.1%) had self-reported ADHD. Adolescents with ADHD were more often males (66% vs. 48%), of similar average age (14.3 vs. 14.1 years), more often Caucasian (87% vs. 75%), more often born in Canada (85% vs. 80%), less often living with both parents (56% vs. 71%), and less often perceiving themselves to be “well-off” socioeconomically (47% vs. 56%) than the non-ADHD subgroup (Table 3.11).
3.4.2 Prevalence of Mental Health Indicators

Compared with adolescents without ADHD, those diagnosed with ADHD reported higher prevalence levels of the negative mental health indicators of psychosomatic symptoms and risk behaviours, and lower prevalence levels of the positive mental health indicators of emotional well-being and prosocial behaviours (Table 3.2).

3.4.3 Prevalence of Mental Health Indicators by Biological Sex

Overall, within the subpopulation reporting ADHD, there was strong to moderate evidence indicating females reported a higher prevalence of negative mental health indicators (high psychosomatic symptoms, high risk-taking behaviours, such as tobacco use, certain types of alcohol use, and drug use). In addition, females with ADHD reported lower levels of high emotional well-being, however higher levels of high prosocial behavior than males with ADHD. Males reported a higher prevalence of risk taking behaviours such as physical fighting (Table 3.3).

3.5 Discussion

The most important findings from this national analysis of young people were as follows. First, the sub-population of young Canadians reporting ADHD was dissimilar to other adolescents in terms of a variety of socio-demographic factors. Second, young Canadians with ADHD consistently reported higher levels of negative mental health indicators and lower levels of positive mental health indicators than those not reporting ADHD. And third, within the population of Canadian youth diagnosed with ADHD, females reported higher levels of high psychosomatic symptoms, high prosocial behaviours, specific high risk behaviours, and lower levels of emotional well-being compared to their male counterparts.

Our observation of an approximately 2:1 ratio of males to females within the ADHD youth population is consistent with the findings of past literature, as this condition is more often diagnosed in boys and young men (Bruchmüller, Margraf, & Schneider, 2012). Our observation of higher prevalence levels of ADHD in Caucasian young people is also similar to findings from the National Survey of Children’s Health in the United States (Collins & Cleary, 2016). Factors that appear to influence the diagnosis of ADHD especially in non-Caucasian ethnicity include language barriers that affect access to health services, cultural stigmas towards diagnoses, lack of

Our finding that adolescents with ADHD were less likely to be living with both biological parents is also consistent with past findings (Bramlett & Blumberg, 2007). Past study has suggested the presence of more severe familial conflicts in single parent households (Bramlett & Blumberg, 2007). Other family circumstances such as death of parents, parents being incarcerated, parents using drugs or alcohol and a history of neglect or child abuse could exacerbate the mental health of the child (Bramlett & Blumberg, 2007). The prevalence of ADHD is typically highest in the more extreme levels of socio-economic status (very high, and very low) (Froehlich et al., 2007). Children from higher socioeconomic strata is more likely to be diagnosed with ADHD due to increased access to clinical care (Bussing, Regina Zima & Gary, Faye A Garvan, 2003; Froehlich et al., 2007). Those from a lower socioeconomic strata are more likely to have ADHD that is potentially attributable to risk factors such as low birth weight, lead exposure and in utero tobacco exposure (Froehlich et al., 2007).

We found that Canadian youth with ADHD reported higher prevalence levels of psychosomatic symptoms and lower emotional well-being, representing negative internalizing mental health effects. This is consistent with past observation (Barkley, Anastopoulos, Guevremont & Fletcher, 1991) and potentially attributable to deficits in the executive functioning system responsible for cognitive processes (Castellanos et al., 2006; Seidman, 2006). Impairment in the executive functioning system stems from changes to the prefrontal cortex fostering low self-regulation of emotions among those with ADHD (Barkley, 1997). Affected young people exhibit increased emotional responsivity to provocation, diminished ability to anticipate emotional reactions, distress (Strine et al., 2006), inability to regulate emotional states (Barkley, 1997) and high levels of comorbidity with depression (Lundervold et al., 2016). Less acutely, youth with ADHD experience poorer motor skills, academic performance, school behaviour, peer relationships and family functioning (Faraone et al., 2003).

Increased engagement in externalizing behaviours is also associated with diagnoses of ADHD, with increases in risk taking and decreases in prosocial behaviour reported by those who also report diagnoses of ADHD. The latter is supported by past study (Kofler, Larsen, Sarver, & Tolan, 2015), with ADHD also being highly comorbid with antisocial disorders such as oppositional defiant disorder and conduct disorder (Andrade & Tannock, 2014). As a result, adolescents with ADHD may be less likely to form positive peer interactions and default to non-prosocial behaviour to garner social impact (Andrade & Tannock, 2014). Moreover, adolescents
with ADHD have reported to be twice as likely to engage in overt risk behaviours such as alcohol, drug and illicit substance misuse (Burke et al., 2001) and casual sex (Eck et al., 2015). The latter tendencies may stem from deficits in the executive functioning system leading to impulsivity and difficulty with regulating and delaying gratification (Molina & Pelham, 2003).

Many of the patterns observed for the various mental health indicators are gendered in origin. The higher prevalence levels of psychosomatic symptoms reported by females vs. males, which include headache and backache, could perhaps be attributable to menstruation (Egger, Costello, Erkanli, & Angold, 1999). However, past findings surrounding such discrepancies are inconsistent (Holmberg & Hjern, 2006). More consistent with others, our findings suggested that girls with more severe ADHD may be more likely to be detected and diagnosed (Holmberg & Hjern, 2006), leading to elevations in symptoms and risk behaviour detection relative to population norms. Analogously, females also reported significantly lower emotional well-being, with more severe cases being identified among females vs. males affected by ADHD (Bruchmüller et al., 2012; Klassen et al., 2004). This extended to outcomes of prosocial behaviour, although some argue that adolescents with ADHD have the same capacity to develop prosocial skills as their peers; however, they are often limited by a lack of support in their environments (Andrade, Browne, & Tannock, 2014; Tseng et al., 2012). We found that girls with ADHD reported higher prosocial behaviour than boys, and less aggressive behaviours. Higher levels of physical aggression are common to boys, and this results in lower peer functioning in boys with ADHD (Tseng et al., 2012).

Lastly, our study found moderate to strong evidence that females with ADHD reported a higher prevalence of certain risk behaviours such as binge drinking, illicit drug use, and lifetime cannabis use. While weaker evidence was found that indicated that females with ADHD reported higher prevalence levels of sexual behaviour and bullying compared to males with ADHD. This supports past study that has concluded that, relative to boys, girls with more overt or severe ADHD are more likely to be diagnosed with ADHD (Bruchmüller et al., 2012). Health care professionals are more likely to diagnose boys with ADHD as they fit the “prototype” of the ADHD child compared to girls (Bruchmüller et al., 2012). Moreover, milder cases of ADHD in girls that went undiagnosed may appear in organized educational settings at an older age (Bruchmüller et al., 2012). However, due to the lack of medication and treatment, females with ADHD diagnoses at later ages may be particularly prone to substance abuse in order to self-medicate (Nussbaum, 2012).
Limitations of our analysis include its reliance on self-reports leading to potential inaccuracies and misclassification. Youth with more severe ADHD may have been less likely to complete the survey due to attentional difficulties. Additionally, ADHD status was self-reported by adolescents, thus increasing the chances of misclassification. Consequently, affecting the representativeness of our sample of youth with ADHD and leading to potential inaccuracies in the prevalence levels of the mental health indicators. Strengths of our study also warrant comment. The HBSC is a large and nationally representative study, and this provided us the opportunity to identify a robust sample of young people diagnosed with ADHD for focused study. The anonymous nature of the survey promotes confidentiality and encourages accuracy in response.

Our findings could guide future public health efforts by targeting highly vulnerable adolescents with ADHD who have distinct socio-demographic characteristics, such as those who identified as non-Caucasian ethnicity and those of lower socioeconomic status. Furthermore, the Canadian ADHD Resource Alliance (CADDRA) (2010) outlines the importance of clinicians assessing children and youth thoroughly for comorbid conditions that may complicate the presentation of ADHD. CADDRA emphasizes the need for referral to an ADHD specialist especially in youth with high comorbidity rates, where additional psychological tests may be required to rule out comorbid conditions. These comorbid conditions could result in the failure of ADHD diagnosis, if not detected and result in differential ADHD diagnoses with more straightforward cases being detected and treated by healthcare professionals.

3.6 Conclusion

This national study of Canadian adolescents demonstrates that young people with ADHD differ socio-demographically with those who do not. In addition, those with ADHD report higher prevalence levels of negative internalizing and externalizing mental health and a lower prevalence of positive internalizing and externalizing mental health compared to Canadian adolescents without ADHD. Female adolescents with ADHD reported a higher prevalence of psychosomatic symptoms, low emotional well-being, and high prosocial behaviour than male adolescents with ADHD. Excesses in overt risk-taking were also observed in young women, consistent with differential diagnoses of more acute cases of ADHD in females versus males.

3.7 Acknowledgements

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3.8 Funding

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3.9 Conflict of Interest

None declared.
3.10 References


Eck, K. Van, Flory, K., & Willis, D. (2015). Does distress intolerance moderate the link between ADHD symptoms and number of sexual partners, 39–47.


Table 3.1 Comparison of socio-demographic characteristics of Canadian adolescents with and without self-reported ADHD in the 2013/2014 HBSC Study.

<table>
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<th>Sociodemographic Characteristics</th>
<th>Adolescents without ADHD</th>
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<td>Prevalence (%)</td>
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<td>Other</td>
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<td>7.3</td>
</tr>
<tr>
<td>Immigration Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Born in Canada</td>
<td>22855</td>
<td>80.1</td>
</tr>
<tr>
<td>Have lived more than 5 years in Canada</td>
<td>4098</td>
<td>14.4</td>
</tr>
<tr>
<td>Have lived 1-5 years in Canada</td>
<td>1566</td>
<td>5.5</td>
</tr>
<tr>
<td>Family Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both parents</td>
<td>19611</td>
<td>71.1</td>
</tr>
<tr>
<td>Single parent</td>
<td>4723</td>
<td>17.1</td>
</tr>
<tr>
<td>Other</td>
<td>3240</td>
<td>11.8</td>
</tr>
<tr>
<td>Socioeconomic Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well-off</td>
<td>15359</td>
<td>56.4</td>
</tr>
<tr>
<td>Average</td>
<td>9411</td>
<td>34.6</td>
</tr>
<tr>
<td>Not well-off</td>
<td>2464</td>
<td>9.0</td>
</tr>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>28624</td>
<td>14.1 (1.5)</td>
</tr>
<tr>
<td>Min-Max</td>
<td>8.7-18.4</td>
<td>1216</td>
</tr>
</tbody>
</table>

*All results are significant at the p-value <0.0001 level, which represents the overall Rao Scott Chi-square association between each sociodemographic characteristic and ADHD youth vs. non-ADHD youth.
Table 3.2 Comparison of the prevalence levels of mental health indicators among Canadian adolescents with and without self-reported ADHD in the 2013/2014 HBSC Study.

<table>
<thead>
<tr>
<th>Mental Health Indicators</th>
<th>Adolescents without ADHD</th>
<th>Adolescents with ADHD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Prevalence (%)</td>
<td>Confidence Limit</td>
</tr>
<tr>
<td><strong>Negative Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Psychosomatic Symptoms</td>
<td>26571</td>
<td>27.7</td>
<td>(26.9, 28.6)</td>
</tr>
<tr>
<td>High Risk Behaviour</td>
<td>28769</td>
<td>40.5</td>
<td>(39.6, 41.4)</td>
</tr>
<tr>
<td><strong>Positive Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Emotional Well-being</td>
<td>28928</td>
<td>55.5</td>
<td>(54.6, 56.4)</td>
</tr>
<tr>
<td>High Prosocial Behaviour</td>
<td>26747</td>
<td>77.0</td>
<td>(76.3, 77.8)</td>
</tr>
</tbody>
</table>
Table 3.3 Comparison of mental health indicators among Canadian adolescents with self-reported ADHD by biological sex in the 2013/2014 HBSC Study.

<table>
<thead>
<tr>
<th>Mental Health Indicators</th>
<th>N</th>
<th>Male</th>
<th>N</th>
<th>Female</th>
<th>Difference</th>
<th>Confidence Limit</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative Indicators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychosomatic Symptoms, once a week or more</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td>777</td>
<td>35.1</td>
<td>403</td>
<td>53.9</td>
<td>18.8</td>
<td>(9.1, 28.4)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Stomachache</td>
<td>762</td>
<td>20.8</td>
<td>399</td>
<td>36.5</td>
<td>15.7</td>
<td>(6.9, 24.5)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Backache</td>
<td>754</td>
<td>30.3</td>
<td>385</td>
<td>45.7</td>
<td>15.4</td>
<td>(5.5, 25.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>Feeling low or depressed</td>
<td>766</td>
<td>34.0</td>
<td>377</td>
<td>53.9</td>
<td>19.9</td>
<td>(10.0, 29.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Irritability or bad temper</td>
<td>769</td>
<td>47.9</td>
<td>392</td>
<td>60.0</td>
<td>12.0</td>
<td>(2.2, 22.0)</td>
<td>0.02</td>
</tr>
<tr>
<td>Feeling nervous</td>
<td>770</td>
<td>45.8</td>
<td>398</td>
<td>67.4</td>
<td>21.6</td>
<td>(11.9, 31.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Difficulties in getting to sleep</td>
<td>787</td>
<td>50.8</td>
<td>397</td>
<td>63.8</td>
<td>13.1</td>
<td>(3.2, 22.9)</td>
<td>0.01</td>
</tr>
<tr>
<td>Feeling dizzy</td>
<td>774</td>
<td>29.0</td>
<td>400</td>
<td>48.9</td>
<td>19.9</td>
<td>(10.4, 29.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Risk Behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking Cigarettes, frequently (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifetime smoking history</td>
<td>768</td>
<td>8.5</td>
<td>396</td>
<td>13.0</td>
<td>4.5</td>
<td>(1.96, 10.9)</td>
<td>0.01</td>
</tr>
<tr>
<td>Use of alternative tobacco products</td>
<td>749</td>
<td>11.4</td>
<td>393</td>
<td>16.9</td>
<td>5.5</td>
<td>(-2.03, 13.1)</td>
<td>0.27</td>
</tr>
<tr>
<td>Alcohol and Drug Use, frequently (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td>805</td>
<td>15.0</td>
<td>418</td>
<td>21.5</td>
<td>6.4</td>
<td>(-1.4, 14.3)</td>
<td>0.22</td>
</tr>
<tr>
<td>Number of drinks per event*</td>
<td>371</td>
<td>37.0</td>
<td>215</td>
<td>54.7</td>
<td>17.7</td>
<td>(3.1, 32.3)</td>
<td>0.05</td>
</tr>
<tr>
<td>Lifetime drunkenness history</td>
<td>776</td>
<td>15.9</td>
<td>405</td>
<td>26.3</td>
<td>10.3</td>
<td>(1.5, 19.7)</td>
<td>0.05</td>
</tr>
<tr>
<td>Binge drinking*</td>
<td>365</td>
<td>11.8</td>
<td>215</td>
<td>18.6</td>
<td>7.7</td>
<td>(-4.2, 17.9)</td>
<td>0.16</td>
</tr>
<tr>
<td>Illicit drug use*</td>
<td>372</td>
<td>23.4</td>
<td>216</td>
<td>40.2</td>
<td>16.9</td>
<td>(2.8, 31.1)</td>
<td>0.003</td>
</tr>
<tr>
<td>Lifetime cannabis use*</td>
<td>363</td>
<td>23.1</td>
<td>211</td>
<td>37.9</td>
<td>14.9</td>
<td>(0.3, 29.4)</td>
<td>0.06</td>
</tr>
<tr>
<td>**Sexual Behaviour, frequently (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex without contraceptive use*</td>
<td>307</td>
<td>2.3</td>
<td>170</td>
<td>6.1</td>
<td>3.8</td>
<td>(-2.9, 10.7)</td>
<td>0.31</td>
</tr>
<tr>
<td>**Manifest Behaviour, frequently (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical fighting</td>
<td>781</td>
<td>26.0</td>
<td>404</td>
<td>19.0</td>
<td>-7.1</td>
<td>(-14.8, -0.7)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Bullying others</td>
<td>799</td>
<td>6.9</td>
<td>407</td>
<td>8.2</td>
<td>1.3</td>
<td>(-4.0, 6.5)</td>
<td>0.39</td>
</tr>
<tr>
<td>**Unhealthy Diet, frequently (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Energy drink consumption</td>
<td>795</td>
<td>10.1</td>
<td>403</td>
<td>9.6</td>
<td>-0.5</td>
<td>(-0.6, 5.1)</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Positive Indicators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotional Well-Being</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>779</td>
<td>6.8</td>
<td>410</td>
<td>6.1</td>
<td>0.7</td>
<td>(0.5, 1.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>7.0</td>
<td></td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td></td>
<td>8.0</td>
<td></td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Prosocial Behaviour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High (%)</td>
<td>727</td>
<td>66.0</td>
<td>388</td>
<td>80.7</td>
<td>14.7</td>
<td>(6.8, 22.8)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Low (%)</td>
<td></td>
<td>34.0</td>
<td></td>
<td>19.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Grade 6-8 students were not asked these questions in the HBSC study.

**The difference in prevalence levels (females vs. males).
Chapter 4

Protective Effects of Physical Activity on the Mental Health of Canadian Adolescents with ADHD
4.1 Abstract

**Objectives:** We examined associations between different types of physical activity and four standard indicators of mental health among Canadian adolescents with attention deficit hyperactivity disorder (ADHD).

**Methods:** Young people with self-reported diagnoses of ADHD were identified in the most recent cycle (Cycle 7; 2013/2014) of the Canadian Health Behaviour in School-Aged Children (HBSC) study. This included 1,225 young people with a diagnosis of ADHD from 215 Canadian schools. Types of physical activity included curriculum time physical activity, outdoor active play, active travel, and participation in sports. The mental health indicators studied were negative and positive measures of internalizing (psychosomatic symptoms, emotional well-being) and externalizing (risk-taking, prosocial) behaviours and symptoms. Following descriptive analyses, multi-level log binomial regression models were developed to estimate the strength of associations between the different types of physical activity and the indicators of mental health. Potential confounders were accounted for using backward elimination and change in estimate approaches. Effect modification by biological sex and age were also considered via inclusion of interaction terms.

**Results:** Among young people with ADHD, three of the four types of physical activity were associated with positive, externalizing (prosocial) behaviours. Inconsistent patterns of association were identified for the remaining types of physical activity and mental health indicators.

**Conclusion:** Among young people with ADHD, the context in which physical activity occurs appears to exert differential effects on their mental health status.

**Keywords:** active travel, adolescence, attention deficit hyperactivity disorder, curriculum time physical activity, epidemiology, mental health, outdoor play, physical activity, sports
4.2 Introduction

Attention deficit hyperactivity disorder (ADHD) is diagnosed in approximately 5-10% of children worldwide, with 80% of those affected continuing to experience its effects into adulthood (Faraone et al., 2003; Polanczyk, 2007). ADHD is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity and impulsivity (American Psychiatric Association, 2013) and those affected are particularly vulnerable to impaired mental health (Biederman, 2005). Young people with ADHD are more likely to feel depressed, anxious and have lower self-esteem (Wehmeier, Schacht, & Barkley, 2010). They also often lack close and positive peer relationships due to the intrusive nature of the disorder (Wehmeier, Schacht, & Barkley, 2010). Moreover, youth with ADHD are more likely to engage in risk taking behaviours such as substance misuse (Brinkman, Epstein, Auinger, Tamm, & Froehlich, 2015; Burke, Loeber, & Lahey, 2001; Eck, Flory, & Willis, 2015).

Medication therapies continue to be the main modes of treatment for ADHD. However only 70% of those with ADHD respond to medication and others who do may experience negative side effects (Wigal, 2009). While medication may decrease ADHD symptoms in adolescents, it may ultimately be ineffective in leading to more positive mental health outcomes (Buhrmester et al., 1992). Alternate or complementary therapies such as physical activity interventions have therefore been explored (Faber, & Kuo, 2009).

The mental health benefits of physical activity have been observed mainly in adults, although its effects in adolescents are likely to be present (Brodersen et al., 2005). Vigorous physical activity alleviates ADHD symptoms and is protective against poor mental health (Bahrke & Morgan, 1978; Hoza et al., 2015; Kiluk et al., 2009; Lufi & Parish-Plass, 2011). However, the evidence base that examines adolescent populations is limited because of its reliance on smaller studies of limited power, with many focused on non-youth centered physical activity (Gapin & Etnier, 2010; Ziereis & Jansen, 2015). Physical activities that youth engage in on a daily basis are also markedly different than adult behaviours (Brodersen et al., 2005). Although physical activity may foster improved mental health, its effects have rarely been explored in populations of young people with ADHD (Brodersen et al., 2005). This is an important research gap due to the vulnerability of young people who are living with this disorder and its consequences.

Mental health includes both negative and positive aspects (Keyes, Dhingra, & Simoes, 2010; Strauss, 2007). Recognized domains include both externalizing and internalizing behaviours and symptoms (Hopwood & Grilo, 2010; Krueger & Markon, 2011). Operationally, these include internalizing-negative (psychosomatic symptoms), externalizing-negative (risk
behaviour) internalizing-positive (emotional well-being), and externalizing-positive (prosocial behaviour) aspects (Freeman et al., 2011).

In this study, we had the opportunity to explore relationships between different forms of physical activity and these four domains of adolescent mental health in a national population of adolescents with a self-reported diagnosis of ADHD. The focus was on the potential protective effects of physical activity experienced in various contexts. We also explored whether the biological sex and age of the adolescents would modify observed associations. Our study was therefore grounded in both biological and psychological theories, which have identified protective effects of physical activity on the health outcomes of individuals with ADHD (Cho et al., 2014; Jeong et al., 2014; Kuo, 2008; Lufi & Parish-Plass, 2011; Robinson et al., 2015). Understanding the types of physical activity, and the contexts in which they occur that might have the greatest protective effects on mental health could better shape physical activity interventions in youth with ADHD. Our hope was therefore that the findings would provide new and robust evidence in support of clinical and health promotion efforts.

4.3 Methods

4.3.1 Study Sample

The data source was the 7th cycle of the Canadian Health Behaviour in School-Aged Children (HBSC) study (Freeman et al., 2011). The HBSC study is affiliated with the World Health Organization (Inchley et al., 2016). It focuses on health experiences and their determinants within populations of adolescents aged 11 to 15 years old. The 7th HBSC cycle was conducted in 2013-14 and the overall sample consisted of 29,784 students from 377 schools from across Canada.

The Canadian HBSC employs a multi-stage cluster sampling method where students are nested within school classes then schools, school boards, and the 10 provinces and 3 territories. Following jurisdictional and local school board approval, random schools and then entire classes were chosen to participate based on the following criteria: school size, public or separate board designation, community size, and main language of instruction. Students who consented were then administered the confidential questionnaire in a single classroom session. Records that emerged from the participants in each province and territory were weighted by age, gender and jurisdiction in proportion to the Canadian student population (Freeman et al., 2011).
4.3.2 Physical Activity Measures

Engagement in different types of physical activity was assessed via four indicators representing different contexts.

**Curriculum time physical activity** was assessed using the questions, “*About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your class time at school?*” Responses were categorized into 0 hours, about half an hour to 2 hours, 3 to 5 hours, and more than 6 hours per week. In its continuous form, this question has a reliability of Spearman’s $r = 0.71$ and criterion validity of Spearman’s $r = 0.33$ (Rangul et al., 2008; Sallis, Prochaska, & Long, 2001).

**Outdoor active play** was measured using two items that asked participants about the amount of hours a day they spent playing outdoors on weekdays and weekends. A composite indicator of total outdoor time per week was estimated. Responses were categorized as 0 hours, about half an hour to 10 hours, 10.5 to 20 hours and more than 20 hours per week.

**Active travel** refers to the engagement in physical transportation through the means of walking and/or bicycling (Gropp, Janssen, & Pickett, 2013; James F Sallis, Frank, Saelens, & Kraft, 2004). It was measured from two items that asked participants how long it took them to travel to school from home and how they typically travelled to school. Adolescents who reported no walking or bicycling to get to school were assigned 0 hours per day. Adolescents who reported engagement in active travel were categorized in two groups consisting of engagement in 15 minutes or less and more than 15 minutes per day, as per precedent (Gropp et al., 2013). The active travel HBSC questions have a test-retest reliability of ICC = 0.94 and validity of Pearson’s $r = 0.45$ with regards to the type and duration of active travel (Ducheyne, Bourdeaudhuij, Lenoir, & Cardon, 2012).

**Engagement in sports** was measured using the question, “*Are you involved in any of these kinds of activities or groups?*” for which response options (“yes” or “no”) included “an individual sport” and “a sports team.” Adolescents were categorized as engaging in no sports, only individual sports, only team sports, or both individual and team sports.

4.3.3 Indicators of Mental Health

Indicators included negative and positive measures of internalizing and externalizing symptoms and behaviours.
Negative Indicators

Internalizing: The psychosomatic symptoms scale (α = 0.84) measures the internalizing-negative aspect of mental health and consists of the questions, “In the last 6 months how often have you had the following...?” The scale involves consideration of 8 items, ranging from psychological (feeling depressed, irritability, feeling nervous, difficulties in getting to sleep) to somatic (headache, stomachache, backache, feeling dizzy) symptoms. Adolescents who reported experiencing four or more symptoms once a week or more were categorized as having “high psychosomatic symptoms,” based on precedent (Kinnunen, Laukkanen, & Kylma, 2010).

Externalizing: An HBSC risk taking behaviour scale measures the externalizing-negative aspect of mental health. Items included questions about tobacco use, alcohol use, other illicit substance misuse, sexual behaviours, aggressive behaviour and unhealthy dietary patterns. Questions regarding sexual behaviour were unavailable for grades 6 to 8 (Kwong, 2015). Engagement in occasional moderate risk taking behaviour can be considered normative for youth (Bonino, Cattelino, Ciairano, Mc Donald, & Jessor, 2005). However, engaging in even one frequent risk taking behaviour has been shown to be highly correlated to other deviant behaviours in youth, making them more vulnerable to serious problems later in life (Bry, McKeon, & Pandina, 1982; Newcomb & Felix-Ortiz, 1992). Thus, for the purpose of our study, adolescents who engaged in at least one risk-taking behaviour on a frequent basis were categorized as having “high risk-taking behaviour.”

Positive Indicators

Internalizing: The emotional well-being scale was measured using an adapted version of the Cantril ladder (Currie, 2014). This measures the internalizing-positive aspect of mental health and ranges from 0 to 10, with 0 indicating worst possible life and 10 indicating best possible life. Adolescents who reported a score of 8 and above were categorized as having “high emotional well-being,” based on established precedent (Boyce, King, & Roche, 2008; Currie, Samdal, Boyce, & Smith, 2001). This adapted version of the Cantril Ladder for adolescents is a good measure of emotional well-being as it has a test-retest reliability of Pearson’s r = 0.70 and convergent validity with other emotional well-being measures (r = 0.62) (Currie, 2014).

Externalizing: An existing prosocial behaviour scale (α = 0.85) measured the externalizing-positive aspect of mental health (Freeman et al., 2011). The 5-item scale consists of a list of various prosocial acts for which adolescents could choose 6 options ranging from the two extremes of “definitely not like me” to “definitely like me”. The total prosocial score therefore
ranged from 0 (lowest) to 30 (highest). Adolescents who scored 16 (the median) or above were categorized as having “high prosocial behaviour.” This was based on the cut-off values used in previous studies, with a slight adjustment due to the age of the sample (King et al., 2005; Tremblay, Vitaro, Gagnon, Piché, & Royer, 1992).

4.3.4 Confounders and Effect Modifiers

Socio-demographic. Biological sex (male vs. female) and grade (6 to 10) were considered as confounders (Estabrooks, Lee, & Gyurcsik, 2003; Hanson & Chen, 2007; Kaltiala-Heino, Marttunen, Rantanen, & Rimpel, 2003). Biological sex and grade were also explored as effect modifiers as both variables may have differential effects on youth with ADHD with regards to mental health, physical activity levels, and their relationships (Steptoe & Butler, 1996). Ethnicity was considered as a confounder (Lock, 1996). Due to limited cell sizes, this variable was collapsed to Caucasian (87.1%) and other ethnicities (12.9%). Socioeconomic status was considered as a confounder and measured from the question, “How well do you think your family is?” Responses were grouped into “well-off”, “average” and “not well-off” (Gaub & Carlson, 1997; Trost et al., 2002).

ADHD and Comorbidities. Based on existing literature, ADHD severity and other comorbidities were considered as potential confounders (Missiuna et al., 2014). ADHD severity was inferred by whether students had an individual education plan for treatment of the ADHD (“yes,” “no” and “don’t know”). Adolescents with more severe ADHD are more likely to be enrolled in special education plans (Barkley, Fischer, Edelbrock, & Smallish, 1990). Other comorbidities were measured from the question that asked participants whether they had any learning exceptionalities. Responses were grouped into “none,” “one comorbidity” and “more than one comorbidity.”

Social Environments. Family structure (Steinhausen & Metzke, 2001) was determined by who the adolescent identified as living with most of the time, which was grouped into, ‘both parents,’ ‘single parent,’ and ‘other.’ Family communication was measured using a scale that consisted of four questions and responses ranged from ‘strongly agree’ to ‘strongly disagree.’ The questions were as follows, “I think the important things are talked about,” “When I speak someone listens to what I say,” “We ask questions when we don’t understand each other,” and lastly “When there is a misunderstanding we talk it over until it’s clear.” Adolescents’ responses were grouped into, ‘high,’ ‘medium,’ and ‘low’ categories. When considered continuously, this
scale has shown good internal reliability among Finnish youth ($\alpha = 0.82$) and their parents ($\alpha = 0.85$) (Rask, Astedt-Kurki, Paavilainen, & Laippala, 2003).

School climate was considered as a confounder (Steinhausen & Metzke, 2001) and measured using a four-item scale which asked the adolescents questions about the school environment such as “The rules of this school are fair;” “Our school is a nice place to be,” “I feel I belong at this school,” and “How do you feel at school at present?” The responses of the adolescents were grouped into, ‘high,’ ‘medium,’ and ‘low’ school climate. The scale when measured continuously has a Cronbach’s alpha of 0.78 (Freeman, Pickett, & King, 2014).

Neighbourhood environment (Aneshensel, 2016) was measured using a social capital (community support) scale which consisted of 5 items, asking the adolescents about the quality of social relationships as well as neighbourhood safety and trust. The questions consist of, “People say hello and often stop to talk to each other in the street,” “It is safe for younger children to play outside during the day,” “You can trust people around here,” “There are good places to spend your free time;” “I could ask for help or a favour from neighbours,” and “Most people around here would try to take advantage of you if they got the chance.” The responses were grouped into, ‘high,’ ‘medium,’ and ‘low’ levels of support. The scale has a Cronbach’s alpha of 0.78 (Freeman, Pickett, & King, 2014).

4.3.5 Statistical Analyses

Frequencies of all key study variables were described. Intraclass correlations (ICC) were estimated to determine the extent of variation in the outcomes at the cluster (school or classroom) level. Multi-level log binomial models were developed in order to estimate relative risks. Effect modification by biological sex and grade were considered through inclusion of interaction terms. A backwards elimination method with a selection criteria of $p<0.15$ was used to identify potential confounders, with subsequent assessment using the change in estimate approach (Rothman, Greenland, & Lash, 2008). All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

Sensitivity analyses were conducted to determine the impact of the missing data on the effect estimates and their interpretation. For each model, extreme values for each variable that had a high level of missing data were imputed and relative risks with 95% confidence intervals were re-estimated.

We employed the following philosophical approach to the interpretation of possible observed effects. Evidence that was used to infer important group effects included: (1) the size
and direction of any observed effects, and whether this coincided with pre-existing theory; (2) the width and nature of any skewness of the confidence intervals that surrounded any observed effects; (3) the consistency of direction of the observed effects indicating a general or inconsistent pattern across multiple indicators, irrespective of statistical significance; (4) the potential gradient of effects across multiple indicators indicating an important pattern; (5) the level of statistical significance achieved, given available study sample size and power to identify group differences. Evidence of important effects included strong and consistent relationships in an expected direction. While the statistical significance of the observed effects was also considered, it was not done in a binary fashion (significant, not significant) but rather using a scale to make decisions about the p-values found, consisting of $1.0 \leq p \leq 0.1$ indicating the weakest evidence, $0.1 < p \leq 0.001$ indicating increasing evidence and lastly $0.001 < p \leq 0.0001$ indicating strong evidence against the null hypothesis (Sterne & Smith, 2001).

4.4 Results

4.4.1 Study Sample

From 29,784 participants, 1,225 from 215 schools reported having a diagnosis of ADHD. All of the participants who self-reported as having ADHD were analyzed. Among those reporting ADHD, there were twice as many males than females and the sample was distributed quite evenly across the various grades. The majority of youth identified as Caucasian, born in Canada, living with both parents and being well-off socioeconomically (Table 4.10).

Based on estimated ICC values (1.8% to 4.4%), the psychosomatic symptoms, emotional well-being, prosocial behaviour and risk behaviour models accounted for clustering at the classroom level. With respect to missing data, there were no substantive differences in the relative risks obtained in the imputed results, either qualitatively or in terms of statistical significance; hence use of a complete case analysis was warranted (Little, & Rubin, 2014).

4.4.2 Physical Activity and Negative Mental Health Indicators

Internalizing Symptoms. Inconsistent associations were found between the different types of physical activity and high psychosomatic symptoms in youth with ADHD (Table 4.11). The majority of the associations had wide confidence intervals and lacked consistency with regards to direction and patterns of association.
4.4.3 Physical Activity and Positive Mental Health Indicators

*Internalizing Symptoms.* Inconsistent associations were found between the different types of physical activity and high emotional well-being, as indicated through the width of the confidence intervals, inconsistency across the associations and weak evidence as shown through the effect estimates (Table 4.3).

*Externalizing Symptoms.* There was moderate to strong evidence that engagement in about an hour to 2 hours of curriculum time physical activity per week and engagement in individual sports were associated with high levels of prosocial behaviour (Table 4.12). Youth who engaged in an increasing amount of hours of outdoor play per week had increasingly stronger associations with reported positive, prosocial behaviour.

4.5 Discussion

The most important findings of our national study of young Canadians with ADHD were as follows: 1) we identified inconsistent associations between different types of physical activity practiced in different contexts, and outcomes of high psychosomatic symptoms, high risk behaviour and high emotional well-being; 2) physical activity other than active travel was associated with high prosocial behaviour in adolescents with ADHD. Overall, this suggests that both the type and context of physical activity is important to consider in the assessment of its effects on mental health indicators among young people with ADHD.

Physical activity may be especially beneficial for youth with ADHD for biological reasons. Those who do not engage in physical activity tend to have lower levels of neurotransmitters such as dopamine and serotonin (Ahn & Fedewa, 2011; Cho, Baek, & Baek, 2014). These are critical neurotransmitters that regulate emotion, motor control, cognition and event predication (Cho et al., 2014). Engagement in physical activity increases the availability of these neurotransmitters and can alleviate negative mood as well as foster positive mental health (Ahn & Fedewa, 2011; Cho et al., 2014).

From the perspective of social theory, physical activity fosters prosocial behaviour by providing an environment in which youth can engage in productive interaction that helps them...
develop skills such as working in groups, resolving conflicts, negotiating, sharing and self-advocacy (McCurdy, Winterbottom, Mehta, & Roberts, 2010; Ransford, 1982). Bandura (1977) postulated that physical activity also increases self-efficacy, the notion of one’s perceived ability, which in turn is protective against low self-regulation of emotion (Eime et al., 2013; Kiluk et al., 2009). This is particularly important for youth with ADHD who have low self-regulation of emotions and as a result are more likely to have poor prosocial behaviour and social skills (Tseng et al., 2012). Furthermore, sports participation fosters moral development and social responsibility as youth must play fairly and show sportsmanship, while having self-control (Rutten et al., 2007).

Limitations of this study warrant comment. Foremost of these is the inability to establish temporality between physical activity levels and the indicators of mental health due to the cross-sectional nature of the HBSC study. Furthermore, the study results may be confounded because of a lack of adjustment for medications and therapies. The self-report nature of the HBSC survey increases the chances of recall error and associated non-differential misclassification. Additionally, social desirability may be a potential source of bias as adolescents with ADHD with lower physical activity levels may report better mental health outcomes than they experience due to this desirability (Adams et al., 2005; Kazdin, & Peiti, 1982). Selection bias may be another source of bias as adolescents with severe ADHD may have more difficulties completing the survey and if these adolescents also have more negative mental health outcomes as well as lower physical activity levels, the effect estimates would be overestimated (Khalife et al., 2014).

Strengths of our study include the novelty of the analysis with respect to its exploration of relationships between different types of physical activity and mental health indicators. Additionally, the HBSC is a large nationally representative study of Canadian adolescents and allowed us to analyze a large sample of Canadian adolescents with ADHD. The anonymous nature of the survey promotes confidentiality and encourages honest and accurate responses, which lessen the chances of the participants responding to the questions in a socially desirable manner. Due to the multi-level structure, the analysis also accounted for possible clustering which accounts for the non-independent nature of the data as the subjects may not have been independent of one another.

Existing research that focuses on the effects of contextual factors related to physical activity on the mental health of adolescents with ADHD is limited. Our study findings suggest that perhaps not all types of physical activity youth engage in may be protective for mental health. Further research is needed to affirm our findings and identify factors that make physical
activity detrimental in some contexts for youth with ADHD. Moreover, longitudinal studies with larger sample sizes would assist in confirming the causal nature of identified associations, as we were unable to establish temporality and many associations did not achieve statistical significance due to the small effect sizes. Lastly, such longitudinal research could also foster new understanding about the pathways in which physical activity fosters, for example, prosocial behaviour in youth with ADHD.

The context in which physical activity typically occurs in adolescents is very important and may exert differential effects on the mental health of youth with ADHD. While we found inconsistent patterns of association between the different types of physical activities and mental health, physical activity overall, was protective for high prosocial behaviour in youth with ADHD. Thus, physical activity interventions could be used as a way to increase prosocial behaviour in adolescents with ADHD and certain environments may yield the most protective effects for these vulnerable youth.

4.6 Acknowledgements

The authors would like to thank all of the participants in the 2014 Canadian HBSC study. The Canadian principal investigators for the HBSC study are Dr. John Freeman and Dr. William Pickett at Queen’s University, Canada. The national coordinator is Mr. Mathew King at Queen’s University, Canada and the international coordinator is Dr. Candace Currie at the University of St. Andrews, Scotland.

4.7 Funding

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4.8 Conflict of Interest

None declared.
4.9 References


http://doi.org/10.1093/jpepsy/jsq107


Eck, K. Van, Flory, K., & Willis, D. (2015). Does distress intolerance moderate the link between ADHD symptoms and number of sexual partners, Attention Deficit and Hyperactivity Disorders, 39–47.


Table 4.1 Description of the 2013-2014 Canadian HBSC weighted study sample population with self-reported ADHD (n=1,225).

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<th>Characteristic</th>
<th>N</th>
<th>%</th>
<th>Characteristic</th>
<th>N</th>
<th>%</th>
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<td>10.5 – 20 hours</td>
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<td>Low</td>
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<td>Low</td>
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### Table 4.2 Relative Risk (RR) estimates describing the association between physical activity and negative indicators of mental health in adolescents with self-reported ADHD (n = 1,225)

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<th>Type of Physical Activity</th>
<th>Negative Indicators</th>
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<tr>
<td></td>
<td>n</td>
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<td>Unadjusted Model</td>
<td>Adjusted Model</td>
<td>n</td>
<td>% High</td>
<td>Unadjusted Model</td>
<td>Adjusted Model</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RR</td>
<td>95% CI</td>
<td></td>
<td></td>
<td>RR</td>
<td>95% CI</td>
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<td><strong>Curriculum Time, per week</strong></td>
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<td></td>
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<td></td>
<td></td>
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<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>170</td>
<td>65.8</td>
<td>Referent</td>
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<td>0.5 – 2 hours</td>
<td>508</td>
<td>49.7</td>
<td>1.45</td>
<td>(0.81, 2.61)</td>
<td>2.43</td>
<td>(1.06, 5.57)</td>
<td>603</td>
<td>53.4</td>
<td>0.50</td>
<td>(0.28, 0.89)</td>
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<td>3 – 5 hours</td>
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<td>0.86</td>
<td>(0.40, 1.84)</td>
<td>1.67</td>
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<td>(0.19, 0.82)</td>
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<td><strong>Outdoor Active Play, per week</strong></td>
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<td>Referent</td>
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<td>(0.41, 1.27)</td>
</tr>
</tbody>
</table>

*Model adjusted for biological sex, grade, socioeconomic status, ethnicity, individual education plan, comorbidities, immigration status, school climate, neighbourhood environment and class-level clustering.

**Model adjusted for biological sex, grade, ethnicity, individual education plan, family structure, school climate, neighbourhood environment and class-level clustering.
Table 4.3 Relative Risk (RR) estimates describing the association between physical activity and positive indicators of mental health in adolescents with self-reported ADHD (n = 1,225)

<table>
<thead>
<tr>
<th>Type of Physical Activity</th>
<th>Positive Indicators</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% High Emotional</td>
<td>n</td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Curriculum Time, per week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>169</td>
<td>34.0</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 2 hours</td>
<td>580</td>
<td>32.6</td>
<td>0.96</td>
<td>(0.51, 1.81)</td>
<td>0.87</td>
<td>(0.40, 1.90)</td>
<td>537</td>
<td>71.4</td>
<td>1.20</td>
<td>(0.63, 2.30)</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>284</td>
<td>42.5</td>
<td>1.52</td>
<td>(0.74, 3.12)</td>
<td>1.20</td>
<td>(0.55, 2.62)</td>
<td>272</td>
<td>71.1</td>
<td>1.14</td>
<td>(0.51, 2.51)</td>
</tr>
<tr>
<td>More than 6 hours</td>
<td>113</td>
<td>61.3</td>
<td>3.09</td>
<td>(1.31, 7.27)</td>
<td>2.38</td>
<td>(0.88, 6.38)</td>
<td>106</td>
<td>76.8</td>
<td>1.33</td>
<td>(0.47, 3.76)</td>
</tr>
<tr>
<td>Outdoor Active Play, per week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>105</td>
<td>30.6</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 10 hours</td>
<td>321</td>
<td>35.1</td>
<td>0.92</td>
<td>(0.41, 2.05)</td>
<td>0.86</td>
<td>(0.34, 2.17)</td>
<td>318</td>
<td>67.7</td>
<td>1.88</td>
<td>(0.94, 3.74)</td>
</tr>
<tr>
<td>10.5 – 20 hours</td>
<td>312</td>
<td>42.4</td>
<td>1.27</td>
<td>(0.56, 2.86)</td>
<td>1.24</td>
<td>(0.53, 2.91)</td>
<td>294</td>
<td>75.9</td>
<td>2.61</td>
<td>(1.18, 5.76)</td>
</tr>
<tr>
<td>More than 20 hours</td>
<td>302</td>
<td>42.2</td>
<td>1.00</td>
<td>(0.41, 2.44)</td>
<td>1.32</td>
<td>(0.49, 3.53)</td>
<td>306</td>
<td>78.5</td>
<td>2.78</td>
<td>(1.28, 6.05)</td>
</tr>
<tr>
<td>Active Travel, per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>850</td>
<td>37.3</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>15 minutes or less</td>
<td>231</td>
<td>45.2</td>
<td>1.39</td>
<td>(0.87, 2.22)</td>
<td>1.05</td>
<td>(0.60, 1.83)</td>
<td>221</td>
<td>69.6</td>
<td>0.83</td>
<td>(0.51, 1.38)</td>
</tr>
<tr>
<td>More than 15 minutes</td>
<td>64</td>
<td>39.8</td>
<td>1.32</td>
<td>(0.47, 3.69)</td>
<td>2.02</td>
<td>(0.69, 5.92)</td>
<td>60</td>
<td>78.0</td>
<td>1.28</td>
<td>(0.46, 3.53)</td>
</tr>
<tr>
<td>Sports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>372</td>
<td>31.7</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Individual only</td>
<td>173</td>
<td>48.3</td>
<td>1.64</td>
<td>(0.86, 3.14)</td>
<td>1.44</td>
<td>(0.69, 2.98)</td>
<td>179</td>
<td>80.0</td>
<td>2.00</td>
<td>(0.96, 4.21)</td>
</tr>
<tr>
<td>Team only</td>
<td>254</td>
<td>39.5</td>
<td>1.10</td>
<td>(0.60, 2.03)</td>
<td>1.02</td>
<td>(0.49, 2.14)</td>
<td>252</td>
<td>71.6</td>
<td>1.15</td>
<td>(0.62, 2.11)</td>
</tr>
<tr>
<td>Team and Individual</td>
<td>324</td>
<td>42.2</td>
<td>1.26</td>
<td>(0.66, 2.41)</td>
<td>0.99</td>
<td>(0.49, 2.01)</td>
<td>315</td>
<td>74.0</td>
<td>1.17</td>
<td>(0.64, 2.17)</td>
</tr>
</tbody>
</table>

*Model adjusted for biological sex, grade, socioeconomic status, family communication, school climate and class-level clustering.

**Model adjusted for biological sex, grade, socioeconomic status, family structure, family communication, school climate, neighbourhood environment and class-level clustering.
Chapter 5
General Discussion

5.1 Study Summary

My thesis had two main foci: 1) to provide a national epidemiological overview of the mental health of Canadian youth with ADHD, and; 2) to explore physical activity and its potential role(s) in protecting young Canadians with ADHD from negative mental health outcomes, while fostering positive mental health.

Using cross-sectional data, I described a variety of mental health indicators in Canadian adolescents with and without ADHD. I examined relationships between the different types and contexts of physical activity and the mental health indicators in Canadian youth with ADHD. Finally, based upon the potential role of biological sex and age I investigated whether the relationships between physical activity and mental health differed by the biological sex and age of these adolescents.

5.2 Summary of Key Findings

5.2.1 Epidemiological Profile of Mental Health among youth people with ADHD

Overall, Canadian youth with ADHD reported poorer mental health status than Canadian adolescents without ADHD. Adolescents with ADHD reported a higher prevalence of negative indicators, including psychosomatic symptoms and risk behaviours, compared to those without ADHD. Youth with ADHD also reported lower levels of emotional well-being and prosocial behaviours. Among youth with ADHD, females reported a higher prevalence of internalizing mental health such as high psychosomatic symptoms and lower levels of emotional well-being. Females with ADHD also reported higher prevalence levels of certain types of high risk behaviours, including alcohol consumption, drug use, sexual behaviour and bullying others.

5.2.2 Associations between Physical Activity and Mental Health

Inconsistent patterns were found between self-reported engagement in various types of physical activity and each of high psychosomatic symptoms, risk behaviour, and emotional well-being. Physical activity in certain contexts had positive relations with high prosocial behaviour.
Overall, engagement in physical activity in certain contexts was beneficial for some positive mental health indicators and associated with reductions in negative mental health indicators; however, the strength and statistical significance of these associations differed by the context of the physical activity.

5.3 Study Limitations

The Health Behaviour in School-Aged Children (HBSC) study is a study that uses self-reported data from adolescents sampled from across Canada. Due to its cross-sectional nature, it is difficult to establish temporality and hence causality of the associations between physical activity and mental health. In the absence of longitudinal designs, it is difficult to infer the direction of these associations and hence the temporal aspects of causality between physical activity and our available indicators of mental health, both positive and negative.

In addition, adolescents with ADHD had to recall their average weekly and daily physical activity levels. The physical activity levels of youth may not be consistent and may change daily or weekly, potentially resulting in inaccurate estimates. Studies in the past have found that children tend to over-report their past physical activity, with self-reported higher levels of physical activity engagement strongly correlated to a higher social desirability index (p=0.02) and validation studies have found that this over-estimation could range from 4 to 11 minutes per day (Adams et al., 2005; Klesges et al., 2004). Recall bias occurs when participants purposefully provide inaccurate information and this differs based on exposure or outcome status (Webb & Bain, 2010). However, it is believed that the error would not occur differentially as youth with both various levels of mental health may recall their physical activity levels inaccurately, thus resulting in recall error rather than bias (Brener, Billy, & Grady, 2003; Webb & Bain, 2010). Thus, non-differential misclassification may have occurred, which would bias the relative risks towards the null.

Another limitation is that adolescents may have self-reported their physical activity levels and mental health in a socially desirable manner. Social desirability bias occurs when individuals systematically underreport undesirable behaviours and over-report desirable behaviours (Oleckno, 2008). Such is the case with physical activity and mental health, as youth may be more likely to report higher levels of physical activity and indicate good mental health (Adams et al., 2005; Kazdin, & Peiti, 1982). If adolescents with ADHD reported higher physical activity levels than their true levels but independent of mental health status, this would result in non-differential
misclassification and bias the results towards the null. However, if adolescents reported higher physical activity levels that are dependent on their mental health status, this would bias the results in either direction, thus resulting in the over-estimation or under-estimation of the effect estimates. Particularly youth with poorer mental health may have been more likely to report higher physical activity levels, resulting in the under-estimation of the effect estimates.

Mental health can be measured in various ways and there are no clear cut-off values for the specific mental health indicators used in our study (Suldo & Shaffer, 2008). Thus, while informed decisions were made about the cut-off values, the conversion of the continuous measures into categories could also have resulted in measurement error. This could potentially result in the underestimation or overestimation of the relative risks. For instance, while our study used a cut-off value of 16 for the psychosomatic symptoms scale, other studies have used different cut-off values, such as 21, corresponding to the mean obtained in their own clinical adolescent samples (Sweeting, West, & Der, 2007). Although in this case a slight change in the cut-off value would be unlikely to change the size of estimated effects in a meaningful way, it would classify more youth with ADHD as having high psychosomatic symptoms and potentially bias the results towards no effect.

Selection bias is another limitation that needs to be considered. Adolescents with ADHD who participated in the HBSC may have been systematically different from the source population. Adolescents with more severe ADHD may have been less likely to participate in the study due to challenges in focusing on the completion of the survey (Khalife et al., 2014), which would potentially affect the prevalence estimates. Beyond representativeness, ADHD severity is also significantly associated with lower physical activity levels and poorer mental health. Hence, if this type of selection bias did occur it would bias the effect estimates and overestimate the relative risk estimates. However, such effects may be minor in our sample; the prevalence of ADHD was approximately 4.1%, which falls in the range of ADHD prevalence found in Canadian studies (Faraone et al., 2003).

Uncontrolled confounding was also a likely limitation of our analysis. For example, information on medication use in youth with ADHD was not available. Medication use has been found to be associated with higher physical activity levels and greater mental health in youth with ADHD (Kim, Mutyala, Agiovlasistis, & Fernhall, 2011). Moreover, we cannot determine from the results of our study whether engagement in physical activity results in higher prosocial behaviour, or whether this is due to confounding by a third variable, for example the personality
traits of the youth who engage in higher levels of physical activity who may also be more likely to display prosocial behaviour. Furthermore, information on individual education plans (IEP) was used as a proxy for ADHD severity, since the direct information on diagnoses of ADHD was not available on the HBSC. Approximately 36% of youth with ADHD self-reported not knowing whether they had an IEP, and thus use of an IEP as a proxy for ADHD severity introduced some inaccuracies. As a result, misclassification may have occurred due to the imprecision of the method used to measure ADHD severity in youth.

Lastly, since the HBSC survey is a self-report survey, the chances of non-differential misclassification increased as adolescents may have not accurately identified themselves as having ADHD. Non-differential misclassification occurs when a participant is misclassified in a category; however, this misclassification is independent of exposure and/or outcome status (Webb & Bain, 2010). In this particular case, youth with ADHD may have not reported their ADHD status due to stigma, regardless of their engagement in physical activity and mental health status (Cauce et al., 2002). Hence, this could affect the prevalence estimates of ADHD in our sample.

5.4 Study Strengths

Strengths of the study also warrant comment. First, the HBSC is a large nationally representative study of Canadian adolescents and this provided us with the opportunity to have access to a robust sample of Canadian adolescents with ADHD.

The anonymous nature of the survey promotes confidentiality and encourages honest and accurate responses, which is especially important when dealing with sensitive issues such as mental health.

Our multi-level analytic approach took into account the potential clustering of the data, with students nested within classrooms and then schools. Participants in our study may have been more similar to each other behaviourally, dependent on the classes and schools that they attended. All of our statistical methods accounted for this clustering and its potential impact on the estimates of variability surrounding the key measures and effects under study.

Lastly, this thesis was grounded in theory, both biological and psychological. Evidence from animal studies and also randomized control trials with ADHD populations have established the existence of relationships between physical activity and a variety of health outcomes. The latter have included cognitive, behavioural, and emotional health outcomes (Cho et al., 2014;
Jeong et al., 2014; Kuo, 2008; Lufi & Parish-Plass, 2011; Robinson et al., 2015). Our study is also novel in its exploration of the protective effects of the different types and contexts of physical activity among adolescents, and its examination of both positive and negative mental health indicators. Moreover, our thesis provided a national epidemiological overview of the current mental health status of Canadian adolescents with ADHD.

5.5 Public Health Implications

Our study findings indicate that female adolescents with ADHD may be particularly vulnerable to mental health problems. As reported in other countries, females with less severe ADHD may be less likely to be diagnosed by healthcare professionals (Bruchmüller et al., 2012) resulting in a pool of diagnosed young women with more severe symptoms and behaviours. This too may be highly detrimental for undiagnosed females with ADHD as they may be unable to receive the proper support from their family, community and educational facilities to better deal with the impairments of ADHD. Moreover, females with undiagnosed ADHD as children and youth, are more likely to later develop substance abuse problems as adults (Nussbaum, 2012).

An over-diagnosis of ADHD in males may also be a problem as it increases health care costs and medication use, resulting in negative side effects, including insomnia and decreased appetite (Batstra & Frances, 2012). ADHD diagnoses are highly vulnerable to clinicians’ biases as there is no standard objective criterion to apply for diagnoses such as a blood test or brain scan (Batstra, Nieweg, Pijl, Van Tol, & Hadders-Algra, 2014).

Batstra et al. (2014) suggests a stepped care and stepped diagnostic approach for treating ADHD in children and youth to prevent both under-diagnosis and over-diagnosis. This model of healthcare delivery involves treating youth with ADHD according to the severity of symptoms presented. Hence, youth presenting milder impairments that may not be identified as ADHD typically, could still receive psychosocial treatment if the impairments persist and youth with more severe impairments would be directed to more intensive treatment such as medication use (Batstra et al., 2014). Youth who follow this model of healthcare have a customized diagnosis and treatment plan, according to the severity of the symptoms presented and how the symptoms progress through time, thus potentially decreasing both under-diagnosis and over-diagnosis. Research on the effectiveness of the step model approach for mental health is limited; however, one study with bulimia nervosa patients found that about 70% of patients recovered after the full
program compared to only 30% of patients recovering with traditional treatment (Bower & Gilbody, 2012).

The key finding of this thesis was that most types and contexts of physical activity were protective for prosocial behaviour in adolescents with ADHD, and this has many public health implications. While many pilot programs have been developed in Canada and America to incorporate physical activity programs at school as a part of healthy and active living in children, only a few programs have targeted children with ADHD specifically (Luepker et al., 2014; J F Sallis et al., 1997; Smith et al., 2013). Our findings show that the opportunity for intervention is likely not complex. The majority of youth with ADHD are already engaging in such physical activities such as physical activity during school, outdoor play and engagement in sports (R. R. Pate, 2006). Therefore, while lower levels of physical activity during school may be sufficient for higher prosocial behaviour in youth with ADHD, increasing hours of outdoor play during the week have been shown to have increasingly greater protective effects for prosocial behaviour.

Public health promotion has mainly focused on the positive biological and psychological effects of physical activity on youth, with minimal attention given to prosocial behavioural effects (Strong et al., 2005). However, our research suggests that physical activity may also be protective for prosocial behaviour, which is especially important for youth with ADHD.

5.6 Future Research Directions

This thesis provided an overview of the current mental health status of youth with ADHD. It also contributed to the existing literature about the effects of physical activity on the mental health of youth with ADHD.

Our findings suggested that within the adolescent population in Canada, females with ADHD were overall reporting poorer mental health than males with ADHD. While the literature on the effects of gender/sex on ADHD diagnoses is limited within the Canadian context, Bruchmüller et al., (2012) found that females are more likely to be under-diagnosed than males due to clinician diagnosis bias towards males. Similar factors may be operating in the Canadian context, resulting in the under-diagnosis of females with ADHD and the over-diagnosis of males with ADHD. However, further research in the Canadian and other contexts is needed to confirm these diagnostic patterns, and whether they are contributing to the epidemiological findings in terms of both prevalence and potential etiology.
Moreover, inconsistent with previous studies, our findings suggested a modest association between low levels of certain types of physical activity (e.g., curriculum time physical activity) and the increased risk of internalizing behaviours (Bahrke & Morgan, 1978; Hoza et al., 2015; Kiluk et al., 2009; Lufi & Parish-Plass, 2011). Further research is required to determine whether these are chance findings, or if a mechanism or pathway exists that connects these two factors.

Lastly, our research indicated that physical activity, other than active travel, is beneficial for prosocial behaviour in youth with ADHD. These latter associations are amongst the least studied, although adolescents with ADHD are particularly vulnerable to poor social skills and relationships. Thus, future research might focus on the use of physical activity as a means of increasing prosocial behaviour in youth with ADHD, and understanding which contexts are most effective. Longitudinal research is also required, as well as research that takes into account potential confounding such as ADHD severity, medication use, parental health-related behaviours and prior mental health status of the youth.

5.7 Conclusion

In summary, adolescents with ADHD are reporting poorer mental health outcomes than adolescents without ADHD in Canada, with female youth reporting poorer mental health than males within the ADHD population. Overall, our findings indicated that physical activity in different contexts may have positive effects on prosocial behaviour in youth with ADHD. Other associations between the different types of physical activity and mental health indicators in the ADHD youth population were inconsistent, modest or insignificant in effect. Other healthcare approaches such as the stepped model for diagnosis and treatment of ADHD should be considered (Batstra et al., 2014). Moreover, further research grounded in longitudinal designs should be conducted on physical activity as a potential way of fostering positive mental health in youth with ADHD.
5.8 References


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Appendix A

The Health Behaviour in School-aged Children Study

The purpose of this appendix is to describe the Health in School-aged Children (HBSC) study, which was used for this thesis.

Methodology of the Health Behaviour in School-aged Children Study

The HBSC is conducted in collaboration with the World Health Organization, and involves the administration of a cross-sectional general health survey every 4 years, to adolescents aged 11-15 years old in 43 countries, including Canada (Currie, & Inchley, 2013). The purpose of the HBSC study is to explore the health and health related behaviours of young people. As of the 2013-2014 school year, Canada participated in its 7th cycle of the survey starting from 1990 (Freeman, King, & Pickett, 2014).

A multi-level cluster sampling method was used to recruit participants for the HBSC study in Canada (Freeman et al., 2014). School jurisdictions were identified within each province and territory and a sampling list was created based on school size, public or Roman designation, community size, and main language of instruction. Students enrolled in private, special needs, or religious schools with the exception of publically funded Roman Catholic schools, were not included in the study (Boyce, King, & Roche, 2008; Freeman et al., 2014). Schools were then randomly selected and a sampling frame of eligible classes from grade 6 to 10 from each participating school was created.

The HBSC questionnaires were administered to students in selected classes within the randomly chosen schools and students willing to complete the survey were given one class period, which was approximately 45 to 70 minutes to complete the survey. Three levels of consent were obtained. This included the school jurisdiction, school principals and parents (Freeman et al., 2014). Depending on the jurisdiction, parental consent was either received in active or passive form. After initial sampling, additional schools within clusters were sampled to rectify non-participation and ensure accurate representation of the characteristics described above. The data from each province and territory were weighted in proportion to the Canadian student population.
The 2014 HBSC was administered to 377 schools across Canada and included a total sample of 29,784 adolescents with an overall response rate of 77% (Freeman et al., 2014). Data used for the second manuscript of the thesis was from 215 schools and 1,225 adolescents with self-reported ADHD.

**Ethics Approval**

The 7th cycle of the HBSC survey has an ethics approval from the General Research Ethics Board at Queen’s University, as well as approval from the Public Health Agency of Canada / Health Canada Research Ethics Board. The HBSC survey has met the principles of research ethics, which includes informed consent from subjects, maximization of benefits and committing no harm, securing the anonymity and confidentiality of the subjects and respecting human dignity (Queen’s University, 2015).
References


Appendix B

HBSC Survey Questions Used

The purpose of this appendix is to show the survey questions used in this thesis for the main exposures and outcomes of interest.

Curriculum Time Physical Activity

26. About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your class time at school?

- [ ] none at all
- [ ] about ½ hour
- [ ] about 1 hour
- [ ] about 2 hours
- [ ] about 3 hours
- [ ] about 4 hours
- [ ] about 5 hours
- [ ] about 6 hours
- [ ] about 7 or more hours

Outdoor Active Play

75. On weekdays, how many hours a day do you usually spend time…?

(Please mark one box for each line)

<table>
<thead>
<tr>
<th>Weekday hours per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>none at all</td>
</tr>
<tr>
<td>e. playing outdoors OUTSIDE SCHOOL HOURS</td>
</tr>
<tr>
<td>[ ]</td>
</tr>
</tbody>
</table>

On weekends, how many hours a day do you usually spend time…?

(Please mark one box for each line)

<table>
<thead>
<tr>
<th>Weekend hours per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>none at all</td>
</tr>
<tr>
<td>playing outdoors</td>
</tr>
<tr>
<td>[ ]</td>
</tr>
</tbody>
</table>
Active Travel

24. How long does it usually take you to travel to school from your home?
   - Less than 5 minutes
   - 5-15 minutes
   - 16-30 minutes
   - 31 minutes to 1 hour
   - More than 1 hour

25. On a typical day, the MAIN part of your journey TO school is made by:
   - Walking
   - Bicycle
   - Bus, train, streetcar, subway or boat/ferry
   - Car, motorcycle or moped
   - Other

Sports Participation

67. Are you involved in any of these kinds of activities or groups? (Check "yes" or "no" for each line)
   Yes                No

   q72a. A sports team (e.g., volleyball, hockey, soccer)
   q72b. An individual sport (e.g., running, cycling, skating)

Psychosomatic Symptoms Scale

34. In the last 6 months, how often have you had the following? (Please mark one box for each line)

<table>
<thead>
<tr>
<th>About every day</th>
<th>More than once a week</th>
<th>About every week</th>
<th>About every month</th>
<th>Rarely or never</th>
</tr>
</thead>
</table>
   a. Headache      |                       |                 |                   |                 |
   b. Stomachache   |                       |                 |                   |                 |
   c. Backache      |                       |                 |                   |                 |
   d. Feeling low (depressed) |                 |                   |                 |
   e. Irritability or bad temper |                 |                   |                 |
   f. Feeling nervous |                 |                   |                 |
   g. Difficulties in getting to sleep |                 |                   |                 |
   h. Feeling dizzy |                       |                 |                   |                 |
Risk Behaviours Scale

Risk Behaviour Category 1: Overt Risk-Taking
Smoking Behaviour
  - Number of days they smoked cigarettes in their life
  - Alternative tobacco products (e.g., e-cigarette, flavoured tobacco...)*
Alcohol and Illicit Substance Use
  - Frequency of alcohol consumption (e.g., beer, wine, cider...)*
  - Number of drinks per typical event
  - Number of times they got drunk in their life*
  - Frequency of binge drinking in the last year*
  - Number of days they used cannabis in their life*
  - Number of times they used hard drugs (e.g., ecstasy, solvents, pain medication...)*
High-Risk Sexual Behaviours
  - Lifetime sexual history and use of contraceptives**
High-Risk Manifest Behaviours
  - Number of times they got into a fight in the last year
  - Frequency of personal bullying behaviours on others*
Unhealthy Dietary Pattern
  - Frequency of energy drink consumption in a typical week

* Grade 6-8 students are not asked these questions in the HBSC Study. Therefore, these behaviours are only found in the Grade 9-10 risk behaviour categories.
** Denote risk behaviours that are a composite measure combining multiple HBSC Study questionnaire items.
* Denote risk behaviours only found in the Grade 6-8 risk behaviour category based on the exploratory factor analysis.

Emotional Well-being Scale

32. Here is a picture of a ladder.

The top of the ladder '10' is the best possible life for you and the bottom '0' is the worst possible life for you.
In general, where on the ladder do you feel you stand at the moment?
Mark the box next to the number that best describes where you stand.
Prosocial Behaviour Scale

68. For each item, mark the box that best describes what you are like as a person.
(Please mark one box for each line)

<table>
<thead>
<tr>
<th></th>
<th>Definitely Not Like Me</th>
<th>Definitely Like Me</th>
</tr>
</thead>
<tbody>
<tr>
<td>q73a</td>
<td>a. I often do favours for people without being asked.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>q73b</td>
<td>b. I often lend things to people without being asked.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>q73c</td>
<td>c. I often help people without being asked.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>q73d</td>
<td>d. I often compliment people without being asked.</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>q73e</td>
<td>e. I often share things with people without being asked.</td>
<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>
Appendix C

Intraclass Correlation Calculations

Intraclass correlations (ICCs) were calculated to determine the amount of variation in the outcomes at the cluster (school or class) level (Table C.1).

Table C.1. Intraclass correlations for Manuscript 2 outcomes

<table>
<thead>
<tr>
<th>Cluster Level</th>
<th>Intra-class Correlation Coefficient (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outcome: High Psychosomatic Symptoms</td>
</tr>
<tr>
<td>School</td>
<td>1.01</td>
</tr>
<tr>
<td>Class</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td>Outcome: High Risk Behaviour</td>
</tr>
<tr>
<td>School</td>
<td>0.17</td>
</tr>
<tr>
<td>Class</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Outcome: High Emotional Well-being</td>
</tr>
<tr>
<td>School</td>
<td>3.06</td>
</tr>
<tr>
<td>Class</td>
<td>4.36</td>
</tr>
<tr>
<td></td>
<td>Outcome: High Prosocial Behaviour</td>
</tr>
<tr>
<td>School</td>
<td>2.02</td>
</tr>
<tr>
<td>Class</td>
<td>2.46</td>
</tr>
</tbody>
</table>
Appendix D

Sensitivity Analyses to Determine the Impact of Missing Data

The purpose of this appendix is to explain why a sensitivity analysis was used to assess the impact of the missing data and to show the effect estimates obtained with extreme imputations of the missing data.

Sensitivity Analyses

Approximately 1,225 youth self-reported as having attention deficit hyperactivity disorder (ADHD) in the 7th cycle of the HSBC study. Furthermore, more than 10% of missingness was found in some of the exposures and outcomes of interest in the ADHD youth subset. Thus, a sensitivity analyses involving imputation of all possible extreme values and their combinations for variables with more than 10% missing data, was conducted to determine whether multiple imputation was required. From the results obtained (Tables D.1-D.4), it was determined that multiple imputation was not necessary as the effect estimates obtained from the sensitivity analysis fell into the 95% confidence intervals of the effect estimates obtained from the complete case analysis. Thus, if multiple imputation was conducted, it would also not significantly change the effect estimates. Hence, the use of complete case analysis was warranted.
Table D.1. Relative Risk (RR) estimates describing the association between physical activity and psychosomatic symptoms in adolescents with self-reported ADHD

<table>
<thead>
<tr>
<th>Type of Physical Activity</th>
<th>Complete Case Analysis</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>RR</td>
<td>RR</td>
<td>RR</td>
</tr>
<tr>
<td>Curriculum Time, per week</td>
<td>Complete Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 2 hours</td>
<td>2.43</td>
<td>(1.06, 5.57)</td>
<td>2.25</td>
<td>2.24</td>
<td>2.39</td>
<td>2.43</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>1.67</td>
<td>(0.72, 3.88)</td>
<td>1.46</td>
<td>1.46</td>
<td>2.21</td>
<td>2.23</td>
</tr>
<tr>
<td>More than 6 hours</td>
<td>1.14</td>
<td>(0.40, 3.21)</td>
<td>0.95</td>
<td>0.97</td>
<td>1.17</td>
<td>1.15</td>
</tr>
<tr>
<td>Outdoor Active Play, per week</td>
<td>Complete Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 10 hours</td>
<td>2.59</td>
<td>(0.95, 7.04)</td>
<td>1.98</td>
<td>1.79</td>
<td>1.79</td>
<td>1.85</td>
</tr>
<tr>
<td>10.5 – 20 hours</td>
<td>0.75</td>
<td>(0.28, 1.98)</td>
<td>0.72</td>
<td>0.64</td>
<td>0.80</td>
<td>0.83</td>
</tr>
<tr>
<td>More than 20 hours</td>
<td>1.44</td>
<td>(0.50, 4.16)</td>
<td>1.12</td>
<td>0.96</td>
<td>1.28</td>
<td>1.43</td>
</tr>
<tr>
<td>Active Travel, per day</td>
<td>Complete Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>15 minutes or less</td>
<td>1.03</td>
<td>(0.54, 2.00)</td>
<td>0.95</td>
<td>0.96</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>More than 15 minutes</td>
<td>0.31</td>
<td>(0.09, 1.02)</td>
<td>0.43</td>
<td>0.44</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>Sports</td>
<td>Complete Case</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
<td>Model</td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Individual only</td>
<td>0.71</td>
<td>(0.34, 1.51)</td>
<td>0.82</td>
<td>0.84</td>
<td>1.04</td>
<td>1.02</td>
</tr>
<tr>
<td>Team only</td>
<td>0.80</td>
<td>(0.35, 1.84)</td>
<td>0.79</td>
<td>0.80</td>
<td>1.08</td>
<td>1.05</td>
</tr>
<tr>
<td>Team and Individual</td>
<td>1.71</td>
<td>(0.81, 3.60)</td>
<td>1.65</td>
<td>1.68</td>
<td>2.29</td>
<td>2.27</td>
</tr>
</tbody>
</table>

1 High psychosomatic symptoms were imputed for the missing psychosomatic values and the greatest amount of outdoor active play was imputed for the missing outdoor active play values.
2 High psychosomatic symptoms were imputed for the missing psychosomatic values and the lowest amount of outdoor active play was imputed for the missing outdoor active play values.
3 Low psychosomatic symptoms were imputed for the missing psychosomatic values and the greatest amount of outdoor active play was imputed for the missing outdoor active play values.
4 Low psychosomatic symptoms were imputed for the missing psychosomatic values and the lowest amount of outdoor active play was imputed for the missing outdoor active play values.
Table D.2. Relative Risk (RR) estimates describing the association between physical activity and risk behaviour in adolescents with self-reported ADHD

<table>
<thead>
<tr>
<th>Type of Physical Activity</th>
<th>Risk Behaviour</th>
<th>Complete Case Analysis Model</th>
<th>Imputed Model$^1$</th>
<th>Imputed Model$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>RR</td>
</tr>
<tr>
<td><strong>Curriculum Time, per week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 2 hours</td>
<td>0.54</td>
<td>(0.25, 1.13)</td>
<td>0.60</td>
<td>0.61</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>0.52</td>
<td>(0.23, 1.19)</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>More than 6 hours</td>
<td>0.64</td>
<td>(0.22, 1.87)</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td><strong>Outdoor Active Play, per week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 10 hours</td>
<td>0.69</td>
<td>(0.26, 1.88)</td>
<td>0.68</td>
<td>0.65</td>
</tr>
<tr>
<td>10.5 – 20 hours</td>
<td>1.27</td>
<td>(0.47, 3.43)</td>
<td>1.25</td>
<td>1.20</td>
</tr>
<tr>
<td>More than 20 hours</td>
<td>1.54</td>
<td>(0.54, 4.38)</td>
<td>1.41</td>
<td>1.44</td>
</tr>
<tr>
<td><strong>Active Travel, per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>15 minutes or less</td>
<td>1.05</td>
<td>(0.57, 1.96)</td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td>More than 15 minutes</td>
<td>1.06</td>
<td>(0.46, 2.42)</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td><strong>Sports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Individual only</td>
<td>0.56</td>
<td>(0.26, 1.24)</td>
<td>0.65</td>
<td>0.63</td>
</tr>
<tr>
<td>Team only</td>
<td>0.74</td>
<td>(0.39, 1.42)</td>
<td>0.77</td>
<td>0.74</td>
</tr>
<tr>
<td>Team and Individual</td>
<td>0.84</td>
<td>(0.44, 1.62)</td>
<td>0.80</td>
<td>0.79</td>
</tr>
</tbody>
</table>

$^1$ The greatest amount of outdoor active play was imputed for the missing outdoor active play values.

$^2$ The lowest amount of outdoor active play was imputed for the missing outdoor active play values.
Table D.3. Relative Risk (RR) estimates describing the association between physical activity and emotional well-being in adolescents with self-reported ADHD

<table>
<thead>
<tr>
<th>Type of Physical Activity</th>
<th>Emotional Well-Being</th>
<th>Complete Case Analysis Model</th>
<th>Imputed Model¹</th>
<th>Imputed Model²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>RR</td>
</tr>
<tr>
<td><strong>Curriculum Time, per week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 2 hours</td>
<td>0.87</td>
<td>(0.40, 1.90)</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>1.20</td>
<td>(0.55, 2.62)</td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>More than 6 hours</td>
<td>2.38</td>
<td>(0.88, 6.38)</td>
<td>2.46</td>
<td>2.46</td>
</tr>
<tr>
<td><strong>Outdoor Active Play, per week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 10 hours</td>
<td>0.86</td>
<td>(0.34, 2.17)</td>
<td>0.75</td>
<td>0.70</td>
</tr>
<tr>
<td>10.5 – 20 hours</td>
<td>1.24</td>
<td>(0.53, 2.91)</td>
<td>1.19</td>
<td>1.13</td>
</tr>
<tr>
<td>More than 20 hours</td>
<td>1.32</td>
<td>(0.49, 3.53)</td>
<td>1.20</td>
<td>1.03</td>
</tr>
<tr>
<td><strong>Active Travel, per day</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>15 minutes or less</td>
<td>1.05</td>
<td>(0.60, 1.83)</td>
<td>1.03</td>
<td>1.03</td>
</tr>
<tr>
<td>More than 15 minutes</td>
<td>2.02</td>
<td>(0.69, 5.92)</td>
<td>1.76</td>
<td>1.76</td>
</tr>
<tr>
<td><strong>Sports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Individual only</td>
<td>1.44</td>
<td>(0.69, 2.98)</td>
<td>1.71</td>
<td>1.71</td>
</tr>
<tr>
<td>Team only</td>
<td>1.02</td>
<td>(0.49, 2.14)</td>
<td>1.21</td>
<td>1.21</td>
</tr>
<tr>
<td>Team and Individual</td>
<td>0.99</td>
<td>(0.49, 2.01)</td>
<td>1.40</td>
<td>1.41</td>
</tr>
</tbody>
</table>

¹ The greatest amount of outdoor active play was imputed for the missing outdoor active play values.
² The lowest amount of outdoor active play was imputed for the missing outdoor active play values.
Table D.4. Relative Risk (RR) estimates describing the association between physical activity and prosocial behaviour in adolescents with self-reported ADHD

<table>
<thead>
<tr>
<th>Type of Physical Activity</th>
<th>Prosocial Behaviour</th>
<th>Complete Case Analysis Model</th>
<th>Imputed Model&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Imputed Model&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>95% CI</td>
<td>RR</td>
<td>RR</td>
</tr>
<tr>
<td>Curriculum Time, per week</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 2 hours</td>
<td>2.19</td>
<td>(0.99, 4.84)</td>
<td>1.99</td>
<td>2.07</td>
</tr>
<tr>
<td>3 – 5 hours</td>
<td>1.49</td>
<td>(0.61, 3.62)</td>
<td>1.26</td>
<td>1.26</td>
</tr>
<tr>
<td>More than 6 hours</td>
<td>1.78</td>
<td>(0.54, 5.87)</td>
<td>1.44</td>
<td>1.40</td>
</tr>
<tr>
<td>Outdoor Active Play, per week</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>0.5 – 10 hours</td>
<td>2.25</td>
<td>(1.04, 4.87)</td>
<td>2.24</td>
<td>1.60</td>
</tr>
<tr>
<td>10.5 – 20 hours</td>
<td>2.32</td>
<td>(0.97, 5.56)</td>
<td>2.32</td>
<td>1.68</td>
</tr>
<tr>
<td>More than 20 hours</td>
<td>4.65</td>
<td>(1.82, 11.9)</td>
<td>3.96</td>
<td>3.24</td>
</tr>
<tr>
<td>Active Travel, per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>15 minutes or less</td>
<td>0.64</td>
<td>(0.33, 1.21)</td>
<td>0.65</td>
<td>0.64</td>
</tr>
<tr>
<td>More than 15 minutes</td>
<td>0.58</td>
<td>(0.19, 1.78)</td>
<td>0.68</td>
<td>0.66</td>
</tr>
<tr>
<td>Sports</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Individual only</td>
<td>2.67</td>
<td>(1.10, 6.47)</td>
<td>2.53</td>
<td>2.45</td>
</tr>
<tr>
<td>Team only</td>
<td>1.34</td>
<td>(0.67, 2.68)</td>
<td>1.51</td>
<td>1.37</td>
</tr>
<tr>
<td>Team and Individual</td>
<td>1.05</td>
<td>(0.51, 2.15)</td>
<td>1.12</td>
<td>1.16</td>
</tr>
</tbody>
</table>

<sup>1</sup> The greatest amount of outdoor active play was imputed for the missing outdoor active play values.

<sup>2</sup> The lowest amount of outdoor active play was imputed for the missing outdoor active play values.
Appendix E

Minimal Detectable Difference Calculations

The purpose of this appendix was to demonstrate a minimal detectable difference calculation and the corresponding relative risks for the second manuscript in this thesis (Table E.1).

Sample Calculation:

Assessing the minimal detectable difference for adolescents with self-reported ADHD from the 2014 HBSC study, using the equations published from Kelsey (1996). Based on 1994/1993 HBSC international data, sample sizes were reduced by a design effect of 1.2 to account for clustering of the data (Roberts, & King, 1996).

Parameter Values:

\[ Z_\beta = 0.84 \text{ (for 80% power)} \]
\[ Z_{\alpha/2} = 1.96 \text{ (for a significance level of } \alpha = 0.05) \]
\( r = \text{ratio of adolescents with ADHD who engage in physical activity levels in the 3 lower quartiles compared to adolescents with ADHD who engage in physical activity levels in the highest quartile} = 3 \]
\( p = \text{prevalence of emotional difficulties in adolescents with ADHD} = 0.33 \text{ (Wehmeier, Schacht, & Barkley, 2010)} \]
\( n = \text{number of adolescents with ADHD that engage in physical activity levels in the highest quartile} = 250 \)

\[
d = \sqrt{\left[ (Z_\beta + Z_{\alpha/2})^2 \ast p(1 - p)(r + 1) \right] \div nr}
\]
\[
d = \sqrt{(1.96 + 0.84)^2 \ast (0.33)(1 - 0.33)(3 + 1) \div (250)(3)}
\]
\[ d = 0.0962 \]

Thus, the minimal detectable difference is 0.0962, given a power of 80%.
Table E.1. Minimal Detectable Difference for the Study Outcome: Emotional Difficulties with No Effect Modification

<table>
<thead>
<tr>
<th>Ratio of Exposed to Unexposed</th>
<th>Number of Adolescents in Highest Physical Activity Quantile</th>
<th>Prevalence</th>
<th>Power</th>
<th>Alpha</th>
<th>Minimal Detectable Difference</th>
<th>Relative Risk</th>
</tr>
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<tbody>
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<td>3</td>
<td>250</td>
<td>0.33</td>
<td>80%</td>
<td>0.05</td>
<td>0.0962</td>
<td>1.31</td>
</tr>
<tr>
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<td>250</td>
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<td>0.05</td>
<td>0.100</td>
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<td>2</td>
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</tr>
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<td>80%</td>
<td>0.05</td>
<td>0.0868</td>
<td>1.24</td>
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Table E.2. Minimal Detectable Difference for the Study Outcome: Emotional Difficulties with Effect Modification by Sex

<table>
<thead>
<tr>
<th>Ratio of Exposed to Unexposed</th>
<th>Number of Adolescents in Highest Physical Activity Quantile</th>
<th>Sex</th>
<th>Prevalence</th>
<th>Power</th>
<th>Alpha</th>
<th>Minimal Detectable Difference</th>
<th>Relative Risk</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>250</td>
<td>0.28</td>
<td>80%</td>
<td>0.05</td>
<td>0.389</td>
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<tr>
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<td>Females</td>
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<td>80%</td>
<td>0.05</td>
<td>0.416</td>
<td>2.63</td>
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<td>80%</td>
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<td>0.120</td>
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Table E.3. Minimal Detectable Difference for the Study Outcome: Emotional Difficulties with Effect Modification by Grade

<table>
<thead>
<tr>
<th>Ratio of Exposed to Unexposed</th>
<th>Number of Adolescents in Highest Physical Activity Quantile</th>
<th>Grade</th>
<th>Prevalence</th>
<th>Power</th>
<th>Alpha</th>
<th>Minimal Detectable Difference</th>
<th>Relative Risk</th>
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<tbody>
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<td>7</td>
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<td>0.05</td>
<td>0.662</td>
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<td>0.05</td>
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<td>4.00</td>
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<td></td>
<td></td>
<td>9</td>
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<td>0.05</td>
<td>0.674</td>
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<tr>
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<td></td>
<td>10</td>
<td>0.36</td>
<td>80%</td>
<td>0.05</td>
<td>0.658</td>
<td>4.37</td>
</tr>
</tbody>
</table>

| 2                             | 333                                                      | 6     | 0.36       | 80%   | 0.05  | 0.402                         | 2.77          |
|                               |                                                          | 7     | 0.37       | 80%   | 0.05  | 0.405                         | 2.71          |
|                               |                                                          | 8     | 0.39       | 80%   | 0.05  | 0.409                         | 2.60          |
|                               |                                                          | 9     | 0.41       | 80%   | 0.05  | 0.412                         | 2.50          |
|                               |                                                          | 10    | 0.36       | 80%   | 0.05  | 0.402                         | 2.77          |

| 1                             | 500                                                      | 6     | 0.36       | 80%   | 0.05  | 0.190                         | 1.71          |
|                               |                                                          | 7     | 0.37       | 80%   | 0.05  | 0.191                         | 1.70          |
|                               |                                                          | 8     | 0.39       | 80%   | 0.05  | 0.193                         | 1.66          |
|                               |                                                          | 9     | 0.41       | 80%   | 0.05  | 0.195                         | 1.62          |
|                               |                                                          | 10    | 0.36       | 80%   | 0.05  | 0.190                         | 1.71          |
References


Appendix F
Ethics Approval

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD (HSREB)

HSREB Initial Ethics Clearance
August 23, 2016
Ms. Mariam Baksh
Department of Public Health Sciences
Queen's University

ROMEO/TRAQ: #6018969
Department Code: EPID.547.16
Study Title: Exploring Mental Health within Canadian Adolescents with Attention Deficit Hyperactivity Disorder and the Protective Role of Physical Activity
Co-Investigators: Dr. W. Pickett
Review Type: Delegated
Date Ethics Clearance Issued: August 23, 2016
Ethics Clearance Expiry Date: August 23, 2017

Dear Ms. Baksh,

The Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) has reviewed the application and granted ethics clearance for the documents listed below. Ethics clearance is granted until the expiration date noted above.

- Thesi Protocol
- 

Documents Acknowledged:

- CORE Certificate – M. Bakshi

Amendments: No deviations from, or changes to the protocol should be initiated without prior written clearance of an appropriate amendment from the HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

Renewals: Prior to the expiration of your ethics clearance you will be reminded to submit your renewal report through ROMEO. Any lapses in ethical clearance will be documented on the renewal form.

Completion/Termination: The HSREB must be notified of the completion or termination of this study

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through the completion of a renewal report in ROMEO.

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information.

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete.

Yours sincerely,

Chair, Health Sciences Research Ethics Board

The HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2), the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP), Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 5 of the Medical Devices Regulations, Canadian General Standards Board, and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is qualified through the CTO REB Qualification Program and is registered with the U.S. Department of Health and Human Services (DHHS) Office for Human Research Protection (OHRP). Federalwide Assurance Number: FW#00004154, IRB#: 00001173

HSREB members involved in the research project do not participate in the review, discussion or decision.