ASSOCIATIONS BETWEEN EXPOSURES TO NATURE AND THE OCCURRENCE OF PSYCHOSOMATIC SYMPTOMS AMONG CANADIAN ADOLESCENTS

by

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Abstract

Background: Spending time outdoors and connecting with nature are beneficial for the physical and mental health of humans. Nature has been associated with promotion of positive mental health through stress reduction and multiple other pathways. Much of the work on this topic has focused on adult populations. The ways that nature may relate to the mental health of young people represents an important gap in knowledge.

Objectives: Using a large, nationally representative sample of Canadian adolescents, the objectives of this thesis were: 1) to examine the association between outdoor play and psychosomatic symptoms; 2) to examine the association between perceived importance of nature connectedness and psychosomatic symptoms; and 3) to determine whether these associations were dependent on sex and/or age.

Methods: In an analysis of data collected from young Canadians in 2013/2014, I described the prevalence of outdoor play, perceived importance of nature connectedness, and psychosomatic symptoms. Next, I developed a series of log-binomial regression models to quantify associations between the exposures to nature and the outcome in the form of relative risks and 95% confidence intervals. After accounting for relevant confounders in the models, sex and age were tested as effect modifiers.

Results: The association between outdoor play and psychosomatic symptoms was found to be modified by sex but not age group. Among female adolescents, playing outdoors for at least 30 minutes/week was associated with a 24% (95% CI: 5%, 40%) reduction in the prevalence of high

psychosomatic symptoms compared to those reporting no weekly outdoor time. Among males, there was no statistically significant relationship between outdoor play and psychosomatic symptoms. The association between perceived importance of nature connectedness and psychosomatic symptoms did not differ according to sex or age. Perception of connection to nature as '*important*' was associated with a 25% (95% CI: 9%, 38%) reduction in the prevalence of high psychosomatic symptoms compared to those who perceived connection to nature as '*not important*'.

Conclusion: This study highlights the importance of adolescent engagement with nature as one strategy to promote their psychological well-being. It also emphasizes the importance of accounting for differences between the sexes when researching, planning, and implementing public mental health initiatives that consider exposure to the outdoors.

Co-Authorship

This thesis is the work of Caroline Piccininni under the supervision of Dr. William Pickett.

Manuscript: *The roles of outdoor play and nature connectedness as potential determinants of internalized mental health symptoms among Canadian adolescents.* The idea to study this topic using HBSC data was generated in a meeting involving Caroline Piccininni, Dr. Pickett, Dr. Ian Janssen, and Dr. Valerie Michaelson. Caroline Piccininni performed the statistical analyses, interpretation of results, and writing of the manuscript with guidance from Dr. Pickett. Drs. Janssen and Michaelson both contributed feedback during the process of manuscript revision.

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List of Abbreviations

CI Confidence interval

HBSC Health Behaviour in School-aged Children study

ICC Intra-class correlation coefficient

RR Relative risk

SES Socioeconomic status

Chapter 1: General Introduction

1.1 Background and Rationale

Spending time in and connecting with the natural environment are thought to hold numerous benefits to human health, but questions remain about the specific impact of these exposures on the mental health of young people.[1,2] With over 80 percent of Canadians living in urban areas, including one-third of population living in the large cities of Toronto, Montreal, and Vancouver, children and youth in contemporary Canadian society spend less time outdoors and feel less connected to nature than ever before.[3,4] With respect to the many health benefits derived from nature, not only do young people potentially share similar benefits with adults, but this group may also experience several unique benefits because of their differentiating characteristics.[2] Furthermore, the high and increasing prevalence of mental health problems among adolescents points to the importance of identifying environmental and other factors that may potentially play an etiological role.[5]

1.2 Objectives

Using data from a large and recent (2013/2014) national sample of Canadian adolescents, I aimed to quantify associations between frequency of outdoor activity and psychosomatic symptoms then between perceived importance of nature connectedness and psychosomatic symptoms. I also tested whether these associations were modified by sex and/or age in order to account for potential differences between boys and girls and by developmental stage.

1.3 Overview of Study Design

The design employed was a cross-sectional epidemiological study. Approximately 30,000 students aged 11 to 15 years from the Canadian provinces and territories participated in the 2013/2014 cycle of the Health Behaviour in School-aged Children (HBSC) study. Participants were asked a range of questions about their physical, mental, social, and spiritual health, as well as their potential individual and contextual health determinants. Questions relating to duration of outdoor activity, perceived importance of nature connectedness, and psychosomatic symptoms were analyzed to address the objectives of this thesis. Using log-binomial regression, final effect estimates were adjusted for relevant confounding variables. Effect modification by sex and age was tested and taken into account when statistically significant.

1.4 Organization of Thesis

This thesis conforms with the style and formatting requirements outlined in the "General Forms of Theses" guidelines provided by the Queen's University School of Graduate Studies. The second chapter is a literature review of underlying theories and past work on relationships between nature and mental health, with particular emphasis on research that has been done in young populations where possible. The third chapter is the manuscript for eventual publication, which addresses the primary thesis objectives to examine associations between both outdoor play and perceived importance of nature connectedness and psychosomatic symptoms. The fourth chapter contains supplementary findings from additional analyses. The fifth chapter is a general discussion of the strengths and limitations of the thesis, with possible implications of this work and future research directions.

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Chapter 2: Literature Review

2.1 Adolescent Mental Health

Mental ill health is the leading cause of disability worldwide.[1] The Canadian Mental Health Association estimates that between 10 and 20 percent of Canadian youth are affected by a mental disorder or problem and 3.2 million 12 to 19 year olds are considered to be at risk for developing depression.[2] Mental health is an essential component of overall health and a strong predictor of both physical and social health status.[3] Mental health problems during adolescence come with a high risk of persistence into adulthood,[4] whereas experiencing positive mental health during adolescence is believed to promote the development of resilience and advantageously impact future health trajectories.[5,6]

The high proportion of youth who are experiencing current problems and who are at risk for developing problems creates the need for expanding knowledge on protection against poor mental health in this population. This need is further escalated by the importance of mental health to overall and future health states. Exposure to and connection with the natural environment are two potential protective factors. The accessibility and affordability of natural exposures greatly strengthens the argument for their possible use as public mental health strategies.

2.2 Relationships between Nature and Mental Health

In Canada, everyday life has become increasingly distant from the natural environment, with approximately 80 percent of Canadians living in urban settings.[7] The majority of children spend more time indoors than children of past generations. For example, a large study in the United States found that 70 percent of mothers played outside everyday compared to only 31 percent of their children.[8]

Decreased outdoor time may contribute to the link between urbanization and increased rates of obesity, poor mental health, and other negative health outcomes, especially among children.[9–11] Indeed, the term "nature deficit disorder" describes the consequences of children spending less time engaged in outdoor activities. According to Richard Louv, such nature deficits lead to "diminished use of the senses, attention difficulties, and higher rates of physical and emotional illnesses".[12]

Scholars from a variety of disciplines have studied the ways in which natural environments may impact human well-being and children have been identified as a key social group that could gain health benefits from use of the outdoors. A strong body of psychological research supports the hypothesis that direct contact with nature benefits mental health and this research points to several mechanisms that may underlie the positive links between nature and psychological well-being. These mechanisms will be reviewed below.

2.2.1 Theoretical Underlying Mechanisms

Multiple mechanisms by which people may derive a sense of psychological well-being from the natural environment have been proposed, reflecting the highly differentiated ways in which people experience the outdoors.[13] Five of these mechanisms that have received the most support will be outlined separately in the following sections; however, it should be noted that they are likely synergistic and may well vary in importance within a single nature contact, as well as between contacts, population sub-groups, environment types, and across cultures.[14]

Mechanism #1—Recovery from Stress and Attention Fatigue

In the field of environmental psychology, there are two prevailing theories that draw on evolutionary principles in order to explain the psychological benefits of nature. Because humans evolved

in natural environments, it is proposed that engagement with such environments remains positively adaptive. The first of these theories is psycho-evolutionary stress reduction theory, proposed by Ulrich in 1979, which holds that stress recovery in natural settings is derived from an unconscious, autonomic response to specific attributes of the environment and is most noticeable among individuals who have been stressed before the exposure.[15] On the other hand, urban settings tend to hinder the same recovery process. This recovery process is thought to promote positive emotions and contact with nature has been shown to very rapidly bring about improvements in mood among people experiencing acute stress.[14] Stress relief, as measured through muscle tension, heart rate, blood pressure, and electrical brain activity, has been demonstrated to occur within minutes of exposure to a green environment.[16] In line with these objective measures, stress reduction consistently emerges as one of the key benefits perceived subjectively from various types of natural experiences. In a survey conducted by Frerichs, 95% of respondents reported a visit to a natural setting as an ideal way of relieving stress.[17]

The second theory is attention restoration theory, proposed by Kaplan and Kaplan in 1989, which centres on the idea that nature can replenish attentional capabilities through an unconscious, cognitive response to intrinsically interesting aspects of the natural environment.[18] Attention fatigue occurs during the performance of cognitive tasks that require prolonged use of directed attention and suppression of irrelevant information. This theory posits that urban life leads to attention fatigue and that natural experiences allow for attention to be restored through an effortless process, which in part accounts for promotion of a positive emotional response. Natural environments help to facilitate this process because they do not require large amounts of information to be managed. Herzog et al. added that these kinds of environments contribute to the replenishment of attentional capabilities by allowing for organization of

thoughts and reflection on personal goals.[19] Other work has found that people are better able to concentrate after both spending time in nature and observing images of natural landscapes.[20]

Informed by one or both of these theories, experiments done in laboratory and field settings generally report some restorative advantage of more natural as compared to less natural environments, including reliable evidence of reductions in self-reported anger, fatigue, anxiety, and sadness, as well as increases in feelings of energy and positive mood with time spent outdoors.[21–23] A meta-analysis comparing measurements of well-being in natural versus urban environments showed that the most consistent evidence was in support of a positive emotional response as the strongest restorative outcome of exposure to nature.[21]

Mechanism #2—Encouragement of Physical Activity

Alternatively, natural space may encourage physical activity, which is known to contribute directly to the promotion of physical and mental well-being across the lifespan.[24] Within existing research concerning children's use of outdoor spaces, a general relationship exists between time spent outdoors and physical activity levels.[25] Outdoor play is more physically demanding of children than playing indoors and likewise, several studies have shown that having access to a nearby park increases physical activity levels in school-aged children.[26–28] A recent experiment involving 60 adolescent participants in the United Kingdom found that almost half the time in the natural environment condition was spent in moderate-to-vigorous physical activity compared to a quarter of the time in the built environment.[29]

Adults who exercise more frequently report fewer depressive symptoms and lower anxiety levels,[30–32] while physical inactivity has been shown to increase the risk of developing depression (OR

range: 1.54-4.01 for males; 1.87-4.44 for females).[33] Studies of older children have demonstrated that physical activity is associated with improved mood and emotional well-being.[34,35]

Exercising outdoors has been linked not only to benefits from performing the physical activity itself, but also with specific benefits derived from the fact that the exercise was conducted in natural spaces.[36] Experimental studies have consistently found short-term positive effects of physical activity in nature when compared with the same amount of physical activity in built environments. For example, Pretty et al. compared the emotional responses of participants exposed to a sequence of natural and urban landscape images while running on a treadmill and found that both mood and self-esteem improved when viewing natural landscapes, indicating that exercise may deliver greater psychological benefits when it occurs in the presence of nature.[24] A study using data from a national survey in Finland found that emotional well-being and sleep quality were more positively related to physical activity in nature compared to both physical activity indoors and physical activity outdoors in built environments.[37] A systematic review led by Thompson Coon summarized the benefits of outdoor versus indoor exercise, which include increased energy and feelings of revitalization, as well as decreases in tension, confusion, anger, and depression.[38] With this being said, of four studies done to investigate the extent to which the relationship between nature and health may be mediated by physical activity levels, only one concluded that physical activity itself was an important mediator.[39–42]

Mechanism #3—Facilitation of Social Contact

Another possible explanation for observed relationships between nature and health is that natural spaces facilitate opportunities for increased social contact, which subsequently promotes well-being.[42,43] Much as for physical activity, positive associations have been documented between social relationships

and health. Social contact is thought to encourage healthy behaviours and to reduce feelings of social isolation, with the latter being a risk factor for poor mental health.[14] The few studies available suggest a positive relationship between natural environments and social cohesion. Outdoor activities improve contact with friends and neighbours, promote the formation of social ties, and in turn improve mental health and well-being in elderly populations.[44,45] A Dutch study of more than 10,000 households showed that loneliness and perceived shortage of social support partly mediated the relationship between the percentage of green space around the respondents' homes, as assessed using aerial photographs, and health outcomes, including perceived general health, number of health complaints, and self-rated propensity for psychiatric morbidity.[46] In young people, documented benefits of outdoor time included learning social skills and the promotion of peer group formation.[47]

Mechanism #4—Stimulation of Personal Development

Based on Wilson's biophilia hypothesis, which proposed that people have a basic need to affiliate and feel connected with the natural world, it is thought that individuals may gain a sense of belonging and purpose in natural environments.[48] Such experiences yield psychological benefits and encourage self-reflection and personal development. Kyriakopoulos reported that outdoor experiences offer a venue for achieving personal change.[49] Studies of leisure time spent in natural settings have indicated that nature holds ideal conditions for stimulating feelings of relaxation and autonomy and making people more open to reflection.[50] Natural elements often refer symbolically to values that give meaning to life.[14] Meaning in life was found to mediate the association between nature connectedness and well-being in a study of Canadian university students.[51] Korpela and Hartig link a sense of well-being with the provision of space for young people to spend time quietly and release tension built up in

other areas of life.[23] In a retrospective study of participants in outdoor programs, Kellert concluded that natural environments have an enhanced ability to assist children in resolving their internal conflicts and fears and to facilitate self-esteem, autonomy, and independence.[52] The findings highlighted potential character development as a result of outdoor experiences.

Mechanism #5—Exposure to Sunlight

Sunlight has been demonstrated to affect mood during activities occurring in outdoor settings.[53] When exposed to sunlight, ultraviolet B photons penetrate into the epidermis and Vitamin D3 is produced.[54] Metabolites of Vitamin D can cross the blood-brain barrier and both Vitamin D receptors and enzymes that convert 25-hydroxyvitamin D to its active form have been identified in cells of the central nervous system, including brain regions involved in the pathophysiology of mood disorders (e.g., amygdala, hippocampus, hypothalamus, and dopaminergic system of the substantia nigra).[55] Between 2001 and 2004, it was reported that 9% of the pediatric population in the United States was Vitamin D deficient (less than 37.5 nmol/L) and 61% had insufficient levels (37.5-75 nmol/L).[56]

An Australian study that assessed mental health symptoms using the 21-item Depression Anxiety Stress Scales found that an increase in serum Vitamin D concentration by 10 nmol/L decreased total scores in young adult males by 9% (RR range: 0.87-0.95) and depression subscale scores by 8% (RR range: 0.87-0.96); however, this relationship was not observed among females.[57] A study of adults in the United States found that both males and females with serum Vitamin D less than or equal to 50 nmol/L were significantly more likely to experience depressive episodes compared to those with serum Vitamin D greater than or equal to 75 nmol/L.[58] Although there exist several other ways to maintain Vitamin D levels in the body, sunlight exposure from spending time in the outdoors remains an important source

and constitutes one potential pathway between exposure to nature and promotion of psychological well-being.

2.2.2 Findings from Past Studies

Relationships between nature and mental health have been studied using a variety of methodologies and in multiple disciplines. The primary focus of this section will be on epidemiological studies. For measurement purposes, exposure to nature has been classified into three levels of contact with nature: viewing nature, having access to nearby nature, and active participation in nature.[59] Of these, studies at the population level have often assessed exposure to nature using measures of how much natural space can be found in the area surrounding participants' place of residence.

Research using this method of exposure assessment has demonstrated a relationship between the amount of green space in one's living environment and improved well-being.[60–64] Proportion of neighbourhood greenery has been connected to increased happiness,[63] reduced mental distress,[65] and reduced stress on subjective and objective levels.[66] A 2016 review paper concluded that there is strong evidence from high-quality studies for a positive relationship between the quantity of green space in a small area surrounding one's residence and self-reported mental health.[67] For example, Maas et al. found an inverse relationship between living less than one kilometre away from a green space and depression and anxiety symptoms,[46] a relationship that was reported to be stronger for youth. On the other hand, a past study using HBSC data found that amount of natural space in youth's immediate environment was not a main contributor to their self-reported life satisfaction.[68]

Studies relying on geographic measures alone tend to be limited by uncertainty regarding the actual usage of the surrounding green space and by the possible influence of selective migration,

whereby healthier individuals may choose to live in greener environments or have an increased ability to do so.[46,67,69,70] Geographic measures may miss gardens and street trees, which are thought to be important sources of nature in densely populated urban settings and will be increasingly important sources as a greater fraction of the population continues to inhabit urban areas.[71] It should also be noted that many such studies fail to provide a specific definition of what was considered green space, which further limits the ability to synthesize this body of work and draw meaning from it.[72] A 2015 meta-analysis of 32 studies concluded that much of the heterogeneity regarding the effect of nature on positive mood relates to the use of divergent types of measurement of natural exposure.[73] The following sections review studies that have used measures of time spent in nature and self-reported connectedness to nature, which are the two ways in which exposure was assessed in the present thesis.

Time Spent Outdoors and Mental Health

Experimental research on the popular Japanese practice of "shinrin yoku" or "forest bathing" has shown that sympathetic nervous system activity, measured via pre-frontal cortex activity, salivary cortisol levels, heart rate variability, pulse rate, and blood pressure, is significantly lower in natural environments.[74–76] Other studies in controlled settings have found that walks in green environments as compared to non-green urban environments can reduce stress, anger, and cortisol levels, and improve mood.[20,77]

There are few large-scale epidemiologic studies that have focused on average time spent outdoors as an independent variable within populations of young people, but a number of studies have employed this measure among adults. A systematic review by Douglas in 2005 concluded that there is good quality scientific evidence that contact with nature in urban areas improves mental health and helps

in the restoration of psychological well-being.[78] Using data from a large survey of adults in Finland, Korpela et al. found a modest positive association between participation in nature-based recreation and emotional well-being, which was attributed to restorative experiences.[79] The reported β range in this study was 0.24 to 0.98 per point-wise increase in nature-based recreation time, with average time spent on nature-based recreation measured on a four-point scale ranging from "not at all or very little" to "very much" and emotional well-being scored on a scale from 0 to 100. A recent study by van den Berg et al. found that time spent in green spaces was significantly associated with self-rated mental health among adults in four European cities.[80] This group reported a β range of 0.02 to 0.04 per hour with total duration of visiting green spaces measured in hours per month and mental health scored on a scale from 0 to 100. Another study, using data from the Scottish Health Survey, similarly found that each additional weekly use of natural environment lowers the risk of poor mental health by approximately 6%.[81]

Negative moods such as anger and frustration have been reported to decrease after spending time in a park and regular park users report lower levels of sadness and anxiety.[70,82] Likewise, a case-control study of adults who work outdoors demonstrated decreasing mood difficulties with increasing hours of outdoor work, although the calculated odds ratio comparing those who worked outdoors greater than two hours per day to those who worked outdoors less was not significant (OR range: 0.34-1.18).[83] Emotional stability has also found to be regulated and increased by people's active interaction with nature.[84] Spending time walking or running in a natural environment was associated with reduced negative emotions, decreased anxiety, higher energy levels, improved attention span, and feelings of tranquility compared to spending the same amount of time walking or running in an urban synthetic environment.[21,85] Both more visits and more time spent per week in green space were significantly

associated with lower levels of perceived stress (OR range: 0.57-0.71) after controlling for age, sex, and socioeconomic status.[61,86]

Children who experience higher levels of contact with nature reported significantly higher global self-worth.[87] A study of children aged 7 to 10 in Barcelona found that increased green space playing time was negatively associated with total difficulties as measured by the Strengths and Difficulties Questionnaire (-6.6% change), emotional symptoms (-8.2% change), and peer relationship problems (-15.4% change).[88] In a qualitative study of children's mental and social health, Maller found that direct contact with nature, facilitated by curriculum-based nature activities in schools, had a positive impact on self-esteem, self-confidence, and mental well-being.[89] In addition, there is emerging evidence that childhood interactions with nature may influence attitudes towards and perceived benefits of nature later in life. For example, van den Berg et al. found that childhood nature experience was a significant effect modifier of the relationship between time spent visiting green spaces and mental health in their adult sample.[80]

Nature Connectedness and Mental Health

A related idea to amount of time spent in nature is nature connectedness, defined as "a stable individual difference in cognitive, affective, and experiential connection with the natural environment".[90] The idea that spiritual and emotional strength can be garnered through a close relationship with nature has resonated across history.[91] Past studies have highlighted the role that individuals' preferences for nature may play in its impact on psychological functioning. Thus, an individual's feelings of nature connectedness may influence the way in which natural environments affect his or her mood and cognitive function or nature connectedness may enhance well-being in its

own right.[92] Two proposed mechanisms by which feeling connected to nature may enhance psychological well-being are by fostering intrinsic value orientation and by satisfying the psychological need of relatedness.[93] Intrinsic value orientation refers to pursuing goals around personal growth, intimacy, and community while relatedness refers to establishing connections with other living and non-living things.

Significant associations have been found between nature connectedness and indices of well-being, lending support to the idea that many individuals' experiences of well-being depend on their relationship with the natural world.[94] Mayer and Frantz revealed a significant correlation between nature connectedness and life satisfaction ($r = 0.2$, $p < 0.05$) and perspective-taking ability ($r = 0.51$, $p < 0.01$).[95] In a later study, Mayer et al. found that connectedness to nature was significantly associated with positive affect ($r = 0.54$, $p < 0.01$) and the ability to cope with life's problems ($r = 0.44$, $p < 0.01$).[96] In 2011, another group showed that nature connectedness was positively associated with autonomy, personal growth, purpose in life, openness to experience, and positive affect, but not with life satisfaction.[97] Brymer et al. reported that individuals' experiences of wellness are strongly related to their relationship to the natural world.[94] A study of Canadian university students found that nature connectedness was positively correlated with psychological ($r = 0.27$, $p < 0.001$), social ($r = 0.23$, $p < 0.001$), and emotional ($r = 0.17$, $p < 0.05$) well-being.[98] A 2014 meta-analysis based on 30 samples concluded that there is a small but significant relationship between nature connectedness and happiness ($r = 0.19$, $p < 0.05$) and that those who are more connected to nature report higher levels of positive emotions and life satisfaction.[90] Of the happiest people participating in a study in the United Kingdom, 80% said that they have a strong connection with nature compared with less than 40% of the unhappiest

participants.[99] Nature connectedness has also been associated with several of the proposed mechanisms underlying the relationship between nature and mental health, including physical activity and social cohesion.[92] Although relationships between nature connectedness and psychological well-being have been consistently demonstrated in adults, this topic remains persistently underexplored in younger populations.

2.3 Psychosomatic Symptoms

There is a growing interest in the field of public health to determine factors which influence the well-being of individuals from their subjective perspective, especially during childhood and adolescence when morbidity and mortality quantified using conventional measures tend to be less prevalent.[100] In this study, we have chosen to use psychosomatic symptoms as our outcome measure. The frequencies of occurrence of the following symptoms are measured by the scale: headache, stomach ache, backache, feeling dizzy, feeling low or depressed, irritability or bad temper, feeling nervous, and difficulties in getting to sleep. The first four of these symptoms compose the somatic dimension of the scale while the latter four compose the psychological dimension. Just as definitions of nature vary across contexts and disciplines, so do definitions of what constitutes a negative or positive mental health state. This eight-symptom scale is one of several ways in which the HBSC attempts to quantify respondents' mental health and there exist other dimensions of mental health that are not measured on this survey. With this being said, the psychosomatic symptoms scale has some unique features which supported its use to examine the relationships of interest in this population.

Firstly, the psychological dimension of the scale includes three symptoms that may potentially indicate respondents' emotional state (feeling low or depressed, irritability or bad temper, and feeling

nervous). The range of symptoms included can be reliably examined by individual symptom.[101] Secondly, these subjectively perceived symptoms may be experienced by an individual with or without a defined clinical diagnosis. Thus, the scale is not intended to be utilized for diagnostic purposes, but rather for making group inferences in studies of subjective psychological and somatic health complaints and their correlates.[102] Using a subjective measure highlights the importance of experience and interpretation at the individual level, which is beneficial when trying to understand how perceiving and reporting these symptoms potentially impacts well-being. To this end, experiencing multiple or recurrent health complaints has been associated with psychological distress, decreased well-being, and decreased quality of life among adolescents. Lastly, it has been demonstrated that this age group is able to understand each symptom from a common frame of reference and reliably evaluate and report these complaints.[101] Put together, these qualities of the psychosomatic symptoms scale provided strong rationale for the selection of this outcome measure over other measures which aim to quantify adolescent mental health on the HBSC.

2.4 Confounders and Effect Modifiers

Plausible confounders and effect modifiers were identified from current literature investigating associations between nature and health. The variables that were tested as potential confounders were sex, age, socioeconomic status (SES), ethnicity, school climate, family support and communication, peer support, neighbourhood social capital, and urban-rural status. Additionally, sex and age were tested as effect modifiers because several previous studies have suggested that the health benefits of nature may differ significantly for males and females and based on developmental stage.[103–108] This is in line with past work that has stressed the importance of avoiding the assumption that green space has uniform

health benefits across subgroups of the population that differ demographically.[109] **Figure 1** provides an illustration of the conceptual model and a brief rationale for the inclusion of each potential confounder and effect modifier is included below. Please refer to the Chapter 3 for additional information on the measurement of each variable using the HBSC and how each was categorized for analysis.

Sex: Being female is associated with poorer self-perceived mental well-being[110] and past findings from the HBSC indicate that girls consistently report lower scores on measures of mental health than boys.[102,111,112] It has also been suggested that sex differences exist in both perceptions and patterns of use of natural environments.[113,114] Past studies exploring effect modification by sex have found contradictory results with some reporting a stronger relationship between green space and mental health among males[104,109] and others reporting greater benefits to mental health for females.[115,116]

Age: Age is used as a proxy for developmental stage. Older adolescents report higher rates of poor emotional health than younger adolescents.[111] It is also known that outdoor spaces are used in varied ways by different age groups of children.[113] Concordant with theories of development, it is possible that observed associations may differ for adolescents in younger and older age groups; hence age was also investigated as an effect modifier.

SES: Lower family income is associated with increased adolescent emotional problems and socioeconomic differences account for significant variation in adolescent psychosomatic symptoms.[117] Regarding the use of nature, one hypothesis is that children of lower SES strata may have more unstructured time, which they fill with both screen time and outdoor play time.[118] Another view is that children from families of higher SES may have more access to natural spaces due to the location of their homes in greener areas and increased resources available to travel to natural areas during vacation

time.[119] Due to potential associations with both exposure and outcome variables, perceived family wealth was tested as a confounder.

Ethnicity: Ethnicity is known to be associated with mental health among Canadian adults, with members of minority ethnic communities who have lived in Canada for two to twenty years more likely to report poor mental health than those who have lived in Canada for less than two or greater than twenty years.[120] Among females, this study found that South Asian females had the lowest probability of reporting mental distress compared to other ethnicities while among males, those of British descent were least likely to report mental distress.[120] In addition, certain ethnic groups have lower or higher participation in outdoor recreation activities. Differences among cultures in prevailing social constructions of nature may contribute to the observed variation between ethnic groups in use of and conceptualizations of the outdoors.[121]

School Climate: Students with low quality school experiences are more likely to report psychosomatic symptoms.[122] Increasingly negative experiences of school are related to more psychosomatic complaints, with the effects of a negative school climate being more pronounced for females.[123] The school experience may also be associated with the nature-related variables by exerting an influence on students' environmental actions and environmental identity.[124]

Family Support and Family Communication: There is an association between both mother-child and father-child communication and young people's life satisfaction, with mother-daughter relationships being especially important.[125] Young people with high parent trust and communication are less likely to report psychosomatic symptoms and positive family climate has also been associated with

protection against depression.[4,111] In addition, parental influences have been shown to act as a key determinant of children's patterns of outdoor behaviour.[114]

Friend Support: Although the influence of friend support is not as strong as for parental support, having a supportive network of peers has been found to contribute to better emotional health, indicated by fewer psychosomatic symptoms.[126] Experiencing support from friends is plausibly associated with increasing the amount of time children spend outdoors and promoting their positive feelings toward nature. The reverse may also be true, wherein adolescents with high scores for the exposure variables may experience increased peer group support via the fostering of social interactions in natural environments.

Neighbourhood Social Capital: Individuals with negative perceptions of their neighbourhood environment are more likely to have negative perceptions of their health and to have depressive symptoms.[127] Neighbourhood safety has been shown to predict mental health among adults[128] and neighbourhood safety is an important feature associated with outdoor play.[129] In the context of childhood and adolescence, negative perceptions of the neighbourhood can strongly influence maternal fear of outdoor play.[130] It is suspected that this variable may be more likely to confound the associations for female adolescents as some researchers have shown that females dedicate more importance to quality and safety of green spaces.[46,131]

Urban-Rural Status: A lower risk of depression has been reported in rural areas, which has been attributed to a stronger sense of community belonging.[132] In a study of predictors of intentions to engage with nature, participants who had grown up in more rural areas were more likely to report

positive orientations towards engagement.[133] In addition, there is typically a greater abundance of natural spaces and greater levels of access to these spaces for children residing in rural areas.[119]

2.5 Synopsis of Chapter

In accordance with five key proposed mechanisms, spending time outdoors and cultivating connections with nature may influence psychological well-being. A strong body of existing literature supports the presence of these associations among adults; however, the features of these associations as experienced by young people remain unclear. Few large-scale epidemiological studies have been conducted on this topic and those that have often rely on geographic measures without taking individual usage and perceptions of nature into account. Although not without their own weaknesses, we chose to examine these more subjective measures in a large, national sample of Canadian adolescents. The association between these exposures and the occurrence of psychosomatic symptoms was of interest to study in this population for several reasons. Firstly, children and adolescents have experienced a recent decline in usage of the outdoors coupled with a rise in reported mental health problems. Secondly, our findings have potential to support nature-based public health strategies, which are likely to be more accessible and less expensive than other forms of intervention. Finally, adolescence is characterized by unique qualities that may make it a particularly amenable developmental stage during which to intervene with the goal of improving symptoms of poor mental health. Based on this rationale, this thesis aimed to comprehensively examine quantitative relationships between outdoor play, perceived importance of nature connectedness, and psychosomatic symptoms in the Canadian context.

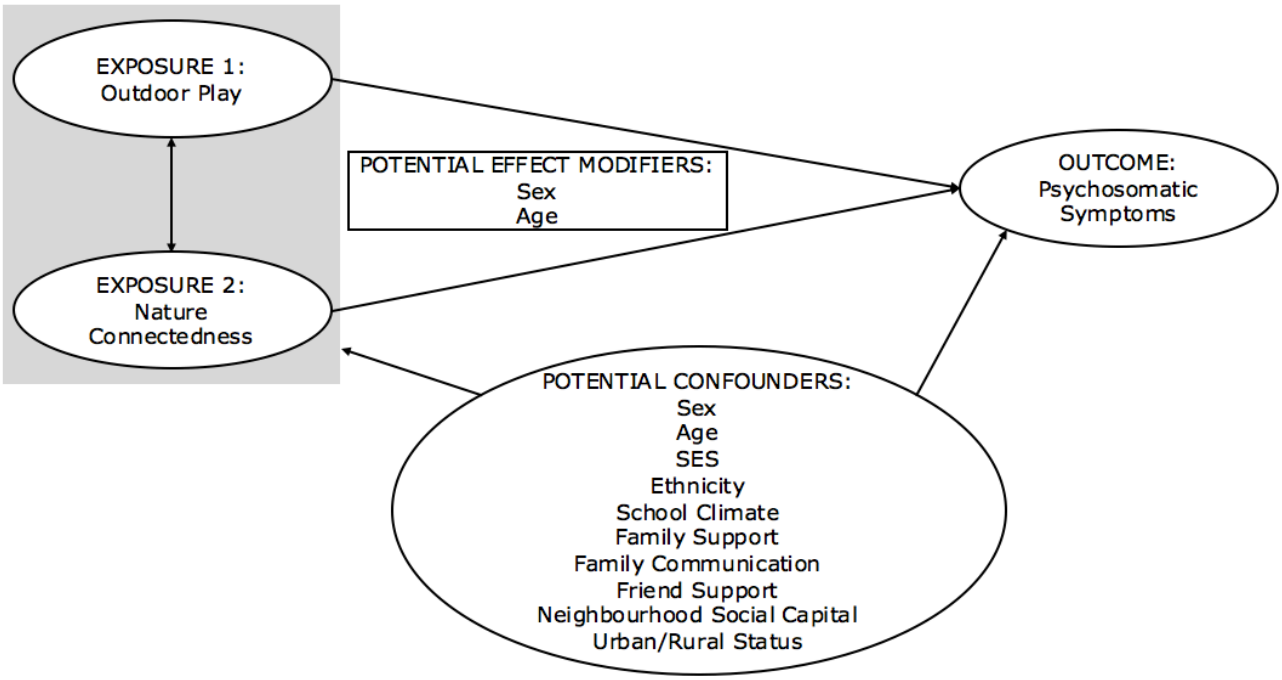

Figure 1. Diagram illustrating potential confounders and effect modifiers of the proposed relationship between outdoor play, perceived importance of nature connectedness, and psychosomatic symptoms

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Chapter 3: Outdoor play and nature connectedness as potential determinants of internalized mental health symptoms among Canadian adolescents

3.1 Abstract

Objectives: This study explored how duration of outdoor play and subjective feelings of nature connectedness relate to the prevalence of recurrent psychosomatic symptoms, one indicator of poor mental health, among Canadian adolescents. An additional objective was to identify whether these associations differed according to sex or age.

Methods: A cross-sectional epidemiologic study design using data from the 2013/2014 cycle of the Health Behaviour in School-aged Children (HBSC) study was employed. The weighted Canadian sample for this cycle included 29,784 students with an approximate age range of 11 to 15 years from 377 schools nationally.

Results: Associations between outdoor play and psychosomatic symptoms differed by sex but not by age group. Among female adolescents, spending greater than 0.5 hours/week outdoors was associated with a 24% (95% CI: 5%, 40%) lower prevalence of high psychosomatic symptoms, compared to those who spent no time playing outdoors in the average week. Among male adolescents, no statistically significant relationship between outdoor play and psychosomatic symptoms was observed. Perception of connection to nature as '*important*' was associated with a 25% (95% CI: 9%, 38%) reduction in the prevalence of high psychosomatic symptoms; this association did not differ by sex or age.

Conclusions: This study highlights the potential importance of adolescent engagement with nature as one strategy to promote their psychological well-being. It also emphasizes the importance of accounting for differences between the sexes when researching, planning, and implementing public mental health initiatives that consider exposure to the outdoors.

3.2 Introduction

As day-to-day life becomes increasingly technophilic, many individuals spend less time outdoors and feel less connected to nature than ever before.[1] This may be harmful to both physical and mental health.[2] Questions remain about the specific impact of exposures to nature on young people's mental health. During adolescence, mental health problems are common, with some emergent to epidemic proportions,[3,4] and some likely to persist into adulthood.[5] There is a need to recognize diverse prevention and promotion initiatives that are effective, accessible, and affordable. Satisfying these conditions, provision and protection of natural space and efforts to engage young people with nature may constitute valuable public health strategies.

Despite a growing research and policy interest in the psychological benefits of nature,[6] few large-scale studies of children have examined this topic. The majority of these past studies have focused on adult populations and have assessed exposure to natural environments through quantification of natural space in participants' neighbourhoods using geographic information systems or survey methods.[7–12] Using these measures, existing evidence suggests that the amount of public natural space within five kilometers of youth's school or home is only weakly related to positive emotional well-being after controlling for family, peer, and other contextual factors.[7] However, the potential mental health benefits of contact with and feelings towards nature, which are more proximal variables and take into account youth's own perceptions, have not been quantified on a population basis. Interaction with nature could have unique psychological benefits for young people; specifically, this population may derive additional benefits from nature in terms of providing opportunities for play, learning about risks, and becoming familiar and comfortable with being exposed to natural environments.[6,13]

We had a unique opportunity to conduct a large and nationally representative cross-sectional epidemiologic study to address this important gap in the paediatric literature. Our aims were to explore how outdoor play and perceived importance of nature connectedness relate to the prevalence of psychosomatic symptoms, one indicator of poor mental health.[14] Based on precedent and the increasing use of targeted interventions in public health,[15,16] an additional objective was to identify whether these associations differ by sex and age.

3.3 Methods

Data Source and Study Sample

Data collected as part of the 2013/2014 cycle of the Health Behaviour in School-aged Children (HBSC) study were used. HBSC is a cross-sectional survey administered every four years to gather information on the health (physical, social, emotional, and spiritual domains) of adolescents aged 11 to 15 years.[17] In 2013/2014, the weighted Canadian sample included 29,784 students from 377 schools across the country. Multi-stage cluster sampling was used, in which students were nested within classrooms, which in turn were nested within schools, school boards, then provinces and territories. The national sample is considered representative of public school students (>93% of the population)[18] based on language (English, French, Inuktitut), school board type (public, separate), size of the surrounding community (urban-rural continuum), and geographic location. A 77% participation rate was obtained at the individual student level.[19] The Canadian HBSC study holds ethics approval from the General Research Ethics Board at Queen's University and Public Health Agency of Canada/Health Canada and this secondary analysis was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board.

Outdoor Play Measure (Exposure 1)

Outdoor play was assessed using two items. The first asked students: "*On weekdays, how many hours a day do you usually spend time playing outdoors outside school hours?*" The second asked the same about weekends.[19] For both questions, possible responses in hours/day were '*none at all*', '*half an hour*', '*1 hour*', '*2 hours*', '*3 hours*', '*4 hours*', '*5 hours*', '*6 hours*', and '*7 hours or more'*. Weekday hours/day were multiplied by five, and weekend hours/day by two, to create a total weekly average. Outcome-based spline modelling was used to determine the most optimal cutpoints for a posteriori categorization of this variable.[20]

Nature Connectedness Measure (Exposure 2)

This measure comprises one of four domains of the HBSC spiritual health scale.[21,22] Two questions were intended to capture the level of importance placed on connecting to and caring for nature by students.[22] Participants were asked: "*How important is it for you to feel connected to nature?*" and: "*How important is it for you to care for the natural environment?*" Responses to both of these items were provided on a five-point scale with one indicating '*not at all important*' and five being '*very important*'. The responses for each question were summed then divided into three categories based on standard cutpoints: not important (2-4), somewhat important (5-7), and important (8-10).[22]

Psychosomatic Symptoms Measure (Health Outcome)

Psychosomatic symptoms were measured using an eight-item scale that asked participants about the following complaints: psychological—feeling low or depressed, irritability or bad temper, feeling nervous, and difficulties in getting to sleep; somatic—headache, stomach ache, backache, and feeling dizzy.[23] This composite scale has been shown to have good internal consistency with a Cronbach's alpha

of 0.84.[24] This measure also shows acceptable test-retest reliability as a whole (Pearson-r = 0.79) and somewhat lower reliability for the two sub-scales and single symptoms (Pearson-r = 0.61 to 0.76).[25] For each symptom, respondents were asked to indicate how often it occurred in the past six months, with possible responses being '*about every day, 1; more than once a week, 2; about every week, 3; about every month, 4; and rarely or never, 5*'. Responses were summed across the eight items to create a total score for each participant ranging from 8 (uppermost experience with psychosomatic symptoms) to 40 (lowest experience). A high score for psychosomatic symptoms was defined as having a total score of 8 to 28, as per precedent.[5]

Confounders and Effect Modifiers

Plausible confounders and effect modifiers were derived from previous work investigating associations between nature and health. Factors that have been previously associated with both adolescent experiences in nature and adolescent mental health are sex,[26,27] age,[28,29] socioeconomic status (SES),[30,31] ethnicity,[32,33] school climate,[34,35] family support,[36,37] family communication,[26,36] friend support,[38,39] neighbourhood social capital,[40–42] and urban-rural status.[43] Sex and age were additionally tested as effect modifiers because previous work has suggested that the health benefits of nature may differ considerably for males and females and based on developmental stage.[27,29]

Sex was determined using the question: *"Are you male or female?"* Age was calculated using the date of HBSC administration and the two questions: *"What year were you born?"* and *"What month were you born?"* SES was assessed using a proxy measure that asked students: *"How well off do you think your family is?"* The five responses to this item ranged from '*very well off*' to '*not at all well off*', and were grouped into three categories: above average, average, and below average.[24] Ethnicity was

determined using the question: *"People living in Canada come from many different cultural and racial backgrounds. How do you describe yourself?"* The different options were grouped into seven categories based on those used in the Canadian Census of Population[44]: Canadian dominant culture (North American, European) and Aboriginal youth, Arab and West Asian, South Asian and East Indian, East and Southeast Asian, African, Latin American, and other.

The School Climate Scale (Cronbach's alpha = 0.78)[19] is made up of four items: *"How do you feel about school at present?"* and *"Please show how much you agree or disagree with the following statements… 1) The rules in this school are fair. 2) Our school is a nice place to be. 3) I feel I belong in this school."* The possible responses to the question regarding feelings about school are: '*I like it a lot*', '*I like it a bit*', '*I don't like it very much*', and '*I don't like it at all*'. The scale for the other three items ranges from '*strongly agree*' to '*strongly disagree*'.

The Family Support Scale (Cronbach's alpha = 0.91)[19] also consists of four items: *"Please show how much you agree or disagree with the following statements… 1) My family really tries to help me. 2) I get the emotional help and support that I need from my family. 3) I can talk about my problems with my family. 4) My family is willing to help me make decisions."* Similarly, the Family Communication Scale (Cronbach's alpha = 0.87)[19] asks students to indicate their level of agreement with four statements: *"In my family… 1) I think the important things are talked about. 2) When I speak someone listens to what I say. 3) We ask questions when we don't understand each other. 4) When there is a misunderstanding we talk it over until it's clear."*

The Friend Support Scale (Cronbach's alpha = 0.92)[19] asks students to indicate their level of agreement with four statements: *"1) My friends really try to help me. 2) I can count on my friends when*

things go wrong. 3) I have friends with whom I can share joys and sorrows. 4) I can talk about my problems with my friends."

Students select their level of agreement with five statements in response to the Neighbourhood Social Capital Scale (Cronbach's alpha = 0.78)[19]: *"1) People say 'hello' and often stop to talk to each other in the street. 2) It is safe for young children to play outside during the day. 3) You can trust people around here. 4) There are good places to spend your free time (e.g. recreation centres, parks, shopping centres). 5) I could ask for help or a favour from neighbours."*

Lastly, an ecological measure of urban-rural status was included by using school postal codes linked with Statistics Canada data to determine the corresponding Beale code for each according to population size and adjacency to a metropolitan area.[45]

Statistical Analysis

Analyses were conducted using SAS software version 9.4 (Cary, NC: SAS Institute Inc.). Standardized weights were applied in order to ensure the national representativeness of the sample by sex and age. Intra-class correlation coefficients (ICCs)[46] were estimated to quantify the amount of variation in the outcome accounted for at individual and then area (classroom and school) levels.

Descriptive analyses were performed to profile the full sample, as well as the individuals falling in the high psychosomatic symptoms category, according to each exposure variable and suspected confounder and effect modifier. Rao-Scott chi-square tests[47] accounting for clustering were done to determine whether there were significant differences in proportions of those with the outcome between levels of each predictor.

Using data from complete cases, generalized linear regression models were created using the PROC GENMOD procedure with a binomial distribution and log link in order to estimate relative risks and their 95% confidence intervals. To derive the most parsimonious regression models, a backwards elimination strategy was used, starting with full models that included all potential confounders. The criteria for confounders to remain in the final model involved a liberal P-value of 0.15.[48] Variables with P-values greater than 0.15 were removed in descending order of significance. A change-in-estimate approach was also used to assess the consequences of variable removal, with any variables causing a change in the main effect estimate by 10% or greater kept in the final model.[49] Effect modification by sex and age was assessed through inclusion of two-way interaction terms. In subsequent analyses, the associations between outdoor play and perceived importance of connectedness to nature and individual psychosomatic symptoms, rather than the psychosomatic symptoms scale in full, were explored to determine whether one symptom or a group of symptoms was unequally impacting the findings. In order to assess the impact of excluding those with missing data, sensitivity analyses involving imputation of missing data as the most extreme combinations of values for exposure and outcome variables were performed.

3.4 Results

Study Sample

The sample is described in **Table 1**. Upon removal of respondents missing data for any of the study variables, the final sample consisted of 20,697 students. The adolescents had a mean age of 14.1 (range: 8.9-18.4) years and the sample was 49% male. There were no significant differences between those included in and excluded from the analysis with regards to the distributions of key variables,

including outdoor play, perceived importance of nature connectedness, psychosomatic symptoms, sex, age, ethnicity, and perceived family wealth.

Prevalence of Outdoor Play and Perceived Importance of Nature Connectedness

The adolescents reported playing outdoors for a mean of 15.0 (95% CI:14.9, 15.9) hours per week and 8.9% of participants reported no weekly outdoor play time on either weekdays or weekends during the average week. Average weekly outdoor time was higher among males (16.8 hours/week) than females (13.4 hours/week) and decreased slightly with increasing grade/age from 15.8 hours/week in Grade 6 to 14.1 hours/week in Grade 10. Connection to nature was considered '*important*' by 59.2% of participants, with slight differences between males and females (57.2% and 61.0%, respectively). The proportion of students ranking connection to nature as '*important*' decreased with increasing grade/age from 72.0% in Grade 6 students to 50.3% in Grade 10 students.

Prevalence of Psychosomatic Symptoms

Approximately 28% of participants reported having high psychosomatic symptoms. This was reported by 18.9% of males and 37.5% of females. Higher proportions of females and older students reported experiencing each of the eight symptoms more often than once a week. There were also significant bivariate associations between having high psychosomatic symptoms and perceived family wealth, ethnicity, urban-rural status, school climate, neighbourhood social capital, family support, family communication, and friend support (**Table 1**).

Associations between Outdoor Play and Psychosomatic Symptoms

In empty models, the ICCs were 4.2% at the school level and 6.7% at the classroom level, indicating that homogeneity at the area level accounted for up to 10.9% of the observed variance in

psychosomatic symptoms. Classrooms were specified as random effects in subsequent regression models.

There was evidence of effect modification by sex, but not by age, in the relationships between outdoor play and psychosomatic symptoms. Thus, results are presented separately for females and males (**Table 2**). After adjusting for confounding factors, outdoor play for greater than 0.5 hours weekly was associated with a 24% (95% CI: 5%, 40%) reduction in the prevalence of high psychosomatic symptoms among females, while no statistically significant relationship was observed among males. Using spline modelling, there appeared to be a threshold effect in the observed relationship whereby the prevalence of high psychosomatic symptoms decreased from 0.5 hours of weekly outdoor play to 14 hours weekly and levels past this did not result in further benefit.

Among females, when examined by reporting individual symptoms at a frequency of greater than once per week, outdoor play for greater than 0.5 hours weekly was consistently and most strongly related to reductions in the four items that constitute the psychological dimension of the psychosomatic symptoms scale: feeling low or depressed (RR: 0.73; 95% CI: 0.56, 0.91), irritability or bad temper (RR: 0.72; 95% CI: 0.57, 0.91), feeling nervous (RR: 0.76; 95% CI: 0.62, 0.92), and difficulties in getting to sleep (RR: 0.75; 95% CI: 0.60, 0.92). Relationships between outdoor play and the four somatic symptoms were less consistent and not statistically significant. Among males, the only individual symptom that was significantly associated with outdoor play for greater than 0.5 hours weekly was feeling low or depressed (RR: 0.60; 95% CI: 0.42, 0.86) (**Supplementary Table 1**).

Associations between Perceived Importance of Nature Connectedness and Psychosomatic Symptoms

Identifying connection to nature as '*somewhat important*' was associated with a 21% (95% CI: 5%, 34%) lower prevalence of high psychosomatic symptoms while ranking connection to nature as '*important*' was associated with a 25% (95% CI: 9%, 38%) lower prevalence, after adjusting for confounders (**Table 3**). No differences were observed in this relationship based on sex or age. Similar to what was observed for outdoor play, placing importance on nature connectedness was most strongly related to the symptoms comprising the psychological dimension of the psychosomatic symptoms scale: feeling low or depressed (RR: 0.72; 95% CI: 0.58, 0.88), irritability or bad temper (RR: 0.62; 95% CI: 0.52, 0.74), feeling nervous (RR: 0.84; 95% CI: 0.71, 0.99), and difficulties in getting to sleep (RR: 0.78; 95% CI: 0.66, 0.94) (**Supplementary Table 2**).

3.5 Discussion

Using data from a nationally representative sample of Canadian adolescents, we found that spending time outdoors was associated with decreased prevalence of psychological symptoms among females, and placing importance on feeling connected to nature was associated with decreased prevalence of psychosomatic symptoms for both males and females. Furthermore, the strongest relationships existed for the four items that make up the psychological dimension of the psychosomatic symptoms scale: feeling low or depressed, irritability or bad temper, feeling nervous, and difficulties in getting to sleep. The study findings therefore suggest a potential protective role of engagement with natural environments against symptoms that may indicate poor mental health among Canadian adolescents.

Comparisons with Previous Studies and Potential Explanations of Findings

This study contributes to an emergent body of literature on the relationship between nature and mental health among young Canadians. A past study found weak and inconsistent relationships between amount of public natural space in the area within five kilometers of students' homes and their emotional well-being.[7] The more consistent patterns of relationships in our study may reflect our application of more direct measures of usage and perceptions of natural space relative to the previously employed geographically measured indicators. Although proximity to and availability of natural space are important determinants of its usage, mental health benefits derived from nature are more closely related to individual differences in frequency of visits to nature.[50–52] Similarly, having participants report on subjective feelings of the importance of connectedness to nature captures perceptions of nature at a more individual level. Nature relatedness has been previously associated with a number of well-being indicators in samples of Canadian university students.[53]

It remains uncertain how much outdoor play is sufficient to affect the prevalence of poor mental health among adolescents. However, our findings correspond with those of two other recent studies, both of which focused on adult samples, which have suggested as little as 30 minutes weekly may be associated with a lower prevalence.[54,55] The majority (91.1%) of adolescents in our sample met this 30 minutes/week threshold. A study using data from the Scottish Health Survey also concluded that being active in a natural environment even once per week may be sufficient for positive benefits.[56]

Outdoor play and perceived importance of nature connectedness were found to be significantly associated with the symptoms that make up the psychological but not the somatic dimension of the psychosomatic symptoms scale. Past work on this scale has established that the two dimensions may

have unique etiologies requiring differentiated intervention.[24] Our findings reflected this idea, suggesting that during adolescence, outdoor play and nature connectedness may be implicated as protective factors against experiencing only the psychological symptoms. It is also thought that the two dimensions may differ in timing, with psychological symptoms being the initial expression of perceived stress and developing into somatic symptoms in later stages of perceived stress.[57] In this regard, exposures to nature may be more beneficial for adolescents with milder symptoms, and who are in the earlier stages of the stress process rather than for those who experience the most stress.

The observed differences in associations between outdoor play and psychosomatic symptoms between boys and girls are consistent with several past studies conducted with samples of children and adults.[58–61] The amount of green space surrounding homes has been associated with cognitive benefits for female children only; this difference attributed to males playing farther away from homes than females.[61] Our findings tell a similar story, and suggest that even when time spent playing outdoors is measured more directly, no relationship is observed with psychosomatic symptoms among male adolescents. Sex differences in the expression of poor mental health are one likely explanation of this finding. In general, females tend to report and be diagnosed with higher rates of mood and anxiety disorders while males show higher rates of antisocial disorders.[62] Among other influences, the attribution of these sex differences to different average standings on internalizing and externalizing dimensions of emotional expression has garnered substantial support.[62] Thus, it is possible that the findings would have been different if an externalizing measure such as antisocial or risky behaviour had been used, as this type of measure may provide a better indication of poor mental health among male adolescents. In addition to a tendency to internalize, excesses in symptoms among females have also

been attributed to a stronger female disposition to attend to bodily cues and a greater willingness to report perceived symptoms to others.[63,64] Past research has also suggested that certain aspects of males' tendency to externalize may actually protect adolescent boys against developing some of the symptoms included in the psychological dimension of the scale.[65] For these reasons, the use of different cut-off values for males and females to be classified as having high psychosomatic symptoms may be warranted.

Strengths and Limitations

One of the main strengths of this study was that it simultaneously considered both the usage of outdoor space and subjective feelings of connectedness to nature in a series of novel analyses. Many past studies[7–12] have used geographic measures to indicate the amount of natural space in the area surrounding participants' homes or schools, which does not take usage of and feelings towards nature into account. Measures used in this study are more likely sensitive to the lived experiences of young people, who use and perceive nature differently from adults and who may be subject to parental control of their decision making on where, when, and how they interact with the outdoors, regardless of the amount of natural space in the surrounding area. Because of its large sample size, the study also had sufficient power to identify existing associations and controlled for many important confounders, which has been a limitation of previous studies on the topic.

Since outdoor activity or connections to nature may be considered desirable, respondents may have overestimated their participation when answering these survey items. This may have resulted in bias in the form of underestimation of observed effect estimates, assuming social desirability of these items would not differ by presence of psychosomatic symptoms. Additionally, recalled measures are

prone to error, which can alter the likelihood of identifying associations. Because cross-sectional designs measure both the exposure and outcome at a single time point, these designs do not allow for confirmation of temporality, and therefore, causality. The resulting vulnerability of cross-sectional designs to reverse causality is a particular problem in this situation as it is plausible that poor emotional health among adolescents may impact their usage of and feelings towards the outdoors. With this being said, for studies of nature and health, commonly cited theoretical frameworks[56,66–74] do support considering stress, mood, and other components of mental health as the outcome, and both experimental and longitudinal observational designs pose their own challenges. Measuring and controlling for important covariates have been identified as a methodological gap in past research on nature and mental health. Though we attempted to control for most potential confounders, there are likely other factors that contribute to the risk of poor mental health, such as having a history of mental illness, which were not measured on the HBSC.[75]

3.6 Conclusion

Implications

This is not the first study to conclude that exposure to nature may constitute an effective strategy for preventing symptoms of poor mental health at the population level;[54,76,77] nonetheless, this study adds evidence on the unique experiences of young people. Increased participation in outdoor activities during childhood and adolescence has been found to increase the likelihood of making longer and more frequent visits to green spaces in adulthood. On the contrary, low levels of contact with nature during this critical developmental window have been shown to track across the life course, and have a detrimental effect on future health and well-being.[68,78–80] For female adolescents, spending time outdoors

may constitute an affordable and widely accessible way to promote mental well-being and prevent mental ill health. For all adolescents, nature contact may promote mental well-being through its positive effect on nature connectedness.[81–83] Strategies that aim to foster this intricate link between spending time in nature and feeling a sense of connection with nature may prove particularly beneficial. To ensure success of these strategies, it will be crucial to address current barriers to young people playing outdoors, including parental and personal safety concerns (especially for females) and dependence on indoor activities involving technology.[84]

Future Research Directions

There are several ways in which future studies may help to clarify the roles of outdoor play and connectedness to nature in adolescent mental health. These exposures are thought to impact the lives of adolescents in a variety of ways and the pathways underlying these relationships are varied and poorly understood. Based on the results, we remain unable to identify the specific mechanisms that are acting to bring about the observed effects or how long lasting the effects will be. These unanswered questions may be addressed using randomized controlled trials of nature-based interventions or longitudinal studies. Qualitative or mixed methods research would also be beneficial to identify which specific aspects of the environment influence adolescents' frequency of outdoor play and perceptions of the importance of feeling connected to nature.

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Table 1. Description of exposure variables and potential confounders and effect modifiers for full study sample and for students reporting high psychosomatic symptoms in the Canadian 2013/2014 HBSC study

	Complete Case Sample (n=20697)	High Psychosomatic Symptoms (n=5928)		
	n	n	Row% (95% CI)	P-value*
Exposure Variables				
Outdoor Play				
0 hours weekly	1775	712	40.1 (37.1,43.2)	
0.5-6.5 hours weekly	5767	1753	30.4 (28.7,32.1)	
7-13.5 hours weekly	4593	1231	26.8 (24.9,28.6)	
14-34.5 hours weekly	7018	1783	25.4 (23.9,26.8)	
≥35 hours weekly	1610	449	27.9 (24.8,31.0)	<0.0001
Connection to Nature				
Not important	1885	829	44.0 (40.8,47.2)	
Somewhat important	6682	2112	31.6 (30.0,33.3)	
Important	12196	2964	24.3 (32.2,25.3)	<0.0001
Potential Confounders and Effect Modifiers				
Sex				
Female	9821	3683	37.5 (36.3,38.7)	
Male	10942	2068	18.9 (17.7,19.8)	<0.0001
Grade				
6	2903	537	18.5 (16.7,20.2)	
7	3995	919	23.0 (21.3,24.6)	
8	4206	1140	27.1 (25.4,28.9)	
9	5060	1665	32.9 (31.1,34.7)	
10	4600	1628	35.4 (33.4,37.4)	<0.0001
Perceived Family Wealth (SES)				
Below average	1904	918	48.2 (46.0,52.0)	
Average	7130	2396	33.6 (32.1,35.1)	
Above Average	11732	2628	22.4 (21.3,23.4)	<0.0001
Ethnicity				
Canadian dominant culture	16574	4939	29.8 (28.8,30.7)	
African	643	125	19.4 (15.7,23.0)	
Arab & West Asian	359	97	27.0 (21.0,32.9)	
East & Southeast Asian	1473	379	25.7 (22.6,28.8)	
Latin American	212	61	29.0 (20.6,37.5)	

South Asian & East Indian	816	161	19.7 (16.2,23.2)	
Other	687	161	23.5 (19.0,27.8)	<0.0001
Urban-Rural Status				
1 (most rural)	825	215	26.1 (23.4,28.8)	
2	7536	2246	29.8 (28.3,31.2)	
3	4013	1112	27.7 (25.7,29.7)	
4	5233	1491	28.5 (26.9,30.1)	
5 (most urban)	3157	833	26.4 (24.6,28.2)	0.0269
School Climate				
Low	6650	3066	46.1 (44.5,47.8)	
Medium	7368	1798	24.4 (23.0,25.7)	
High	7089	1035	14.6 (13.5,15.7)	<0.0001
Neighbourhood Social Capital				
Low	6307	2523	40.0 (38.3,41.7)	
Medium	7368	1894	25.7 (24.4,27.1)	
High	7089	1460	20.6 (19.3,21.9)	<0.0001
Family Support				
Low	7055	3203	45.4 (43.8,47.1)	
Medium	6963	1532	22.0 (20.7,23.3)	
High	6746	1113	16.5 (15.3,17.8)	<0.0001
Family Communication				
Low	6399	2988	46.7 (45.0,48.3)	
Medium	7827	1863	23.8 (22.5,25.1)	
High	6538	1059	16.2 (15.0,17.4)	<0.0001
Friend Support				
Low	6961	2325	33.4 (31.9,34.9)	
Medium	7253	1857	25.6 (24.2,27.0)	
High	6550	1683	25.7 (24.3,27.2)	<0.0001

*P-value from Rao-Scott chi-square tests for significant difference in proportion with outcome (high PS) between the levels of each variable

Table 2. Results of multivariate log-binomial regression models for the association between weekly outdoor play and having high psychosomatic symptoms stratified by sex*

Outdoor Play	Unadjusted Model RR (95% CI)	Adjusted Model† RR (95% CI)
	Males (n = 10438)	
0 hours/week	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**0.62** (0.48,0.79)	0.99 (0.72,1.36)
0.5-6.5 hours/week	**0.65** (0.49,0.88)	1.07 (0.74,1.53)
7-13.5 hours/week	**0.63** (0.48,0.81)	1.01 (0.72,1.40)
14-34.5 hours/week	**0.57** (0.43,0.76)	0.92 (0.65,1.29)
≥35 hours/week	**0.68** (0.49,0.96)	1.04 (0.70,1.56)
	Females (n = 11401)	
0 hours/week	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**0.56** (0.47,0.67)	**0.76** (0.60,0.95)
0.5-6.5 hours/week	**0.59** (0.49,0.72)	**0.78** (0.61,0.99)
7-13.5 hours/week	**0.50** (0.41,0.62)	**0.69** (0.53,0.89)
14-34.5 hours/week	**0.54** (0.45,0.65)	**0.76** (0.59,0.98)
≥35 hours/week	**0.69** (0.52,0.91)	0.92 (0.64,1.33)

Note: Bold font indicates significance at $P < 0.05$

*Interaction between sex and outdoor play significant at $P < 0.05$

†Models adjusted for age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

Table 3. Results of multivariate log-binomial regression models for the association between perceived importance of nature connectedness and having high psychosomatic symptoms (n = 20697)

	Unadjusted Model	**Adjusted Model**[†]
Nature Connectedness	**RR (95% CI)**	**RR (95% CI)**
Not important	1.00 (ref)	1.00 (ref)
Somewhat important	**0.59** (0.51,0.69)	**0.79** (0.66,0.95)
Important	**0.42** (0.36,0.49)	**0.75** (0.62,0.91)

Note: Bold font indicates significance at $P < 0.05$

[†]Model adjusted for sex, age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

Supplementary Table 1. Results of multivariate log-binomial regression models for the association between weekly outdoor play (≥0.5 hours/week compared to 0 hours/week) and having individual psychosomatic symptoms greater than once a week stratified by sex*†

Symptom	Females (n=11401) RR (95% CI)	Males (n=10438) RR (95% CI)
	1.00 (ref)	1.00 (ref)
Psychological		
Feeling low/depressed	**0.72** (0.58,0.91)	**0.60** (0.42,0.86)
Irritability/bad temper	**0.72** (0.57,0.91)	0.91 (0.66,1.24)
Feeling nervous	**0.76** (0.62,0.92)	0.83 (0.62,1.13)
Difficulties in getting to sleep	**0.75** (0.60,0.92)	0.85 (0.67,1.09)
	1.00 (ref)	1.00 (ref)
Somatic		
Headache	0.95 (0.76,1.17)	0.83 (0.57,1.20)
Stomach ache	0.81 (0.62,1.07)	0.93 (0.61,1.40)
Backache	0.98 (0.76,1.25)	0.90 (0.64,1.26)
Feeling dizzy	0.91 (0.72,1.16)	0.93 (0.63,1.38)

Note: Bold font indicates significance at $P < 0.05$

Note: RRs for male adolescents differ from those presented in Table 2 due to use of different cut-off values for having single versus multiple psychosomatic symptoms

*Interaction between sex and outdoor play significant at $P < 0.05$

†Models adjusted for age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

Supplementary Table 2. Results of multivariate log-binomial regression models for the association between perceived importance of nature connectedness ('*important*' compared to '*not important*') and having individual psychosomatic symptoms greater than once a week† (n = 20697)

	Complete Case Sample
Symptom	**RR (95% CI)**
	1.00 (ref)
Psychological	
Feeling low/depressed	**0.72** (0.58,0.88)
Irritability/bad temper	**0.62** (0.52,0.74)
Feeling nervous	0.84 (0.71,1.00)
Difficulties in getting to sleep	**0.78** (0.66,0.94)
	1.00 (ref)
Somatic	
Headache	0.99 (0.81,1.21)
Stomach ache	0.98 (0.76,1.26)
Backache	0.85 (0.69,1.04)
Feeling dizzy	0.84 (0.67,1.06)

Note: Bold font indicates significance at $P < 0.05$

†Models adjusted for age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

Chapter 4: Supplementary Findings

4.1 Overview of Chapter

This chapter includes a number of supplementary findings that are complementary to the manuscript (Chapter 3). First, I present epidemiological descriptions of the outcome and exposures examined in this thesis: psychosomatic symptoms, outdoor play, and perceived importance of nature connectedness. These provide more detail that may assist in the interpretation of the main findings and in the development of targeted interventions. Second, effect estimates for the associations between each significant confounding variable and psychosomatic symptoms are presented. These are included to illustrate the strong contribution of these other factors to the occurrence of such symptoms among adolescents. Third, I present findings from two regression models that assess the relationship between the two exposure variables (outdoor play and perceived importance of nature connectedness). These are included to address the degree and nature of associations between exposures in order to assist interpretively. Fourth, findings from a sensitivity analysis that explored the impact of using sex-specific cut-offs for psychosomatic symptoms for boys and girls are provided. These findings help to clarify whether the absence of a relationship between outdoor play and psychosomatic symptoms among males was observed because of use of an inappropriate (too low) cut-off value. Lastly, results of a missing data analysis are provided in support of my decision to perform a complete case analysis.

4.2 Socio-demographic Patterns in Psychosomatic Symptoms

Table 4.1 gives a breakdown of the number and percentage of students reporting each of the eight psychosomatic symptoms at a frequency of greater than once a week. In this sample, the most prevalent symptoms were difficulties in getting to sleep (28.3%), feeling nervous (24.0%), and

irritability or bad temper (18.3%). Approximately double the proportion of females reported each symptom compared to males. Despite being experienced at much different frequencies, the most prevalent symptoms were consistent between the sexes. Among females, the most prevalent symptoms in rank order were difficulties in getting to sleep (34.0%), feeling nervous (31.6%), irritability or bad temper (23.0%), and headache (23.0%). Among males, the most prevalent symptoms in rank order were difficulties in getting to sleep (22.2%), feeling nervous (15.8%), and irritability or bad temper (13.4%).

The proportions of students experiencing high psychosomatic symptoms varied across socio-demographic groups (see also **Table 1** of the manuscript in Chapter 3). Reports of high psychosomatic symptoms were significantly associated with older age, lower SES, low school climate, low neighbourhood social capital, low family support, low family communication, and low friend support. Prevalence increased with grade/age with 18.5% of those in Grade 6 reporting high psychosomatic symptoms compared to 35.4% in Grade 10. Among respondents reporting '*below average*' SES, 48.2% had high psychosomatic symptoms compared to 22.4% in the '*above average*' group. Being in the highest category of school climate, neighbourhood social capital, family support, family communication, and friend support was associated with a lower prevalence of high psychosomatic symptoms. Adjusted RRs from the final models are provided for these associations in the next section.

Table 4.1. Prevalence of psychosomatic symptoms occurring greater than once a week among adolescents in the Canadian 2013/2014 HBSC Study, overall and by sex

	n (%)	n (%)	n (%)
Symptom	**Overall**	**Boys**	**Girls**
'*Headache*'	5053 (17.3)	1612 (11.4)	3441 (23.0)
'*Stomach ache*'	2856 (9.9)	846 (6.0)	2010 (13.5)
'*Backache*'	4106 (14.2)	1418 (10.6)	2625 (18.0)
'*Feeling low (depressed)*'	4554 (15.8)	1330 (9.5)	3224 (21.7)
'*Irritability or bad temper*'	5294 (18.3)	1886 (13.4)	3409 (23.0)
'*Feeling nervous*'	6940 (24.0)	2230 (15.8)	4711 (31.6)
'*Difficulties in getting to sleep*'	8216 (28.3)	3135 (22.2)	5081 (34.0)
'*Feeling dizzy*'	3420 (11.8)	1221 (8.7)	2199 (14.7)

4.3 Relationships between Confounders and Psychosomatic Symptoms

Table 4.2 provides the adjusted RRs for each variable that was determined to have a P-value less than 0.15 using a backwards elimination approach during the model building stage. Although the primary focus of the present study is on outdoor play and perceived importance of nature connectedness, these results are included here to underline the multifactorial nature of the development of psychosomatic symptoms during adolescence. Factors other than outdoor play and perceived importance of nature connectedness that were significantly associated with a decreased prevalence of high psychosomatic symptoms in the regression models were age, SES, ethnicity, school climate, neighbourhood social capital, family support, and family communication.

Among females, being in Grades 6, 7, and 8 was associated with a lower prevalence of having high psychosomatic symptoms compared to being in Grade 10 and the association was strongest in Grade 6 (RR: 0.42; 95% CI: 0.32, 0.54). Among males, there was no statistically significant relationship between age and psychosomatic symptoms. This finding supports the idea that psychosomatic symptoms may not be the most sensitive measure of mental health status for male adolescents. Compared to those with below average perceived family wealth, those with average perceived family wealth and above average also had a 42% to 54% (95% CI: 24%, 64%) decreased prevalence of high psychosomatic symptoms for both males and females. Of the remaining variables, high school climate compared to low was the most strongly related to high psychosomatic symptoms for both males (RR: 0.37; 95% CI: 0.30, 0.46) and females (RR: 0.31; 95% CI: 0.26, 0.38).

Table 4.2. Relative risks and 95% confidence intervals for associations between confounding variables and having high psychosomatic symptoms in multivariate log-binomial regression models stratified by sex*

Variable	Females (n=11401) RR (95% CI)†	Males (n=10438) RR (95% CI)†
Grade		
10	1.00 (ref)	1.00 (ref)
9	0.96 (0.78,1.18)	1.00 (0.76,1.31)
8	**0.61** (0.49,0.76)	1.00 (0.75,1.32)
7	**0.56** (0.45,0.76)	0.85 (0.64,1.12)
6	**0.42** (0.32,0.54)	0.85 (0.63,1.14)
Perceived Family Wealth (SES)		
Below Average	1.00 (ref)	1.00 (ref)
Average	**0.56** (0.44,0.70)	**0.58** (0.45,0.76)
Above Average	**0.48** (0.38,0.62)	**0.46** (0.36,0.59)
Ethnicity		
Canadian dominant culture	1.00 (ref)	1.00 (ref)
African	**0.50** (0.31,0.80)	**0.44** (0.28,0.71)
Arab & West Asian	0.96 (0.55,1.65)	1.03 (0.61,1.75)
East & Southeast Asian	**0.70** (0.53,0.93)	0.81 (0.56,1.19)
Latin American	0.78 (0.47,1.32)	0.87 (0.31,2.42)
South Asian & East Indian	**0.64** (0.42,0.98)	**0.61** (0.41, 0.92)
Other	0.71 (0.46,1.08)	0.90 (0.55,1.48)
Urban-Rural Status		
1 (most rural)	1.00 (ref)	1.00 (ref)
2	0.91 (0.71,1.16)	1.03 (0.73,1.45)
3	0.85 (0.65,1.12)	1.36 (0.95,1.95)
4	0.87 (0.68,1.12)	1.28 (0.90,1.81)
5 (most urban)	0.90 (0.68,1.21)	1.45 (0.98,2.16)
School Climate		
Low	1.00 (ref)	1.00 (ref)
Medium	**0.44** (0.38,0.52)	**0.49** (0.40,0.61)
High	**0.31** (0.26,0.38)	**0.37** (0.30,0.46)
Neighbourhood Social Capital		
Low	1.00 (ref)	1.00 (ref)
Medium	**0.74** (0.62,0.86)	**0.77** (0.63,0.94)
High	**0.80** (0.67,0.97)	**0.80** (0.64,1.01)
Family Support		
Low	1.00 (ref)	1.00 (ref)

Medium	**0.54** (0.45,0.65)	**0.64** (0.52,0.79)
High	**0.50** (0.39,0.65)	**0.75** (0.58,0.97)
Family Communication		
Low	1.00 (ref)	1.00 (ref)
Medium	**0.67** (0.56,0.80)	**0.62** (0.51,0.76)
High	**0.51** (0.48,0.77)	**0.50** (0.39,0.65)

Note: Bold font indicates significance at $P < 0.05$

*****Interaction between sex and outdoor play significant at $P < 0.05$

[†]Models adjusted for outdoor play, perceived importance of nature connectedness, age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

4.4 Socio-demographic Patterns in Outdoor Play

Table 4.3 provides an epidemiological profile describing the number and percentage of HBSC respondents reporting different amounts of outdoor play. Findings are stratified by weekdays versus weekends. In general, higher amounts of outdoor play were reported on weekends than on weekdays. This can likely be attributed to the fact that weekday school attendance limits the number of hours on weekdays that are available to spend playing outdoors and the question specifically inquired about time "outside school hours".

Although the vast majority of the sample reported some outdoor play, 15.0% reported no time spent playing outdoors on the average weekday, 10.8% reported none on weekends, and 8.9% reported none on either weekdays or weekends. This finding is consistent with a previous study on the prevalence of outdoor play among children aged 3 to 12 living in the United States, which found that approximately 10% participated in outdoor activities once a week or less often.[1] In terms of geographic trends, larger proportions of the students in the HBSC sample from the most urban areas reported spending no time playing outdoors in the average week (12.4% compared with 5.6% in the most rural areas).

With respect to the highest level of outdoor play (greater than or equal to 7 hours/day), only 4.0% reported this on weekdays and 9.4% reported this on weekends. Since it is possible (albeit unlikely) that children have the ability to play outside for 7 or hours or more on weekdays during the school year, these prevalence values may indicate that at least some of these responses were misclassified or respondents put greater weight on time spent outdoors during the summer than during the school year. Misclassification may also contribute to the explanation of why the observed

relationship between outdoor play and psychosomatic symptoms did not hold for the highest level of exposure (Chapter 3).

Table 4.3. Prevalence of daily outdoor play among adolescents in the Canadian 2013/2014 HBSC study

	n (%)	n (%)
Frequency	**Weekdays**	**Weekends**
'*None at all*'	4076 (15.0)	2908 (10.8)
'*Half an hour*'	4301 (15.8)	2795 (10.3)
'*1 hour*'	6014 (22.1)	3907 (14.5)
'*2 hours*'	5095 (18.7)	4663 (17.2)
'*3 hours*'	3024 (11.1)	3644 (13.5)
'*4 hours*'	1933 (7.1)	3042 (11.2)
'*5 hours*'	1093 (4.2)	2147 (7.9)
'*6 hours*'	604 (2.2)	1406 (5.2)
'*7 hours or more'*	1079 (4.0)	2528 (9.4)

Table 4.4 profiles selected characteristics of HBSC respondents reporting the extremes of outdoors play (none at all and the highest quartile). Notable differences occur by sex, age, SES, ethnicity, urban-rural status, school climate, neighbourhood social capital, family support, family communication, and friend support. Among males, 29.6% were in the highest quartile of time spent playing outdoors while 20.6% of females reported this level of outdoor play. In contrast, there was no difference between the proportions of males (9.2%) and females (8.6%) reporting no outdoor play. The proportion of students reporting no outdoor play increased significantly with grade/age from 4.3% of those in Grade 6 to 12.5% of those in Grade 12. An opposite trend was observed for the proportion falling in the highest quartile of outdoor play. The proportion of students reporting no outdoor play significantly declined with increasing SES with 11.5% of those in the '*below average*' category compared to 7.5% of those in the '*above average'* category. A similar significant decreasing trend was seen for urban-rural status from 12.4% reporting no outdoor play in the most urban areas to 5.6% reporting no outdoor play in the most rural areas. School climate, neighbourhood social capital, family support, family communication, and friend support also showed decreasing trends with a lower proportion of those in the lowest category for each of these variables reporting no outdoor play compared to the highest category.

Table 4.4. Description of students reporting no weekly outdoor play and highest quartile of weekly outdoor play (≥23 hours/week) in the Canadian 2013/2014 HBSC study

	No Outdoor Play (n = 1845)		High Outdoor Play (n = 5262)	
	n (Row %)	**P-value***	**n (Row %)**	**P-value†**
Sex				
Female (n = 9821)	904 (9.2)		2023 (20.6)	
Male (n = 10942)	941 (8.6)	0.24	3239 (29.6)	<0.0001
Grade				
6 (n = 2903)	125 (4.3)		833 (28.7)	
7 (n = 3995)	260 (6.5)		1111 (27.8)	
8 (n = 4206)	303 (7.2)		1039 (24.7)	
9 (n = 5060)	582 (11.5)		1194 (23.6)	
10 (n = 4600)	575 (12.5)	<0.0001	989 (21.5)	<0.0001
Perceived Family Wealth (SES)				
Below average (n = 1904)	219 (11.5)		499 (26.2)	
Average (n = 7130)	763 (10.7)		1654 (23.2)	
Above Average (n = 11732)	880 (7.5)	<0.0001	3015 (25.7)	0.01
Ethnicity				
Canadian dominant culture (n = 16574)	1293 (7.8)		4260 (25.7)	
African (n = 643)	84 (13.0)		185 (28.7)	
Arab & West Asian (n = 359)	52 (14.4)		85 (23.6)	
East & Southeast Asian (n = 1473)	230 (15.6)		273 (18.5)	
Latin American (n = 212)	27 (12.9)		44 (20.7)	
South Asian & East Indian (n = 816)	101 (12.4)		149 (18.2)	
Other (n = 687)	67 (9.7)	<0.0001	185 (27.0)	<0.0001
Urban-Rural Status				
1 (most rural) (n = 825)	46 (5.6)		238 (28.9)	
2 (n = 7536)	625 (8.3)		2042 (27.1)	
3 (n = 4013)	309 (7.7)		1112 (27.7)	
4 (n = 5233)	481 (9.2)		1120 (21.4)	
5 (most urban) (n = 3157)	391 (12.4)	<0.0001	657 (20.8)	<0.0001
School Climate				
Low (n = 6650)	798 (12.0)		1769 (26.6)	
Medium (n = 7368)	589 (8.0)		1783 (24.2)	
High (n = 7089)	475 (6.7)	<0.0001	1708 (24.1)	0.02
Neighbourhood Social Capital				
Low (n = 6307)	908 (14.4)		1280 (20.3)	
Medium (n = 7368)	553 (7.5)		1805 (24.5)	

High (n = 7089)	376 (5.3)	<0.0001	2098 (29.6)	<0.0001
Family Support				
Low (n = 7055)	910 (12.9)		1573 (22.3)	
Medium (n = 6963)	487 (7.0)		1643 (23.6)	
High (n = 6746)	438 (6.5)	<0.0001	1943 (28.8)	<0.0001
Family Communication				
Low (n = 6399)	832 (13.0)		1427 (22.3)	
Medium (n = 7827)	603 (7.7)		1878 (24.0)	
High (n = 6538)	405 (6.2)	<0.0001	1857 (28.4)	<0.0001
Friend Support				
Low (n = 6961)	835 (12.0)		1531 (22.0)	
Medium (n = 7253)	558 (7.7)		1704 (23.5)	
High (n = 6550)	459 (7.0)	<0.0001	1919 (29.3)	<0.0001

*P-value from Rao-Scott chi-square tests for significant difference in proportion with no exposure between the levels of each variable

†P-value from Rao-Scott chi-square tests for significant difference in proportion with high exposure between the levels of each variable

4.5 Socio-demographic Patterns in Perceived Importance of Nature Connectedness

Table 4.5 describes the proportions of students within different socio-demographic groups placing the lowest and highest levels of importance on feeling connected to nature. The observed patterns were similar to those reported for outdoor play. There were several exceptions to this general observation, however. Differences observed between the sexes were the opposite for perceived importance of nature connectedness compared to outdoor play. While more males reported the highest level of outdoor play, more females reported the highest level of importance on feeling connected to nature (61.0% compared to 57.4% of males). Contrary to the urban-rural geographic trend observed for outdoor play, there were no significant differences in the proportion of students rating connection to nature as '*not important*' based on whether they lived in an urban or rural area.

Consistent with the age trend observed for outdoor play, the proportion of students reporting that connection to nature was '*not important*' increased significantly with grade/age from 5.3% of those in Grade 6 to 12.1% of those in Grade 12. The proportion of students placing the lowest importance on connectedness to nature significantly decreased with increasing perceived family wealth with 14.1% in the '*below average*' category compared to 7.9% in the '*above average*' category. Proportions of students reporting the lowest level of importance also decreased for increases in school climate, neighbourhood social capital, family support, family communication, and friend support.

Table 4.5. Description of students classifying connection to nature as '*not important*' and '*important*' in the Canadian 2013/2014 HBSC study

	'*Not Important*' (n = 1948)		**'*Important*' (n = 12250)**	
	n (Row %)	**P-value***	**n (Row %)**	**P-value†**
Sex				
Female (n = 9821)	854 (8.7)		5991 (61.0)	
Male (n = 10942)	1094 (10.0)	0.02	6259 (57.2)	<0.0001
Grade				
6 (n = 2903)	154 (5.3)		2154 (74.2)	
7 (n = 3995)	296 (7.4)		2661 (66.6)	
8 (n = 4206)	370 (8.8)		2528 (60.1)	
9 (n = 5060)	587 (11.6)		2641 (52.2)	
10 (n = 4600)	557 (12.1)	<0.0001	2314 (50.3)	<0.0001
Perceived Family Wealth (SES)				
Below average (n = 1904)	268 (14.1)		1043 (54.8)	
Average (n = 7130)	749 (10.5)		3907 (54.8)	
Above Average (n = 11732)	927 (7.9)	<0.0001	7309 (62.3)	<0.0001
Ethnicity				
Canadian dominant culture (n = 16574)	1575 (9.5)		9729 (58.7)	
African (n = 643)	87 (13.5)		337 (52.4)	
Arab & West Asian (n = 359)	43 (12.1)		209 (58.3)	
East & Southeast Asian (n = 1473)	85 (5.8)		918 (62.3)	
Latin American (n = 212)	27 (12.6)		103 (48.6)	
South Asian & East Indian (n = 816)	60 (7.4)		533 (65.3)	
Other (n = 687)	55 (8.0)	<0.001	442 (64.4)	<0.0001
Urban-Rural Status				
1 (most rural) (n = 825)	64 (7.8)		513 (62.2)	
2 (n = 7536)	716 (9.5)		4341 (57.6)	
3 (n = 4013)	349 (8.7)		2524 (62.9)	
4 (n = 5233)	529 (10.1)		3030 (57.9)	
5 (most urban) (n = 3157)	278 (8.8)	0.23	1885 (59.7)	0.0001
School Climate				
Low (n = 6650)	1039 (15.7)		3185 (47.9)	
Medium (n = 7368)	560 (7.6)		4229 (57.4)	
High (n = 7089)	340 (4.8)	<0.0001	5132 (72.4)	<0.0001
Neighbourhood Social Capital				
Low (n = 6307)	908 (14.4)		3109 (49.3)	
Medium (n = 7368)	560 (7.6)		4303 (58.4)	

High (n = 7089)	447 (6.3)	<0.0001	4877 (68.8)	<0.0001
Family Support				
Low (n = 7055)	1357 (15.2)		3266 (46.3)	
Medium (n = 6963)	623 (7.3)		4122 (59.2)	
High (n = 6746)	418 (5.0)	<0.0001	4918 (72.9)	<0.0001
Family Communication				
Low (n = 6399)	973 (15.2)		2976 (46.5)	
Medium (n = 7827)	618 (7.9)		4563 (58.3)	
High (n = 6538)	327 (5.0)	<0.0001	4727 (72.3)	<0.0001
Friend Support				
Low (n = 6961)	842 (12.1)		3648 (52.4)	
Medium (n = 7253)	617 (8.5)		4243 (58.5)	
High (n = 6550)	478 (7.3)	<0.0001	4402 (67.2)	<0.0001

*P-value from Rao-Scott chi-square tests for significant difference in proportion with low exposure between the levels of each variable

†P-value from Rao-Scott chi-square tests for significant difference in proportion with high exposure between the levels of each variable

4.6 Relationships between Outdoor Play and Perceived Importance of Nature Connectedness

In a supplementary analysis, we explored the relationship between responses to the outdoor play and perceived importance of nature connectedness questions. Despite being examined as two separate exposure variables in this thesis, outdoor play and nature connectedness are known to relate to each other in a complex manner.[2,3] **Tables 4.6** and **4.7** show the findings from log-binomial regression models quantifying associations between the two exposure variables.

Playing outdoors was significantly associated with rating connectedness to nature as being '*important*'. Increasing amounts of weekly outdoor play corresponded to an increased likelihood of subjective evaluation of nature connectedness as being important. Compared to a referent group of those who reported no time outdoors in the average week, students who spent at least half an hour outdoors each week were 1.57 (95% CI: 1.35, 1.83) times more likely to place importance on connectedness to nature while those in the highest category (≥35 hours/week) were 2.29 (95% CI: 1.83, 2.85) times more likely to express this level of importance. Similarly, related to a referent group who rated connectedness to nature as '*not important*', participants who rated it as being '*somewhat important*' were 1.50 (95% CI: 1.18, 1.90) times more likely to spend at least half an hour outdoors each week while those who evaluated it as '*important*' were 2.18 (95% CI: 1.71, 2.79) times more likely to do so.

Table 4.6. Results of multivariate log-binomial regression models for the association between outdoor play and subjective evaluation of nature connectedness as '*important*' (n = 20697)

Outdoor Play	Unadjusted Model RR (95% CI)	Adjusted Model† RR (95% CI)
0 hours/week	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**1.90** (1.68, 2.16)	**1.57** (1.35,1.82)
0.5-6.5 hours/week	**1.55** (1.35,1.79)	**1.27** (1.07,1.49)
7-13.5 hours/week	**1.91** (1.65,2.20)	**1.55** (1.31,1.84)
14-34.5 hours/week	**2.13** (1.86,2.45)	**1.81** (1.53,2.14)
≥35 hours/week	**2.61** (2.15,3.18)	**2.29** (1.83,2.85)

Note: Bold font indicates significance at $P < 0.05$

†Model adjusted for sex, age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

Table 4.7. Results of multivariate log-binomial regression models for the association between subjective evaluation of the importance of nature connectedness and ≥0.5 hours weekly outdoor play (n = 20697)

Nature Connectedness	Unadjusted Model RR (95% CI)	Adjusted Model[†] RR (95% CI)
Not important	1.00 (ref)	1.00 (ref)
Somewhat important	**1.80** (1.46,2.22)	**1.50** (1.18,1.90)
Important	**2.95** (2.40,3.64)	**2.18** (1.71,2.79)

Note: Bold font indicates significance at $P < 0.05$

[†]Model adjusted for sex, age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

4.7 Sensitivity Analyses

4.7.1 Sex-Specific Cut-Off Values for Psychosomatic Symptoms

As discussed in the manuscript in Chapter 3, there may be sex differences in the reporting of health complaints, whereby females may experience these symptoms at higher rates and have a lower threshold for recognizing such complaints, bringing them to the attention of others, or reporting them in surveys.[4] The cut-off value that was used in the present study (total score of 8 to 28) classified 37.5% of female respondents as having high psychosomatic symptoms compared to 18.9% of males.

Table 4.8 shows the results when the cut-off for psychosomatic symptoms is increased for males such that approximately 38% are classified as having high psychosomatic symptoms (total score of 8 to 32). Even with this reclassification, there was no statistically significant relationship between outdoor play and psychosomatic symptoms. However, the association was stronger with the adjusted RR decreasing from 0.99 (95% CI: 0.72, 1.36) with the old cut-off to 0.85 (95% CI: 0.68, 1.06) with the new cut-off. This indicates that the use of sex-specific cut-off values may be justified in future research.

Table 4.8. Results of multivariate log-binomial regression models for the association between weekly outdoor play and having high psychosomatic symptoms among male adolescents comparing old cut-off for psychosomatic symptoms to new cut-off

Outdoor Play	Unadjusted Model RR (95% CI)	Adjusted Model[†] RR (95% CI)
	Males; Old Psychosomatic Symptoms Cut-Off (n = 10438)	
0 hours/week	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**0.62** (0.48,0.79)	0.99 (0.72,1.36)
0.5-6.5 hours/week	**0.65** (0.49,0.88)	1.07 (0.74,1.53)
7-13.5 hours/week	**0.63** (0.48,0.81)	1.01 (0.72,1.40)
14-34.5 hours/week	**0.57** (0.43,0.76)	0.92 (0.65,1.29)
≥35 hours/week	**0.68** (0.49,0.96)	1.04 (0.70,1.56)
	Males; New Psychosomatic Symptoms Cut-Off (n = 10438)	
0 hours/week	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**0.62** (0.52,0.74)	0.85 (0.68,1.06)
0.5-6.5 hours/week	**0.65** (0.54,0.80)	0.86 (0.68,1.10)
7-13.5 hours/week	**0.62** (0.51,0.76)	0.84 (0.65,1.07)
14-34.5 hours/week	**0.59** (0.49,0.72)	0.82 (0.64,1.06)
≥35 hours/week	**0.64** (0.52,0.80)	0.92 (0.69,1.22)

Note: Bold font indicates significance at $P < 0.05$

*Interaction between sex and outdoor play significant at $P < 0.05$

[†]Models adjusted for age, ethnicity, SES, school climate, family support, family communication, neighbourhood social capital, urban-rural status, and classroom-level clustering

4.7.2 Missing Data

In models to assess the potential impact of missing data, the most extreme scenarios were assumed in which all missing data fell into either the lowest category or highest category for each exposure and outcome. In reality, such scenarios are unlikely to be true since when outcome data were known but exposure data were missing, the proportions of respondents who were classified as having high psychosomatic symptoms remained similar. In the complete case sample, 28.5% had high psychosomatic symptoms. For those missing outdoor play exposure data and who were not missing psychosomatic symptoms data (n = 2610), 26.7% had high psychosomatic symptoms. For those missing nature connectedness data but not psychosomatic symptoms data (n = 2567), 27.9% had high psychosomatic symptoms. Furthermore, relatively few individuals were missing both outdoor play and psychosomatic symptoms data (n = 706; 2.3%) or nature connectedness and psychosomatic symptoms data (n = 653; 2.2%) or all three (n = 521; 1.7%).

The results of the missing data analyses are provided in **Tables 4.9a-c**. Models 1 to 4 represent the different combinations of lowest and highest exposure and outcome categories. On the whole, the RRs from these four models fell within the 95% confidence intervals from the original complete case analysis. This indicates that the impact of excluding those with missing data was minor.

Table 4.9a. Results of multivariate log-binomial regression models assuming the most extreme missing data scenarios for ever versus never outdoor play categorization

Outdoor Play	Complete Case Analysis	Model 1	Model 2	Model 3	Model 4
	Full Sample (n = 20697 (Complete Case); n = 23967 (Models 1-4))				
0 hours/week	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	0.85 (0.71,1.02)	**0.81** (0.69,0.96)	0.87 (0.76,1.00)	0.90 (0.76,1.08)	0.97 (0.84,1.13)
	Males (n = 10438 (Complete Case); n = 11482 (Models 1-4))				
0 hours/week	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	0.99 (0.72,1.36)	0.88 (0.67,1.16)	0.97 (0.79,1.21)	1.06 (0.77,1.46)	1.19 (0.92,1.53)
	Females (n = 11401 (Complete Case); n = 12485 (Models 1-4))				
0 hours/week	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
≥0.5 hours/week	**0.76** (0.60,0.95)	**0.74** (0.60,0.91)	**0.78** (0.66,0.92)	0.80 (0.64,1.00)	0.85 (0.71,1.02)

Model 1: assume outdoor play ≥0.5 hours/week and high psychosomatic symptoms when missing
Model 2: assume outdoor play 0 hours/week and high psychosomatic symptoms when missing
Model 3: assume outdoor play ≥0.5 hours/week and low psychosomatic symptoms when missing
Model 4: assume outdoor play 0 hours/week and low psychosomatic symptoms when missing

Table 4.9b. Results of multivariate log-binomial regression models assuming the most extreme missing data scenarios for five-level outdoor play categorization

Outdoor Play (hours/week)	Complete Case Analysis	Model 1	Model 2	Model 3	Model 4
	Full Sample (n = 20697 (Complete Case); n = 23967 (Models 1-4))				
0	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
0.5-6.5	0.89 (0.72,1.10)	0.85 (0.70,1.03)	0.82 (0.63,1.07)	0.94 (0.76,1.15)	0.81 (0.61,1.06)
7-13.5	**0.81** (0.66,0.99)	**0.77** (0.63,0.92)	0.85 (0.70,1.03)	0.87 (0.71,1.06)	0.94 (0.76,1.15)
14-34.5	0.83 (0.68,1.00)	**0.78** (0.65,0.94)	**0.77** (0.63,0.92)	0.89 (0.73,1.07)	0.87 (0.71,1.07)
≥35	0.94 (0.73,1.21)	0.88 (0.72,1.06)	**0.79** (0.65,0.94)	0.92 (0.75,1.14)	0.89 (0.73,1.08)
	Males (n = 10438 (Complete Case); n = 11482 (Models 1-4))				
0	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
0.5-6.5	1.07 (0.74,1.53)	0.97 (0.71,1.33)	0.77 (0.52,1.13)	1.14 (0.80,1.63)	0.75 (0.47,1.18)
7-13.5	1.01 (0.72,1.40)	0.86 (0.65,1.16)	0.97 (0.71,1.33)	1.10 (0.79,1.55)	1.14 (0.80,1.63)
14-34.5	0.92 (0.65,1.29)	0.83 (0.62,1.12)	0.86 (0.65,1.16)	1.00 (0.71,1.41)	1.11 (0.79,1.56)
≥35	1.04 (0.70,1.56)	0.89 (0.65,1.20)	0.83 (0.62,1.12)	1.00 (0.69,1.45)	1.01 (0.72,1.42)
	Females (n = 11401 (Complete Case); n = 12485 (Models 1-4))				
0	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
0.5-6.5	**0.78** (0.61,0.99)	**0.75** (0.60,0.94)	0.85 (0.61,1.20)	0.82 (0.64,1.04)	0.83 (0.58,1.18)
7-13.5	**0.69** (0.53,0.89)	**0.68** (0.52,0.86)	**0.76** (0.60,0.94)	**0.74** (0.57,0.94)	0.81 (0.64,1.04)
14-34.5	**0.76** (0.59,0.98)	**0.74** (0.59,0.93)	**0.68** (0.54,0.86)	0.81 (0.64,1.03)	**0.74** (0.57,0.94)
≥35	0.92 (0.64,1.33)	0.89 (0.67,1.18)	**0.74** (0.59,0.93)	0.89 (0.66,1.19)	0.81 (0.64,1.03)

Model 1: assume outdoor play ≥35 hours/week and high psychosomatic symptoms when missing
Model 2: assume outdoor play 0 hours/week and high psychosomatic symptoms when missing
Model 3: assume outdoor play ≥35 hours/week and low psychosomatic symptoms when missing
Model 4: assume outdoor play 0 hours/week and low psychosomatic symptoms when missing

Table 4.9c. Results of multivariate log-binomial regression models assuming the most extreme missing data scenarios for perceived importance of nature connectedness

Nature Connectedness	Complete Case Analysis	Model 1	Model 2	Model 3	Model 4
	Full Sample (n = 20697 (Complete Case); n = 23967 (Models 1-4))				
Not important	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Somewhat important	**0.79** (0.66,0.95)	**0.78** (0.66,0.92)	**0.81** (0.71,0.93)	**0.83** (0.69,0.99)	1.02 (0.92,1.14)
Important	**0.75** (0.62,0.91)	**0.77** (0.65,0.92)	**0.80** (0.69,0.92)	**0.78** (0.65,0.94)	1.11 (0.90,1.37)

Model 1: assume connectedness to nature '*important*' and high psychosomatic symptoms when missing
Model 2: assume connectedness to nature '*not important*' and high psychosomatic symptoms when missing
Model 3: assume connectedness to nature '*important*' and low psychosomatic symptoms when missing
Model 4: assume connectedness to nature '*not important*' and low psychosomatic symptoms when missing

4.8 Synopsis of Chapter

This chapter first provided an epidemiological profile of psychosomatic symptoms, outdoor play, and perceived importance of nature connectedness according to various socio-demographic variables. Each of these key variables were found to be associated with grade/age, perceived family wealth, neighbourhood social capital, school climate, family communication, and family support. This suggests that studies of psychosomatic symptoms should account for variations in prevalence that occur socio-demographically and provides evidence in support of targeted interventions. Similar arguments can be made for studies of the outdoor play and perceived importance of connectedness to nature.

Using the models developed to address the main objectives, the RRs for each statistically significant confounder in relation to reporting high psychosomatic symptoms were also provided. For both males and females, the strongest relationships with psychosomatic symptoms were observed for school climate and perceived family wealth. These effect estimates help to demonstrate the multifactorial nature of the development of psychosomatic symptoms and show that there are similarities between boys and girls for some factors.

Next, results from regression models for the relationships between outdoor play and perceived importance of nature connectedness were presented. Higher levels of outdoor play were associated with an increased likelihood of perceiving connection to nature as '*important*' and likewise, placing increasing importance on connection to nature was associated with increased outdoor play. This is suggestive of an interplay between the two exposure variables in this study.

The last section included findings from two sensitivity analyses. The first involved the use of a sex-specific cut-off value for psychosomatic symptoms. Here, it was observed that the strength of the

association between outdoor play and psychosomatic symptoms increased but did not reach statistical significance when a higher cut-off value was used for males. This suggests that the use of a cut-off value that was too low for males may have contributed to the observed sex differences in this association. Lastly, missing data analyses showed that the impact of excluding those with missing data was minimal and the complete case analyses employed in this thesis were therefore appropriate.

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Chapter 5: General Discussion

5.1 Summary of Findings

This thesis focused on the exploration then quantification of associations between outdoor play, perceived importance of nature connectedness, and the occurrence psychosomatic symptoms in young Canadians. It was also determined whether any identified associations differed by sex and/or age. The most important findings first included the identification of a strong and statistically significant relationship between playing outdoors and decreased prevalence of psychosomatic symptoms among females, and second, the identification of a similarly strong and significant relationship between perceived importance of nature connectedness and psychosomatic symptoms among both males and females.

In supplemental analyses, each of the exposure and outcomes variables was described according to a number of socio-demographic factors. Patterns in psychosomatic symptoms, outdoor play, and perceived importance of nature connectedness were observed by factors including perceived family wealth, school climate, and family support. The two exposure measures, outdoor play and perceived importance of nature connectedness, were found to be significantly related to each other in adjusted models. Sensitivity analyses explored the influence of the use of a lower cut-off value for psychosomatic symptoms among males, as well as the minimal potential impact of missing data on the main observed effects.

5.2 Internal Validity

This section addresses issues relating to sample selection, measurement of key variables, and confounding.

Selection Bias: Regarding selection, bias would have occurred only if students who did not participate in the survey (e.g., for reasons such as school absenteeism, non-consent, literacy, etc.) differed according to both exposure and outcome status. For example, if adolescents with the most psychosomatic symptoms were more likely to be absent from school on the day of survey administration, they would have had a decreased likelihood of being included in the study. If having high psychosomatic symptoms was in turn related to the likelihood of playing outdoors or feeling connected to nature, the resulting RRs could be overestimated (if more likely) or underestimated (if less likely). Differences in likelihood of being included based on the exposures or outcome would also affect the representativeness of prevalence values from descriptive analyses.

Information Bias: This thesis relied on self-report data from a sample of adolescents, and self-reported data, especially from young people, will involve some degree of error and bias. Students may have difficulties recalling past events accurately, as was required for both the outdoor play and psychosomatic symptoms items. This recall error would have only biased effect estimates away from the null if students with more psychosomatic symptoms were more or less likely to recall being exposed compared to those with fewer symptoms. Assuming this was not the case, recall error could have resulted in non-differential misclassification, biasing the effect estimates towards the null.

Since outdoor activity and/or connections to nature may be considered desirable qualities by some, respondents could have overestimated their time spent outdoors or positive feelings toward nature

when answering these survey items. This would be a form of social desirability bias. With respect to the outdoor play question, there also may have been interpretation issues where students had difficulties determining their average time spent outdoors on weekends and weekdays, as mentioned in Chapter 4. Misclassification of exposure variables has potential to bias observed effect estimates in either direction if this over- or underestimation was also related to participants' psychosomatic symptoms. If unrelated to psychosomatic symptoms, the observed effect estimates would have been biased towards the null due to non-differential misclassification.

Confounding: While other studies have adjusted for various confounding variables without considering how these factors may also modify or mediate the associations being tested,[1–4] we tried to avoid adjusting for potential mediators identified during the literature review. When a mediator is incorrectly included as a confounder in regression models, the assumptions of confounding are violated and collinearity issues may occur. Further, we considered differences in effects across sub-groups by testing sex and age as effect modifiers. We also attempted to control for many important confounding variables, which has been a limitation in previous studies on the topic. Several potentially important confounders were not measured on the HBSC, including prior mental health and family history of mental illness, which are strong determinants of current mental health, and parental perceptions of the outdoors, which may influence how adolescents use and perceive these spaces. Lack of adjustment for these confounding variables may have resulted in uncontrolled confounding, affecting the accuracy of effect estimates derived from the regression models. Residual confounding is also likely to have occurred to some extent because of imprecise measurement of key confounders inherent to the use of self-report and recall data. Other factors that are known determinants of adolescent mental health such as

early puberty and religion were not included in the analysis because they were unlikely to be related to the exposure variables.

5.3 Chance

This thesis was well-powered to identify existing associations both for the full sample and within sex and age strata. More information on the approach and calculations used to determine study power can be found in **Appendix C**. For the association between outdoor play and high psychosomatic symptoms, we had sufficient statistical power to detect a protective RR of 0.86 or stronger for boys and 0.91 or stronger for girls, while accounting for the clustered nature of the sample. For the association between perceived importance of nature connectedness and high psychosomatic symptoms, the minimum detectable RR was 0.84 for boys and 0.89 for girls. Statistical corrections for multiple comparisons were not performed, which raises the possibility that some statistically significant associations may have been observed due to Type I errors and associated chance.

5.4 External Validity

This section discusses the generalizability of the observed relationships between outdoor play and psychosomatic symptoms in females and between perceived importance of nature connectedness and psychosomatic symptoms in both male and female adolescents. In terms of what to generalize from this study, it is my intention to generalize, qualitatively, the possibility of a causal association between exposures to nature and the minimization of psychosomatic symptoms among young people, and not the exact size of the risk estimates that were identified. HBSC uses a large sample that is considered to be representative of Canadian adolescents aged 11 to 15, hence this property of the study fosters generalizability to other Canadians in this age range.

Generalizability may be limited to geographic areas with similar climates and natural environments to Canada[5] as differences in sunlight exposure and seasons may impact both psychological well-being and outdoor activity routines. Inclement weather conditions may attenuate relationships that can be identified during other seasons.[6] Little is known about how experiences in snow-covered spaces may compare to those in green spaces, so it is possible that relationships may differ in places with shorter or longer average snowy seasons than Canada. On the other hand, positive associations between time spent outdoors and mental health were found to occur independently of climate in a study of adults across four European cities with differing climates.[7]

Lastly, since experiences during the developmental stage of adolescence are often distinct from experiences in other stages of development, the findings of this study may not be generalizable to age groups falling outside the range included. Although there were no significant differences in the observed relationships within the narrow age range included, it remains likely that these relationships operate differently for younger and older age groups.

5.5 Causality

Because cross-sectional designs measure both the exposure and outcome at a single time point, these designs typically do not allow for confirmation of temporality, and therefore, causality. The resulting vulnerability of cross-sectional designs to reverse causality is a particular problem in this study as it is plausible that the occurrence of high psychosomatic symptoms among adolescents may impact their usage of and feelings towards the outdoors. For example, children with the poorest mental health may struggle to find enjoyment in nature and place importance on it, affecting the way that they respond to the nature-related questions. While the outcome measure asked students to report frequency of

psychosomatic symptoms occurring in the most recent six months, the exposure measures did not require students to report on a specific time period prior to this outcome. The outdoor play item required students to estimate how much time they spend playing outdoors on the average weekday or weekend day and the nature connectedness item asked how much importance students place on feeling connected to nature at the time of the survey. Thus, it is possible that the outcome of high psychosomatic symptoms may have preceded outdoor play or placing importance on feeling connected to nature rather than the exposures preceding the outcome and contributing to a lower symptom prevalence. One past study that explored the potential bi-directionality of the relationship found that the strength of the path between average time spent on nature-based recreation and emotional well-being was significantly higher than in the reverse model, but added that a longitudinal study design would be necessary to elucidate the direction of the relationship and causality.[8] With this being said, for studies of nature and health, both experimental and longitudinal observational designs pose their own challenges, such as an increased requirement for time and resources. Experimental study designs may also be subject to potential difficulties with randomizing children's exposure to the outdoors and problems with loss to follow-up may occur when longitudinal designs are employed.

In addition to temporality, other criteria for evaluating causality include strength of the relationship, consistency with past studies, plausibility, and dose-response. The magnitude of the RRs that were statistically significant ranged from 0.69 to 0.79. The strength of these RRs would generally be considered to be weak or moderate and thus these RRs may or may not indicate a causal relationship.[9] The observed findings were consistent with studies conducted in other settings and populations using both similar and different methods. As detailed in Chapter 2, past research has shown relationships

between a variety of measures of exposure to nature and domains of mental health. It should be noted that the observed sex difference for the relationship between outdoor play and psychosomatic symptoms has not been consistently demonstrated, highlighting the need for additional research on this topic that takes sex into consideration as a potential effect modifier. With regards to plausibility, psychological theories lend support to multiple mechanisms by which the observed relationships between outdoor play and perceived importance of nature connectedness and psychosomatic symptoms may occur. There did not appear to be linear dose-response relationships in which increasing levels of the exposures were associated with decreasing prevalence of psychosomatic symptoms. However, there seemed to be a threshold effect in which some minimum amount of exposure was sufficient to lower the prevalence of psychosomatic symptoms and the strength of this relationship did not increase with an increasing amount of exposure. This observation does not necessarily negate the dose-response criteria, but rather may indicate that the true relationships are not characterized by a linear trend.

5.6 Future Research Directions

Multiple mechanisms by which individuals may experience psychological benefits from the natural environment have been proposed, including stress recovery,[10,11] physical activity,[12–15] social contact,[16,17] and stimulation of personal development.[18,19] An aim of future work in this area may be to describe whether these underlying mechanisms are associated with specific biological processes and whether the relative importance of these mechanisms changes across differing contexts, such as cultural contexts and types of natural environment. Additionally, there may be other mediators, including parental overprotection[20,21] and resilience,[22,23] that are specifically relevant to young people's experiences of mental health effects from nature. In order to inform clinical recommendations and

public health approaches, controlled trials of nature-based interventions with measures at different stages of the exposure-outcome relationship are needed not only to elucidate how different mediators may contribute, but also to verify the temporality of relationships between nature and mental health.

Taking into account that both internalizing and externalizing mental health symptoms and disorders may be present in different subgroups of students, future work may create a more comprehensive picture of the relationship between nature and mental health by including one or more negative externalizing behavioural measures as outcomes. Likewise, it also may be beneficial to employ measures of positive mental health. Using a wider range of measures could assist in understanding adolescents' full mental health experience across multiple domains to form a more holistic perspective.

There are important aspects of nature contact, nature connectedness, and psychosomatic symptoms that are difficult to quantify, suggesting limitations of the usual framework of epidemiology for studying this topic. Our quantitative methodology meant that we were unable to capture some of the qualitative properties of adolescents' relationships with nature and how they might impact the occurrence of psychosomatic symptoms. Including qualitative data and analysis, or mixed methods approaches, in future studies may allow for a more comprehensive view of the complexities of the relationship between nature and mental health. These types of data may also help to improve understanding of how young people assign meaning to nature and what their perceptions of nature are.

5.7 Implications

This section outlines several public health and clinical implications that incorporate the observed relationships between nature and psychosomatic symptoms. Mental ill health is a large concern in

Canada and public spending on mental health continues to rise.[24] Within the present sample, a substantial proportion of Canadian students reported high levels of psychosomatic symptoms.

Taken in combination with the growing body of evidence on this topic, findings from this thesis lend support to public mental health initiatives that address characteristics of the physical environment in cities, including public parks and school grounds, as well as initiatives that increase opportunities for girls to play outside and engage youth in natural spaces to cultivate feelings of importance of connections to nature. Some examples of current initiatives include the Canadian Mental Health Association's "Mood Walks" educational walking program[25] and the development of a mobile application to increase connectedness to nature by researchers at the University of British Columbia.[26] Research into which specific types of public health interventions may prove most effective for improving mental health and other health outcomes is warranted.

Although the findings of this thesis relate specifically to psychosomatic symptoms, a non-clinical measure of subjective health complaints, other research has demonstrated that these symptoms are occasionally associated with the development of more severe diagnosable disorders. One systematic review found that experiencing more psychosomatic symptoms was associated with an increased likelihood of depression and anxiety across clinical and community-based samples of children and adolescents.[27] In addition to established methods of nature-based therapy, including wilderness, horticultural, and animal-assisted therapy, it has been encouraged that pediatric health care providers recommend outdoor activities for children and families and refer them to safe and easily accessible natural spaces to do so.[28] As one potential preventative and therapeutic entity for a range of physical and mental health symptoms, nature often fulfills the essential requirements of being low cost and low risk.

A “nature prescription” given by a physician of 45 minutes per day for four days per week has been shown to decrease fatigue, promote a sense of calm, improve sleep, and decrease weight and blood pressure among patients.[29] It is important to note that there are many other factors that affect one’s risk of poor mental health and this form of therapy is not intended to replace other evidence-based medical interventions but rather to supplement them among patients and to promote well-being in the general population.

5.8 Synopsis of Chapter

In this thesis, we observed that spending time outdoors was associated with a decreased prevalence of psychosomatic symptoms among female adolescents only and that placing importance on feeling connected to nature was associated with a decreased prevalence of psychosomatic symptoms among both male and female adolescents. Despite key limitations relating to potential measurement error and uncontrolled confounding, this thesis was well-powered to identify associations and used a nationally representative sample of Canadian youth. The existence of a relationship between nature and mental health in this sample may support the use of outdoor programs in public health and clinical interventions. There is a need for more in-depth study of potential etiological pathways, and controlled trials to determine the effectiveness of nature-based interventions.

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Appendix A: Ethics Certificate

The HBSC survey has been granted ethics clearance from the Queen's University General Research Ethics Board and the Health Canada and the Public Health Agency of Canada Research Ethics Board. An ethics application for the proposed secondary analysis was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board for approval following presentation of the thesis proposal. The clearance letter from the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board is included in this appendix beginning on the following page. In adherence with ethical principles, student identities are not contained in the data set and remained anonymous to the Master's student. Survey responses were obtained with consent from the school jurisdiction, school principal, and students' parents (active or passive). Individual responses were kept confidential and data was removed from the research setting.

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

HSREB Initial Ethics Clearance

August 23, 2016

Miss Caroline Piccininni
Department of Public Health Sciences
Queen's University

ROMEO/TRAQ: #6018996
Department Code: EPID-549-16
Study Title: The role of nature in the emotional health of Canadian adolescents
Co-Investigators: Dr. W. Pickett
Review Type: Delegated
Date Ethics Clearance Issued: August 23, 2016
Ethics Clearance Expiry Date: August 23, 2017

Dear Miss Piccininni,

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.

- Protocol

Documents Acknowledged:

- HBSC Survey 2013/2014
- CORE Certificate – C. Piccininni

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 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,

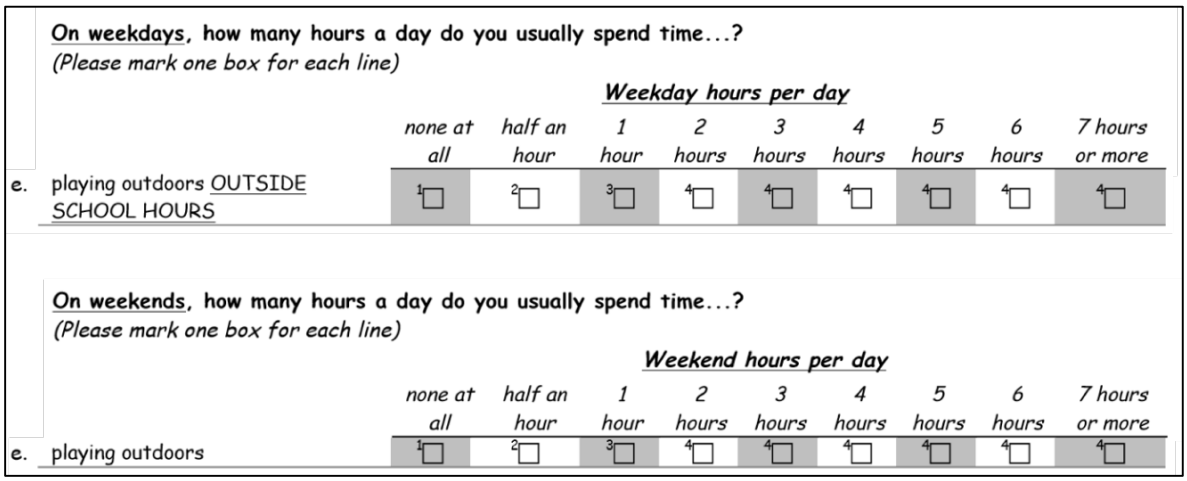
Chair, Health Sciences Research Ethics Board

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 3 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: FWA#:00004184, IRB#:00001173

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

Appendix B: HBSC Survey Items

Exposure 1: Outdoor Activity



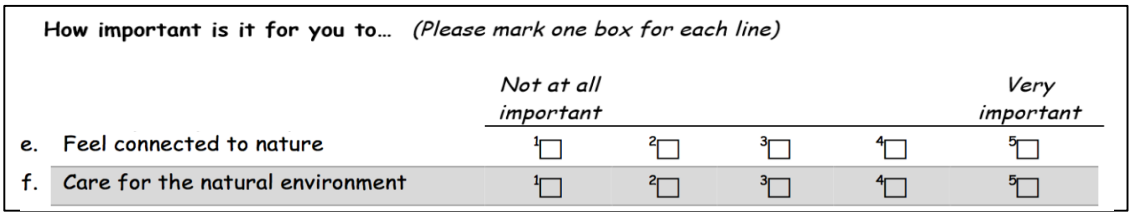
On weekdays, how many hours a day do you usually spend time...?
(Please mark one box for each line)

		Weekday hours per day								
		none at all	*half an hour*	*1 hour*	*2 hours*	*3 hours*	*4 hours*	*5 hours*	*6 hours*	*7 hours or more*
e.	playing outdoors OUTSIDE SCHOOL HOURS	1☐	2☐	3☐	4☐	4☐	4☐	4☐	4☐	4☐

On weekends, how many hours a day do you usually spend time...?
(Please mark one box for each line)

		Weekend hours per day								
		none at all	*half an hour*	*1 hour*	*2 hours*	*3 hours*	*4 hours*	*5 hours*	*6 hours*	*7 hours or more*
e.	playing outdoors	1☐	2☐	3☐	4☐	4☐	4☐	4☐	4☐	4☐

Exposure 2: Perceived Importance of Nature Connectedness



How important is it for you to... *(Please mark one box for each line)*

		Not at all important				*Very important*
e.	Feel connected to nature	1☐	2☐	3☐	4☐	5☐
f.	Care for the natural environment	1☐	2☐	3☐	4☐	5☐

Outcome: Psychosomatic Symptoms

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

		About every day	*More than once a week*	*About every week*	*About every month*	*Rarely or never*
a.	Headache	1☐	2☐	3☐	4☐	5☐
b.	Stomachache	1☐	2☐	3☐	4☐	5☐
c.	Backache	1☐	2☐	3☐	4☐	5☐
d.	Feeling low (depressed)	1☐	2☐	3☐	4☐	5☐
e.	Irritability or bad temper	1☐	2☐	3☐	4☐	5☐
f.	Feeling nervous	1☐	2☐	3☐	4☐	5☐
g.	Difficulties in getting to sleep	1☐	2☐	3☐	4☐	5☐
h.	Feeling dizzy	1☐	2☐	3☐	4☐	5☐

Appendix C: Power Calculations

The equation and parameter values used in calculations of minimum detectable RR and the results of these calculations are provided in this appendix. Power calculations were performed by sex and age strata. Since age was not a significant effect modifier of the observed relationships, only the power calculations by sex strata are provided here.

The sample size for the 2013/2014 HBSC sample was 29,628 adolescents. A design effect of 1.2 was applied to the total sample size to account for the clustered nature of the sampling method.[1] This resulted in an effective sample size of 24,690 (12,188 boys; 12,502 girls) used in calculations. Conservative estimates of the proportion of exposed adolescents for each exposure and of the proportion who reported high psychosomatic symptoms were obtained from the 2013/2014 Canadian HBSC data.

In the study context, the minimum detectable RR represents the smallest protective effect of each exposure against high psychosomatic symptoms that can be detected when power is set at 80% and alpha is set at 0.05. For the association between outdoor play and high psychosomatic symptoms, we had sufficient power to detect a protective RR of 0.86 or stronger for boys and 0.91 or stronger for girls. For the association between perceived importance of nature connectedness and high psychosomatic symptoms, the minimum detectable RR was 0.84 for boys and 0.89 for girls.

The equation used to calculate minimum detectable difference (d) was:

$$Z_{\beta} = \sqrt{\frac{n_{exp}(d)^2 r}{(r+1)p(1-p)}} - Z_{\frac{\alpha}{2}}.$$

Note: Symbols are defined in **Table C.1** on the following page.

Symbol	Definition
n	Sample size of 2013/2014 HBSC Cycle
$\boldsymbol{Z_{\frac{\alpha}{2}}}$	Level of significance ($Z_{\frac{\alpha}{2}}$ = 1.96 corresponds to 95%)
$\boldsymbol{Z_{\beta}}$	Level of power (Z_{β} = 0.84 corresponds to 80%)
$\boldsymbol{\%_{exp}}$	Proportion of the population with the exposure
$\boldsymbol{n_{exp}}$	Number of adolescents in HBSC sample with the exposure
r	Ratio of $\%_{exp}$ to $\%_{unexp}$
$\boldsymbol{p_0}$	Proportion of unexposed with high psychosomatic symptoms
$\boldsymbol{p_1}$	Proportion of exposed with high psychosomatic symptoms
p	Proportion of sample with high psychosomatic symptoms = $\frac{p_1+rp_0}{1+r}$
RR	Relative risk of outcome based on exposure = $\frac{p_1}{p_0}$
d	Difference of proportions = $p_1 - p_0$

The table found below (**Table C.2)** displays parameter values used in calculations of minimum detectable RRs (bolded) comparing each pair of levels of the exposure variable with regards to the outcome of high psychosomatic symptoms.

Exposure Variable	$\%_{exp}$	n_{exp}	r	p_0	p_1	p	d	RR	$Z_{\frac{\alpha}{2}}$	Power
Outdoor Play – Boys	25%	3,047	1	0.215	0.185	0.23	-0.030	**0.86**	1.96	80%
Outdoor Play – Girls	25%	3,126	1	0.373	0.338	0.39	-0.035	**0.91**	1.96	80%
Nature Connectedness – Boys	20%	2,438	1	0.213	0.179	0.23	-0.034	**0.84**	1.96	80%
Nature Connectedness – Girls	20%	2,500	1	0.371	0.332	0.39	-0.039	**0.89**	1.96	80%

References

1. Roberts C, Freeman J, Samdal O, et al. The Health Behaviour in School-aged Children (HBSC) study: methodological developments and current tensions. *Int J Public Heal*. 2009;54:S140-S150. doi:10.1007/s00038-009-5405-9.

Appendix D: Intra-class Correlation Calculations

This appendix provides details on the methods used to calculate intra-class correlation coefficients and the results of these procedures. The sampling strategy utilized to attain the HBSC sample can result in data clustering at the classroom and/or school level. Prior to regression model building, intra-class correlation coefficients were calculated to determine the degree of variation in psychosomatic symptoms at the classroom and school levels. A higher ICC value indicates that clustering by classrooms or schools accounts for a greater amount of variation in psychosomatic symptoms. Although the majority of variance is generally explained at the individual level, it is important to consider variance at the cluster level as an additional source before creating regression models with data that may be clustered. The method to calculate intra-class correlation coefficients involved running an empty model specifying the outcome as the dependent variable and the cluster level as a random effect and then comparing the intercept ($\sigma^2 group$), which represents variance at the group level, to the residual ($\sigma^2 error$), which represents variance at the individual level, using the following equations:

For variation at the classroom level:

$$ICC = \frac{\sigma^2 classroom}{\sigma^2 classroom + \sigma^2 error}$$

For variation at the school level:

$$ICC = \frac{\sigma^2 school}{\sigma^2 school + \sigma^2 error}$$

The following table (**Table D.1**) displays parameter values from calculations of intra-class correlation coefficients (bolded).

Cluster Level	$\sigma^2 group$	$\sigma^2 error$	ICC
Classroom	3.21	44.51	**6.72%**
School	2.03	45.89	**4.24%**

Appendix E: Rationale for Use of Log-Binomial Regression

Log-binomial models are generalized linear models where the link function is the logarithm of the proportion under study and the distribution of the error is binomial. Log-binomial models estimate relative risks rather than odds ratios. Although logistic regression models are often used in cross-sectional studies with binary outcomes, the odds ratios generated by these models can overestimate the relative risk, especially when dealing with common outcomes.[1] Log-binomial models were suitable for use in this study because the outcome is relatively common and both log-binomial and robust Poisson regression have been shown to perform equally well compared to a suitable reference when the model converges and is correctly specified.[2] These types of models are preferred over logistic models for the analysis of cross-sectional studies with binary outcomes because the estimate obtained is more conservative and easier to interpret and communicate.[3]

References

1. Thompson M Lou, Myers JE, Kriebel D. Prevalence odds ratio or prevalence ratio in the analysis of cross sectional data: What is to be done? *Occup Environ Med Occup Env Med*. 1998;55(4):272-277. http://www.jstor.org/stable/27730920. Accessed May 11, 2017.
2. Barros AJD, Hirakata VN. Alternatives for logistic regression in cross-sectional studies: An empirical comparison of models that directly estimate the prevalence ratio. *BMC Med Res Methodol*. 2003;3:21. doi:10.1186/1471-2288-3-21.
3. Greenland S. Interpretation and choice of effect measures in epidemiologic analyses. *Am J Epidemiol*. 1987;125(5):761-768. http://www.epidemiology.ch/history/PDF bg/Greenland S 1987 interpretation and choice of effect measures.pdf. Accessed May 11, 2017.