Association between access to neighbourhood greenness and physical activity in Nova Scotia youth

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1.0 Abstract

Physical activity is an important factor of child growth and is expected to reduce the prevalence of obesity. However, despite these benefits many youth in Nova Scotia do not meet the recommended physical activity guidelines defined by the Canadian Government. Thus, there is a high demand for research that investigates the causes behind variations in levels of physical activity. One possible explanation of these variations is accessibility to neighbourhood greenness. Exposure to green environments has shown to have positive health benefits. However, much is still unknown about the influence neighbourhood greenness has on physical activity in youth. The objective of this study was to investigate the relationship between access to neighbourhood greenness and physical activity levels among a sample of youth in Nova Scotia. Physical activity data was obtained from the study Keeping Pace, conducted in 2009-2010, where accelerometers were used to measure physical activity levels of 1855 students in grades 3, 7 and 11 across Nova Scotia. Normalized Difference Vegetation Index was used to quantify neighbourhood greenness and analysis was computed in a geographic information system. Logistic regression models were used to examine the relationship between neighbourhood greenness and physical activity in youth. A positive correlation between neighbourhood greenness and achieving physical activity guidelines was seen at 1.5 km distance from participants home (P-value = 0.049, OR = 1.0004). Living in a rural or urban area did not have a significant impact on the relationship between physical activity and neighbourhood greenness. Neighborhood greenness may be an essential quality of active neighborhoods. Future research should explore the specific dimensions within the neighbourhood that contribute to greater physical activity and health among youth.

Key words: Physical Activity, Neighbourhood Greenness, Cross Sectional, Geographic Information System (GIS)

2.0 Introduction

2.1 Background

Participating in regular amounts of physical activity contributes to many health benefits such as improved mental health, weight control, reduced risk of cardiovascular disease and type two diabetes (Warburton *et al*, 2006). However, despite the health benefits of regular physical activity, many Canadians do not partake in the recommended amount (Herman *et al*, 2009). The Canadian Physical Activity Guidelines recommend that adults between 18 and 64 accumulate 150 minutes of moderate to vigorous physical activity (MVPA) a week and youth, ages 5 to 17, should accumulate 60 minutes of MVPA daily (CESP, 2011). In 2006, 51% of Canadian adults were sufficiently physically active during their leisure time (Herman *et al*, 2009). Canadian Health Measures Survey found that only 7% of Canadian youth aged 6 to 19 years achieved Canadian physical activity guidelines and on average Canadian youth spent 8.6 hours participating in sedentary activities daily (Colley *et al*, 2011). Lack of regular physical activity is of particular concern among youth as the prevalence of obesity has increased among children and adolescents in Canada over the past several decades (Shields, 2006).

Reported rates of obesity among Canadian youth between ages 5 to 17 are found to be 31%. (Roberts *et al*, 2012). Childhood obesity has been linked to many serious health issues such as diabetes, high blood pressure and cardiovascular disease. It can also lead to psychological problems which include negative self-esteem, withdrawal from peer interaction, depression and anxiety (Deckelbaum, and Williams, 2001). Furthermore, obesity in childhood frequently leads to obesity in adulthood making obese children more vulnerable to health issues later in life. As a result, childhood obesity has become a major public health concern (Nader *et al*, 2006).

Physical activity is an important factor of child growth and development and is influential toward adult health behaviours and patterns. Physical activity is expected to prevent childhood obesity and protect children from developing associated health effects (Steinbeck, 2001). Therefore, there is a high demand for research that investigates the causes behind variations in levels of physical activity.

There are several factors that influence the likelihood of achieving the recommended amount of physical activity for youth. Some of these factors include income level, gender, education level, location, ethnicity/race, parental physical activity, parental support, parental education, attitude, and peer support (Van der Horst *et al*, 2007). In addition, factors that are beyond the control of the individual, such as the configuration of the built environment, may also influence physical activity (Dunton, *et al*, 2011). Exposure to greenness (sometimes referred to as green space or natural environments) has been shown to play a beneficial role in human health. Greenness typically includes open and undeveloped land with natural vegetation, including parks, playing fields, forests, lawns, golf courses or wetlands (Mitchell and Popham, 2008; Richardson *et al.*, 2012; Almanza *et al*, 2012). The benefits of greenness are varied, including improved mental well-being, faster recovery from mental illness, greater social interaction and increased physical activity, as well as more relief from stress, fatigue, anxiety and depression (Mass *et al*, 2006; Van den Berg *et al*, 2010; Lee and Maheswaran, 2011).

While the health benefits of greenness have been well documented in several studies, the biological pathways that yield these benefits are less understood. It has been suggested that the health improvements occur, in part, because access to green areas promote physical activity (Mytton *et al*., 2012). For example, open green areas provided aesthetically pleasing and safe environments for physical activities such as walking, biking and running (Giles-Corti *et al*, 2004;

Cohen *et al*, 2007). Increased neighbourhood greenness is particularly important for youth, as it provides access to areas for them to participant in organized and unorganized play time; increasing overall physical activity levels (Cohen *et al*, 2006). For this study, neighbourhood greenness is defined as the amount of greenness around or near one's home location.

The studies that have investigated the relationship between neighbourhood greenness and physical activity have produced mixed results. Multiple studies have found a positive association between neighbourhood greenness and physical activity (Cohen *et al*, 2007; Coombes *et al*, 2010; Kaczynski *et al*., 2009; Mytton *et al*., 2012). For example, Roemmich *et al* (2006) asked 59 children ages 4 -7 to wear accelerometers for 4 days, and found that neighbourhoods with a greater proportion of park areas were associated with increased physical activity in young children. However, other studies have found no relationship between the two (Hoehner *et al*, 2005; Hillsdon *et al*, 2006; Maas *et al*, 2008; McCormack *et al*, 2008). For example, Ord *et al* (2013) found that the availability of green space in a neighbourhood was not associated with total physical activity when looking at neighbourhood level measures of green space availability, and self-reported physical activity data of 3679 adults (16+) living in urban areas across Scotland. The lack of consistency across these studies may be explained by the differences in the methods used to characterize greenness and physical activity. For instance, some studies used a self-reported measure of physical activity while others used objective measures, such as accelerometers (Timperio *et al*, 2004; Cohen *et al*, 2006; Roemmich *et al*, 2006). For the characterization of greenness, a verity of methods were used ranging from self-reported data, land use classification data and vegetation indices (Almanza *et al*, 2012; Mytton *et al*., 2012; Ord *et al*, 2013).

2.2 Introduction to Study

In Nova Scotia it is recognized that physical inactivity has been increasing and is now considered a major health concern. Thompson and Wadsworth (2012) found that only 28% of boys and 13% of girls in grade seven, and 5% of boys and 1% of girls in grade eleven met physical activity standards of 60 minutes per day for 5 days a week. However, there has yet to be research completed in Nova Scotia on the physical activity of youth and the relationship with neighbourhood greenness.

The objective of this study is to investigate the relationship between access to neighbourhood greenness and physical activity levels among a sample of youth in Nova Scotia. It is hypothesized that youth with greater accessibility to neighbourhood greenness will have significantly higher levels of physical activity than youth with little accessibility to neighbourhood greenness. It is predicted that Nova Scotia youth who obtain 60 minutes of MVPA for at least 6 days of the week will have greater area of greenness around their home, while youth that do not obtain recommended physical activity levels will have significantly less greenness around their home.

2.3 Motivation

Understanding physical activity patterns of youth is critical, as youth health behaviours are predictive of the same adulthood behaviours and physical activity levels decline during the transition from adolescence to adulthood (Herman *et al*, 2009). This study looked at whether the physical activity levels of Nova Scotia youth are influenced through the interaction with neighbourhood greenness. It aimed to contribute to the current body of literature and strengthen our knowledge on the relationship between access to neighbourhood greenness and youth physical activity. This study also provided important information for government, municipalities, schools and organizations that could be used in the future for urban planning, policy making, and program development in order to improve physical activity levels in youth.

2.4 Study Approach

Within this study, a cross-sectional ecological study deign was used. Cross-sectional studies use individual level variables that measure exposure and disease at one point in time, giving a snapshot of the study population. Ecological studies are observational studies commonly used for initial investigations of new or casual hypothesis (Rothman, 2012). As the relationship between neighbourhood greenness and physical activity levels in youth is understudied and is still a relatively new hypothesis, this study designs deems appropriate to investigate the relationship.

Physical activity data was obtained from the Keeping Pace study completed in Nova Scotia, Canada. Keeping Pace is a multi-cycle, cross-sectional study, funded by the Department of Health and Wellness and the Department of Education, which monitors physical activity and Body Mass Index (BMI) of youth in Nova Scotia. The study occurred every four years, starting in 2001-2002, and looked at physical activity and BMI of students within grades 3, 7 and 11 (Thompson and Wadsworth, 2012). Within this study data from 2009-2010 was analyzed.

Geographic Information System (GIS) based approach was used to evaluate neighbourhood greenness, measuring the amount greenness available around each participant's home location. Logistic regression was used to examine the relationship between neighbourhood greenness and physical activity in Nova Scotia youth.

3.0 Literature Review

3.1 Introduction

This literature review contextualizes this study by reviewing the body of knowledge regarding physical activity in youth and impacts of greenness on physical activity. Studies assessing the relationship between access to neighbourhood greenness and increased physical activity levels among residents were critically compared and methods used within this study were justified.

The search method used in this literature review was a topic based methodology. Key terms used in the search included: physical activity, proximity, access, green space, neighbourhood greenness, children, and youth. The databases used were PubMed, Web of Science, ScienceDirect, and Google Scholar. Only English and peer reviewed articles were reviewed from 2000 to present.

3.2 Physical Activity in Youth

Physical Activity, according to the Canadian Physical Activity Guidelines, is defined as the movement produced by skeletal muscles that require energy expenditure and increased heart rate and breathing (CSEP, 2011). Health benefits associated with regular physical activity has been well established within the literature. These health benefits included decreased risk of cardiovascular disease, type 2 diabetes, osteoporosis and certain types of cancer (Biddle *et al*, 2004; Warburton *et al*, 2009). For example, a systematic review of epidemiologic studies revealed that MVPA was associated with decreased risk of cancer, specifically colon and breast cancer. Physically active men and women exhibited a 30%–40% reduction in the risk of colon cancer, and physically active women a 20%–30% reduction in the risk of breast cancer compared with their inactive counterparts (Lee, 2003). Although these health problems are more prevalent in adults, the development of these diseases can begin in childhood and adolescence (Biddle *et al* 2004).

One of the major roles of physical activity plays in childhood health is the prevention of obesity. The prevalence of overweight and obesity has increased among children and adolescents in Canada over the past several decades, with 26% of young people overweight or obese in 2004 (Shields, 2006). A study by Veugelers and Fitzgerald, (2005) estimated the prevalence of overweight to be 32.9% and obesity to be 9.9% in Nova Scotia youth, with children in low-income neighbourhoods being more susceptible to obesity. Insufficient physical activity and poor nutrition are widely acknowledged as some of the primary mechanisms underlying the rise in overweight and obesity rates in youth (Dehghan *et al*, 2005; Veugelers and Fitzgerald, 2005). Physical activity aids in the prevention of overweight and obesity by positively impacting child growth patterns and influencing positive adult health behaviours (Steinbeck, 2001; Dietz, 2005). Herman *et al*, 2009 found, in a study tracking obesity and physical activity from childhood to adulthood in Canadians, 85% of overweight youth remained overweight as adults and almost all healthy weight adults had been healthy weight youth. It is clear that youth physical activity will play an important role in preventing major health issues later in life.

Despite potential benefits, physical activity has been declining at an alarming rate in youth. A 5 year study starting in 1999 assessed developmental trends of physical activity behaviours in British youth. Reductions in physical activity and increases in sedentary behaviour were noticed between ages 11–12 and 15–16 years. Decline in physical activity was greater in girls than in boys (46% versus 23% reduction) (Brodersen *et al*, 2007). A study done in North America by Allison *et al* (2007) found, for males and females, a steady decline in MVPA between ages 14 and 18 years in a study assessing age-related decline in physical activity among high school students in the United States and Ontario. In general physical inactivity seems to increase within adolescents and into adulthood, and females are significantly more inactive then males (Herman *et al*, 2009). Furthermore, youth living in rural communities a significantly less physically active then youth living in urban communities (Joens-Matre *et al*, 2008). Sedentary behaviors such as TV watching and computer usage present a challenge in to meeting recommended physical activity guidelines as it can occupy a large proportion of time (Colley *et al*, 2011; PHAC, 2011). This general pattern of decline is supported by findings from previous studies conducted both in North America and several other countries (Telama and Yang, 2000). With this decline in physical activity and the strong evidence of its health benefits there has been an increase demand for research that investigates the causes behind variations in levels of physical activity.

3.3 Physical Activity in the Outdoor Environment

In addition to individual factors and behaviours, physical activity may be constrained or facilitated by local environments. Theoretically where people live determines what they see, hear and encounter on a daily bases. Having access to greener environments may be a key environmental factor impacting physical activity levels in youth. Recent studies have shown that greater exposure to greenness or more time spent outdoors have a positive influence among children and adolescent resulting in more active play and enhanced physical activity levels (Wen *et al*, 2009; Dunton, *et al*, 2011; Klinker, *et al*; 2014). For example, a study examining the relationship between greenness exposure and free-living physical activity behaviour in children ages 8 to 14 found that children who experiences greater than 20 minutes of daily exposure to greener spaces engage in nearly 5 times the daily rate of MVPA than children with nearly zero daily exposure to greener spaces. (Almanza *et al*, 2012).

There are many neighbourhood-level environmental attributes that may influence physical activity. Neighbourhood safety barriers were found to be a major barrier to outdoor physical activity in youth. Safety barriers included crime and presence of high traffic or major roads (Ding *et al*, 2011). Parent/guardian perception on the safety of the neighbourhood environment was also found to have an impact of outdoor physical activity in youth. if parents/guardians perceived the neighbourhood environment as unsafe they are less likely to allow their children to play freely outside (Janssen, 2014). Greener neighbourhoods may provide a safer environment by promoting stronger social connections allowing parents/guardians to let their children play outside by themselves (Mass *et al*, 2009). Higher physical activity levels are achieved within youth when a parent/guardian was not present (Mackett *et al*, 2007). Higher housing density, street connectivity and mix land use have also been in shown to significantly influence physical activity as it provides greater accessibility within the neighbourhood (Ding *et al*, 2011). Neighbourhood environmental characteristics, such as attractiveness, local gardens, and larger areas of green spaces, were shown to influence physical activity within adults (Giles-Corti *et al*, 2004). It was found that residential proximity to green areas, recreational centers, schools and other facilities such as retail stores will play a role in promoting physical activity in youth (Bedimo-Rung *et al*, 2005; Wheeler *et al*, 2010; Ding *et al*, 2011).

Understanding where physical activity takes place will also play a key role in understanding the variations in levels of physical activity within youth. Time spent commuting was found to be the largest contributor to MVPA in youth (Rainham *et al*, 2012). Cooper *et al* (2010) found that children who walked or biked to school experienced significantly higher physical activity levels then children who used motorised vehicles to commute to school. School and home locations were also to be found to be major areas where children experience MVPA

(Cooper *et al*, 2010; Rainham *et al*, 2012). However, it was shown that physical activity was 2-3 fold higher in outdoor environments then indoors (Cooper *et al*, 2010). Green areas such as parks, wooded areas and vacant land are also key locations where youth achieve high intensity physical activity (Wheeler *et al*, 2010). Wheeler *et al* (2010) found that physical activity tends to be more intense in green areas compared to other locations such commuting, home, or school locations. Within this research it was stated that future research is needed to improve understanding of the time spent in green areas and the role residential proximity will play.

3.4 Physical Activity and Access to Neighbourhood Greenness

Several observational studies have sought to establish whether there is a relationship between neighbourhood greenness and physical activity. Work in this area is young and is far from reaching a conclusion. The studies that have investigated this relationship have produced mixed results with some studies finding a positive association while other studies finding no relationship between neighbourhood greenness and physical activity. Out of the studies examined it was found that 15 found a positive association between physical activity and neighbourhood greenness (Timperio *et al*, 2004; Cohen *et al*, 2006; Roemmich *et al*, 2006; Cohen *et al*, 2007; Tilt *et al*, 2007; Lackey and Kaczynski, 2009; Kaczynski *et al*, 2009; Coombes *et al*, 2010; Sugiyama *et al*, 2010; Wheeler *et al*, 2010; Almanza *et al*, 2012; Mytton *et al*, 2012; Jenssen and Rosu, 2014; McMorries *et al*, 2014) while only 9 studies have found no relationship (Hoehner *et al*, 2005; Giles-Corti *et al*, 2004; Hillsdon *et al*, 2006; Maas *et al*, 2008; Witten *et al*, 2008; Foster *et al*, 2009; McCormack *et al*, 2008; Ord *et al*, 2013; Besenyi *et al*, 2014).The majority of studies have focused on physical activity in adults (Kaczynski *et al*, 2009; Coombes *et al*, 2010; Ord *et al*, 2013) with less focusing on youth (Roemmich *et al*, 2006; Jenssen and Rosu, 2014). Although more studies have found a positive association between greenness and physical activity, the relationships are generally weak and interoperation of results ambiguous.

Majority of these studies have been small and have only studied the association at a local scale (within a region or city). This could result in a lack of statistical power or insufficient heterogeneity of greenness levels in a local area, making it difficult to assess the relationship between greenness and physical activity. Alternatively studies finding positive associations may be due to chance or explained by confounding factors associated with physical activity such as socio-economic status or access to leisure facilities (Mytton *et al*, 2012).

It has been frequently mentioned that the lack of consistency across these studies may be explained by differences in methods used to measure greenness exposure and physical activity. Self-reported data was the most common method used to measure physical activity, specifically in studies looking at physical activity in adults (Hoehner *et al*, 2005; Hillsdon *et al*, 2006; Maas *et al*, 2008; McCormack *et al*, 2008). Accelerometers were also used but more commonly found in studies looking at physical activity in youth (Almanza *et al*, 2012; Besenyi *et al*, 2014). It was noted that different categories of physical activity were used to define physical activity. Some studies looked at overall physical activity levels, while other studies only looked types of physical activity, for example walking or biking. Some studies only examined physical activity solely within green spaces, such as parks. Methods used for measuring greenness exposer also varied across studies. The majority of the studies only looked at public open areas, such as public parks or designated green spaces (Roemmich *et al*, 2006; Wheeler *et al*, 2010). Land use data was also commonly used to identify a mixture of green areas including parks, fields and treed areas (Jenssen and Rosu, 2014). More recent studies have used Normalized Difference Vegetation Index to quantify overall greenness level within ones neighbourhood (Almanza *et al*, 2012; Besenyi *et al*, 2014; McMorris *et al* 2014). Despite the strong underlying theory and some supportive observational evidence, there is still some uncertainty about whether there is a causal relationship between neighbourhood greenness and physical activity.

3.5 Justification of Methods

The mixed findings within the literature could be explained by the variety methods used across the studies to measure physical activity and neighbourhood greenness. The following section will outline the methods used in previous studies and justify methods used within this study. The majority of studies, specifically looking at the relationship within adults, used subjective methods to measure physical activity (Hoehner *et al*, 2005; Hillsdon *et al*, 2006; Maas *et al*, 2008; McCormack *et al*, 2008). Subjective methods include questionnaires, interviews, activity logs and direct observation. Subjective methods limit conclusions drawn from results because perceptions about physical activity behaviour and environmental context are susceptible to bias and misclassification. The accuracy of the information may be influenced by opinion and perceptions of the participant, proxy reporter or investigator. For youth, self-report methods are susceptible to additional bias as children may have difficulty recalling or describing physical activity compared to adults (Corder *et al*, 2008). Objective methods, such as pedometers and accelerometers, provide a more accurate measurement of physical activity. Objective measures involve the measurement of physiological or biochemical parameters and use this information to estimate physical activity levels. Accelerometers are the most common objective method used to assess physical activity in youth (Cohen *et al*, 2006; Roemmich *et al*, 2006; Almanza *et al*, 2012; Dunton *et al*, 2014). However, there are limitations to accelerometers; for example they cannot be worn during water base activities resulting in an underestimation of physical activity. Despite these limitations accelerometers provide reliable and precise measurement of physical activity while eliminating participant bias (Rowlands, 2007; Corder *et al*, 2008).

Methods of classifying and measuring neighbourhood greenness also varied significantly across studies. As seen with in the literature the majority of studies used land use data or self-reported methods of measuring neighborhood greenness (Coombes *et al*, 2010; Wheeler *et al* 2010). Within in these studies public parks were the most common classification (Giles-Corti *et al*, 2004; Cohen *et al*, 2007; Kaczynski et al, 2009; Sugiyama *et al*, 2010). However, it has been shown that youth are more physical activity at home locations, school locations and commuting to and from school and other facilities (Cooper *et al*, 2010; Rainham *et al*, 2012). Furthermore, previous studies have shown that greener environments increase outdoor physical activity, such as walking, biking and running, by providing a safe environment that encourages social connections (Mackett *et al*, 2007). However, these aspects of physical activity are not represented when only looking at neighbourhood parks. NDVI data was successfully used is some studies to better capture neighbourhood greenness (Tilt *et al*, 2007; Almanza *et al*, 2012; Besenyi *et al*, 2014). NDVI has also been used in other epidemiology research evaluating the association between neighbourhood greenness and health (Liu *et al*, 2007; Bell *et al*, 2008). It provides a measurement of greenness that includes all vegetated land use types. NDVI has been found to be highly correlated with expert ratings of greenness and a valid and practical metric for use in epidemiology research (Rhew *et al*, 2011; Almanza *et al*, 2012). Using NDVI has particular advantages including data availability with no cost and ease of application to various boundaries adding to the replication and comparability across studies (Rhew *et al*, 2011). Thus, NDVI data provides a more accurate measurement of neighbourhood greenness and was used within this study.

Buffers were the most common method in measuring access to neighbourhood greenness (). The buffer size represents the distance a person can travel in all directions around their home in a given amount of time. Within the literature the buffers varied between studies. Buffer sizes tend to range 400 m to 3 km, averaging around 1 km (Hoehner *et al*, 2005; Hillsdon *et al*, 2006; Maas *et al*, 2008; Coombes *et al*, 2010; Besenyi *et al*, 2014). However, it is difficult to conclude which buffer size best represents neighbourhood accessibility as results were not consistent with buffer sizes. Additional research is needed to understand what buffer size best represent neighbourhood accessibility in regards to youth. Therefore this study will use multiple buffer sizes to take into consideration these mix findings, and attempt to assess which buffer size most accurately represents the relationship between access to in neighbourhood greenness and physical activity in youth.

Two methods of calculating buffers where found within in the literature; circular buffers (Hoehner *et al*, 2005; Hillsdon *et al*, 2006; Maas *et al*, 2008) and road-based network buffers (Roemmich *et al*, 2006; Tilt *et al*, 2007 Coombes *et al*, 2010; Besenyi *et al*, 2014). Circular buffers are calculated using a straight-line distance making a perfect circle around the participant's home while road-based network buffers use the road network to calculate the distance around the participant's home. Circular buffers assume accessibility in all directions and do not take into consideration natural features, such as rivers, or built features, such as railways, that could influences ones travel. In urban and suburban areas walking typically takes place on public sideways or along roads (Oliver *et al*, 2007). Road-base network buffers take into consideration these barriers and establish an area that accurately represents what people can access around their homes, such as retail stores or designated green spaces, within in a given distance or time. The size of a road-base network will very for each household based on the connectivity of the road network; for example, more intersection allow for a greater area to be covered (Frank *et al* 2005; Oliver *et al*, 2007; Bell *et al*, 2008). Therefore road-base network buffers present a more accurate approach to measuring the accessibility unique to each participants home and was used within this study.

3.6 Physical Activity in Nova Scotia Youth

There have been limited studies done in Nova Scotia in regards to physical activity in youth. However, from the research that has been reviewed Nova Scotia youth follow the same trend of declining physical activity. Campagna et al (2002) found that 45% of boys and 28% of girls in grade 7 and 8.7% of boys and 5.1% of girls in grade 11 within Nova Scotia met physical activity standards of 60 minutes per day for at least 5 days of the week. A more recent study done by Thompson and Wadsworth, (2012) found that only 28% of boys and 13% of girls in grade 7 and 5% of boys and 1% of girls in grade 11 met physical activity standards of 60 minutes per day for 5 days a week. In chief public health officer's report on the public health in Canada it was found that between 2000/2001 and 2009, the percentage of youth who spent 15 or more hours a week participating in sedentary activities increased from 65% to 76% (PHAC, 2011).

It is clear that in Nova Scotia physical activity in youth is declining specifically in adolescents. However, it is unclear how neighbourhood greenness influences this trend. To date there has been no research in Nova Scotia looking at the relationship between access to neighbourhood greenness and physical activity among youth. With evidence supporting the benefits of neighbourhood greenness, including improved physical activity levels, further research should be done to investigate these possible benefits within Nova Scotia youth.

3.7 Conclusion

This literature review highlights background topics in relation to the study. Outlined in this review was the importance of physical activity within youth and the need for research that investigates the causes behind variations in physical activity levels. It was demonstrated that neighbourhood greenness may play a role in influencing physical activity within youth and that greater access to green areas in residential areas may increase overall physical activity levels. Few studies have looked at the association between neighbourhood greenness and physical activity in youth as it is a new topic of research. Within in the body of literature evidence of the relationship is mixed possibly due to the variations of methods used across studies. Within Nova Scotia only studies looking at physical activity levels have been completed. There is a gap in the research regarding the relationship between access to neighbourhood greenness and physical activity levels in Nova Scotia youth. This study aims to contribute to the body of research by investigating this relationship using objective measure of physical activity and neighbourhood greenness. As more research is completed, the relationship between neighbourhood greenness and physical activity will become transparent.

4.0 Materials and Methods

4.1 Overview

The primary objective of this study was to explore the relationship between neighborhood greenness and physical activity levels within Nova Scotia youth. Physical activity data was obtained from the Keeping Pace study, carried out in 2009-2010 in Nova Scotia Canada. The main purpose of this study was to monitor provincial and regional trends of physical activity and body mass index of children and youth in grades 3, 7 and 11 as well as dietary intake and behaviour of students in grades 7 and 11. Students were randomly selected, using probabilistic random sampling, from schools across all of Nova Scotia. Each student was invited to partake in the Keeping Pace study with the intention of recruiting 60 boys and 60 girls from each grade. 1,855 students volunteered to participant in the study with 328 boys and 417 girls in grade 3, 286 boys and 417 girls in grade 7, and 165 boys and 242 girls in grade 11 (Thompson and Wadsworth, 2012).

Physical activity and demographic data was obtained from Keeping Pace for 1,887 participants. Greenness was objectively measured using NDVI data obtained from United States Geological Survey. Network based buffers was used to measure the amount of greenness within the neighbourhood of each participants. Statistical analysis was then completed to evaluate the relationship between neighbourhood greenness and physical activity in Nova Scotia youth.

4.2 Physical Activity Measurement

Actigraph GT1M accelerometers were used to measure physical activity for each participant within Keeping Pace. Participants were instructed to wear the accelerometer during all waking hours for the seven consecutive days, with the exception of showering or other water-based activities. An accelerometer non-use log was used to record physical activities in which participants engaged in when accelerometers were not worn (Thompson and Wadsworth, 2012).

The Actigraph is a uniaxial accelerometer, designed to detect vertical accelerations. These instruments allow for the measurement of normal human motion with the rejection of high-frequency vibrations from other sources (Kelly *et al*, 2011). The accelerations are filtered and digitized with the magnitude summed over a user-specific interval of time. At the end of each interval, the summed value or activity count is stored in memory and the numerical integrator reset (Thompson *et al*, 2005; Kelly *et al*, 2011).

Within Keeping Pace, the accelerometer data were reduced to 1-min counts and categorized into one of four physical activity intensities. Physical activity intensity was measured according to the metabolic equivalent (MET) where 1 MET refers to resting energy expenditure. The physical activity counts were categorized into light (<3 METs), moderate (3–5.9 METs), hard (6–8.9 METs) or very hard (>=9 METs) (Thompson *et al*, 2005).

For this study physical activity levels obtained from Keeping Pace was assessed based on the Canadian physical activity guidelines where children and youth ages 5 to 17 should accumulate 60 minutes of MVPA for at least 6 days a week.

4.3 Green Space Access Measurement

Normalized Different Vegetation Index (NDVI) was used in this study to quantify neighbourhood greenness. The NDVI dataset for this study was acquired from AquaLook images using online search engine Global Visualization Viewer from U.S Geological Survey. A 16-day composite MYD13Q1 image at 250m spatial resolution was acquired from August 2010, in order to maximum greenness levels. NDVI is a remotely sensed vegetation index derived from satellite sensors and measures the amount of photosynthetically active light that is absorbed. NDVI is defined as the difference between near infrared and red reflectance divided by the sum (Solano et al, 2010). The NDVI index ranges from – 1 to + 1 where vegetation levels are depicted in table 1.

Table 1: Vegetation levels and corresponding NDVI values (USGS, 2015)

Vegetation Level	**NDVI Value**
No Vegetation	- 1 to 0.25
Low	0.25 to 0.55
Moderate	0.55 to 0.74
High	0.74 to 0.85
Very High	0.85 to 1

ArcGIS 10.2 Geographic Information System software package was used to calculate average NDVI values around each participant's home location through a series of analysis (Ersi, 2015). Home locations were identified based on postal codes obtained from parent/guardian questionnaires conducted by Keeping Pace. Participant's home locations were geocoded using cross-referencing method. Postal codes spatial locations were determined by cross-referencing the postal code to the Canada Post Postal Code database to obtain geographic coordinates, giving the location of the participant's neighbourhood. Many epidemiology studies relay on postal code location as a proxy for the location of residence. Postal codes are a well-accepted method within the literature for determining home location and are an accurate proxy for address locations (Bow et al, 2004). Geographic coordinates (home locations) obtained from the geocoded postal codes were added into ArcGIS using display XY Data tool. This tool adds a new map layer based on XY events from a table layer. The average NDVI value, used to quantify neighbourhood greenness, was calculated within 0 km, 0.5 km, 1 km, 1.5 km, 2 km, 2.5 km and 3 km around the participant's home location using road-based network buffers. Seven buffer sizes where chosen based on the mixed findings within the literature for an ideal buffer size to measure neighbourhood accessibility. Buffer sizes where chosen to represent the range found within literature.

Road-based network buffers were calculated using Network Analyst in ArcGIS. Network dataset Canada wide, essential for the network analysis, was obtained from the GISciences Center at Dalhousie University. For ease of analysis the data was cut down to just the province Nova Scotia. This was completed by using the Select Feature Tool to only select the road network dataset that covered the province of Nova Scotia. The selected attributes where then exported into a new network dataset file using Export Data Tool. Once the network dataset was obtained the road-based network buffers could be calculated using Network Analyst tools. Figure 1 illustrates the steps taken to obtain road-based network buffers in Network Analyst in ArcGIS.

Once the buffer polygons were created using Network Analyst, the buffers were overlaid with NDVI data and home locations in ArcMap. Before any analysis could be completed on the NDVI dataset the unknown sinusoidal projection had to be transformed in order to match the projection of the rest of data. This was done using the Project Raster Tool, which transformers a raster dataset from on projection to another. NDVI dataset was transformed to have a projection coordinate system of Canada Albers Equal Area Conic and a geographic coordinate system of GCS North America 1983.

The average NDVI value for each buffer was determined using a tool called Zonal Statistics. Zonal Statistics is a tool in ArcGIS software that is used to calculate and summarize statistics, such as area, range, mean and standard deviation, on values of raster within the zones of another dataset. Results can then be reported as a table or a new layer within the program (Esri, 2012). However, since the majority of buffers were overlapping, the Zonal statistics as Table Tool in AcrGIS would not calculate average NDVI values for the buffers. As a result a tool to calculate zonal statistics with an overlapping polygon feature class was downloaded. The tool breaks up an overlapping polygon feature class into feature classes with no overlapping polygons and runs the zonal statistics using a spatial join system tool (ESRI *et al*, 2012). Results from the zonal statistics using overlapping polygon tool were exported to an Excel spread sheet for further statistical analysis.

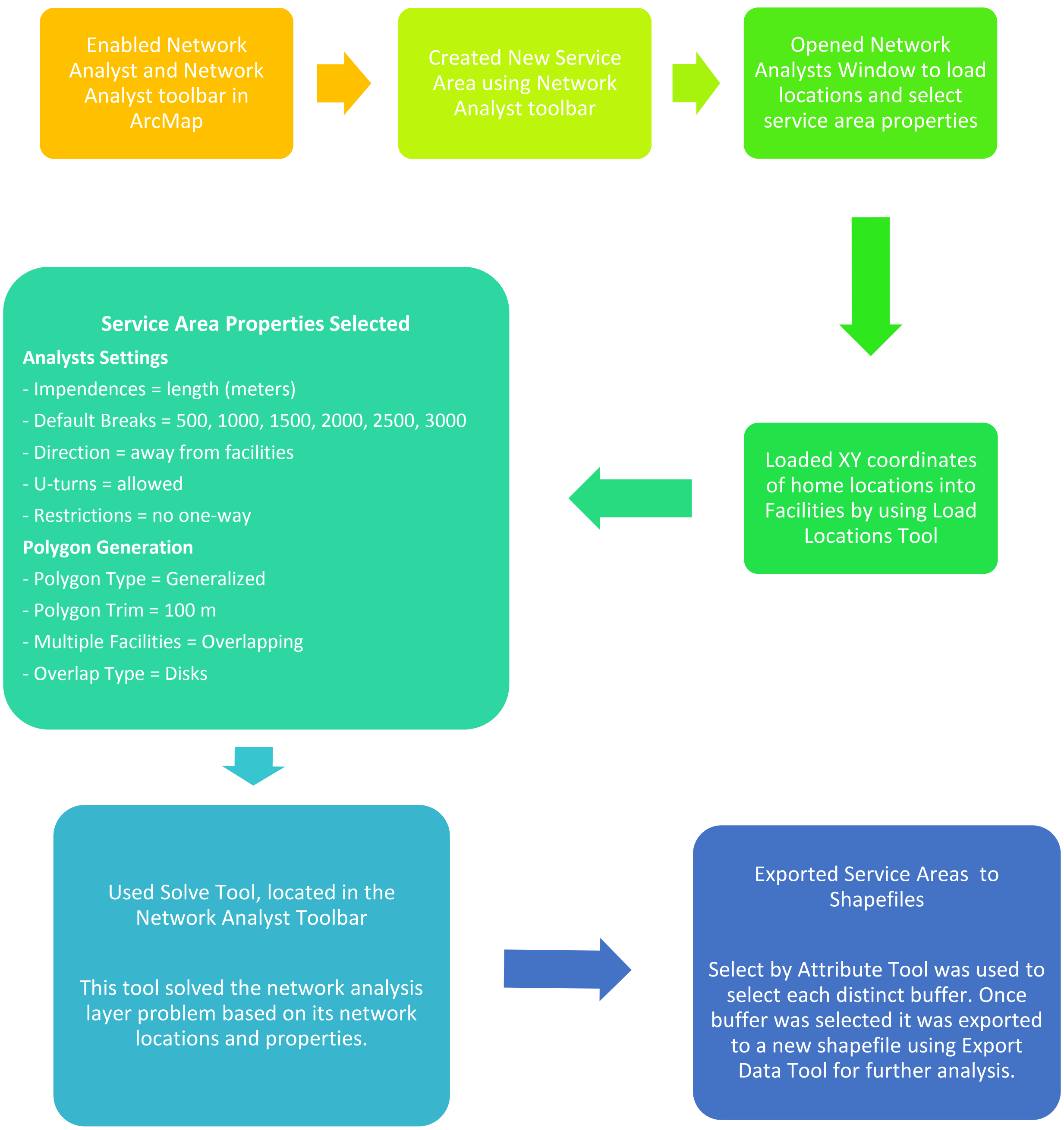

Figure 1: Service area creation process using Network Analyst in ArcGIS 10.2 used to create road-based network buffers around each participants home location

4.4 Additional Explanatory Variables

Self-reported questionnaire about physical activity were completed by each student in grades 7 and 11 within the Keeping Pace study. The questionnaire examined environmental and psychosocial factors that may influence physical activity behaviours of the participants. A parent/guardian questionnaire about physical activity was also completed (Thompson and Wadsworth, 2012). Additional variables were included in the statistical model to take into consideration other factors that could explain physical activity within the participants. In order to standardize the variables across the three grades only results from the parent/ guardian survey were used within this study since the participants in grade three did not complete a self-report questionnaire. The following variables from the parent/guardian survey were include in the statistical model; sex, grade, and household income. An additional variable was created and included in the model to determine whether a participant lived in a rural or urban area. This variable was categorized based on postal codes and was classified as location. Postal codes that start with B0 indicated that the participant lived in a rural area while postal codes that started with B and any other number (i.e. B7) indicated that the participant lived in an urban area. These four variables were included in the model because there was strong evidence within the literature that these variables have a strong influence on the outcome of physical activity in youth.

4.5 Statistical Analysis

Logistic regression model was used to examine the relationship between access to neighbourhood greenness and physical activity in Nova Scotia youth. Logistic regression is commonly used is situations where the dependent variable has two possible outcomes. The outcomes are coded 0 or 1 where 1 is the noteworthy or success outcome and 0 is the contrary or failure outcome. The odds of success are based on the values of the independent variables. Within in this study the physical activity was coded based on Canadian physical activity guidelines where youth who achieved physical activity guidelines will be coded 1 and youth that have failed to meet physical activity guidelines will be coded 0. The reference category will be youth that failed to meet physical activity guidelines. The model will be interpreted based on odds ratio. Seven models, one for each buffer, were completed. Additional variables were included in the model in order to take into consideration other factors that could explain physical activity outcomes. Gender, grade, household income, and location were all included in the model. An interaction term between location and NDVI measurement was added to the model to determine if living in a rural or urban area would have an effect on the relationship between neighbourhood greenness and achieving physical activity guidelines. Interaction terms between the remaining variables were checked and dropped based on significance to the model. The final regression model was as followed:

Physical activity ~ NDVI + sex + grade + household income + location + NDVI: location + Gender: Grade

All models will be analysed in the statistical software R (version 3.0.1) and significance will be determined at $p < 0.05$.

5.0 Results

5.1 Descriptive Statistics

Of the 1887 participants at baseline, 194 individuals were removed due to no postal code data, essential for measuring neighbourhood greenness, and 102 individuals were removed due to no physical activity data. This resulted in a final sample size of 1591 participants. In general there were more female participants (58.6%) then male participants (41.4%). There was a notable decrease in the number participants in grade 11 only representing 20% of the sample size, while participants in grade 3 represented 42% and participants in grade 7 represented 38%. The highest income level ($80 000 or more) contained the majority of participants at ~30%. There was a notable decrease in the number of participants with decreasing income. It was also noted that 12.2% of participants did not provide income data. There was equal amount of participants living in both rural and urban areas. Table 2 further demonstrates demographic characteristics of participants within this study.

Table 2: Demographic characteristics of participants (n = 1591)

	Sample Size (n)	Percentage (%)
Gender		
Male	657	41.4
Female	932	58.6
Grade		
3	559	42
7	600	38
11	322	20
Income (per year)		
less than 30 000	233	14.6
30 000 – 49, 999	289	18.1
50 000 – 79, 999	399	25.1
80 000 or more	475	29.83
No answer	195	12.2
Location		
Rural	805	50.6
Urban	786	49.4

Achieving physical activity was considered obtaining more than 60 minutes of MVPA 6 days of the week. 62% of participants achieved physical activity guidelines, while 38% of participants failed to achieve physical activity guidelines. 69% of participants living in urban areas achieved physical activity guidelines while only 56.5% of participants living in rural areas achieved physical activity guidelines. In general males had higher average daily MVPA then females across all grades (Table 3). Average daily MPVA decreased with increasing grade (Table 3).

Table 3: Descriptive statistics of average daily MVPA levels of participants (n = 1591)

	Mean	**Medium**	**Standard Deviation**	**Maximum**	**Minimum**
Grade 3					
Male	131	129	50.7	352	7.57
Female	118	119	44.3	265	8.43
Grade 7					
Male	66.3	61.4	30.4	179	6.14
Female	47.7	45.0	22.8	121	1.71
Grade 11					
Male	37.4	34.1	21.1	102	6.00
Female	23.6	19.7	15.9	116	0.71

Overall Nova Scotia had an NDVI value of 0.823 which represents high vegetation levels. Figure 2 displays the vegetation map used to assess neighbourhood greenness. It is clear that the majority of Nova Scotia is covered in high or very high vegetation levels with a small amount of moderate vegetation level in more populated areas. On average the mean NDVI for each of the buffers ranged around 0.76 which is also considered a high vegetation level (Table 4). Furthermore, Figure 3 indicates that the majority of students live in high vegetated areas (43%), with very few participants (3%) living in low vegetated areas and no participants living in no vegetated areas at 0 km form the home location. This trend was seen in all buffers.

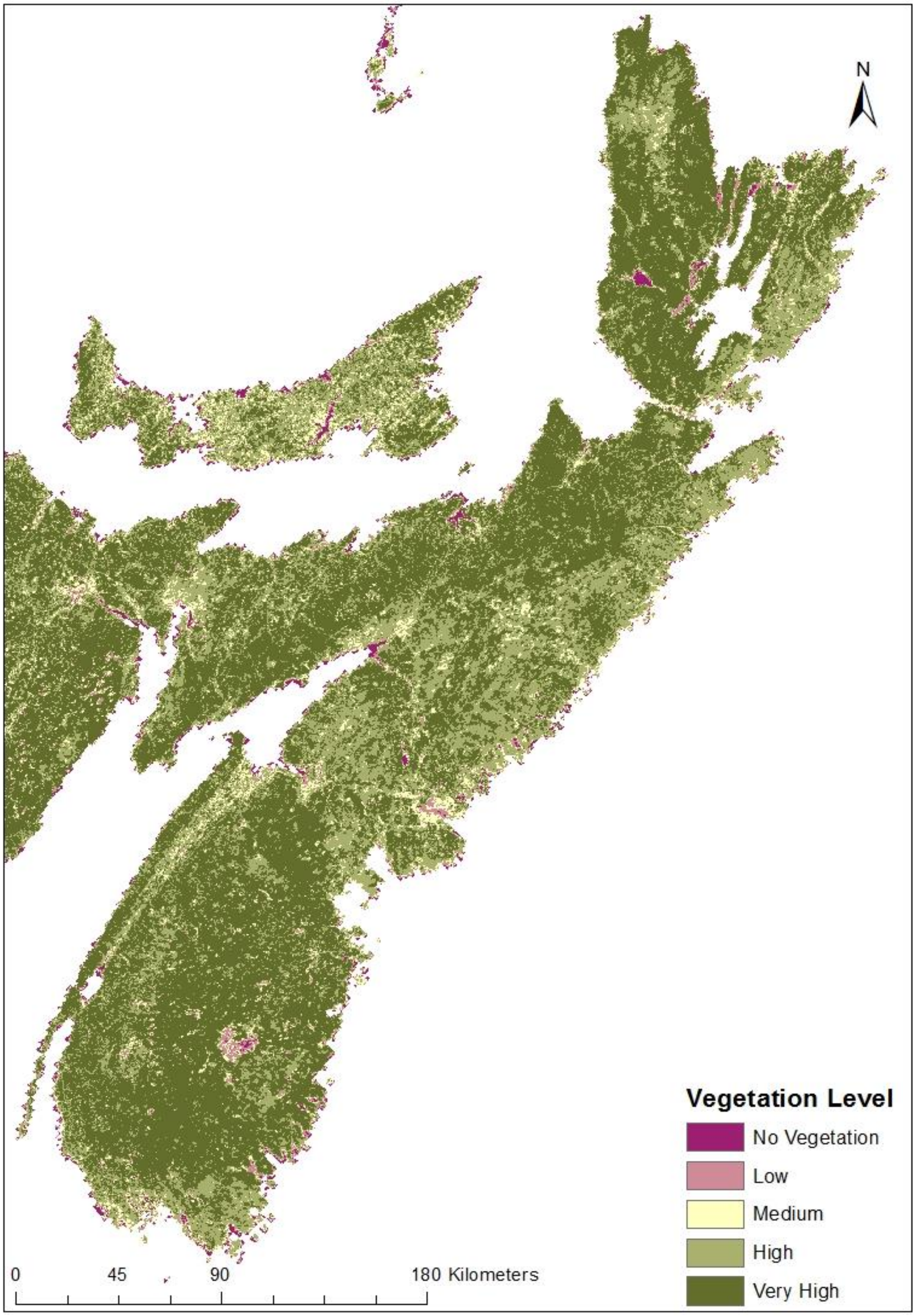

Figure 2: Vegetation map of Nova Scotia used to determine neighbourhood greenness for each participant. Vegetation level was measured using NDVI where values are as followed; No vegetation = – 1 to 0.2, Low = 0.25 to 0.55, Medium = 0.55 to 0.74, High = 0.74 to 0.85 , Very High = 0.85 to 1

Table 4: Descriptive statistics of NDVI (greenness) for each buffer

Buffer	Mean	Medium	Standard Deviation	Maximum	Minimum
0.0 km	0.771	0.806	0.095	0.908	0.291
0.5 km	0.754	0.800	0.146	0.899	0.424
1.0 km	0.758	0.791	0.119	0.892	0.411
1.5 km	0.771	0.794	0.079	0.897	0.414
2.0 km	0.771	0.787	0.078	0.898	0.468
2.5 km	0.771	0.792	0.075	0.895	0.476
3.0 km	0.773	0.792	0.073	0.893	0.527

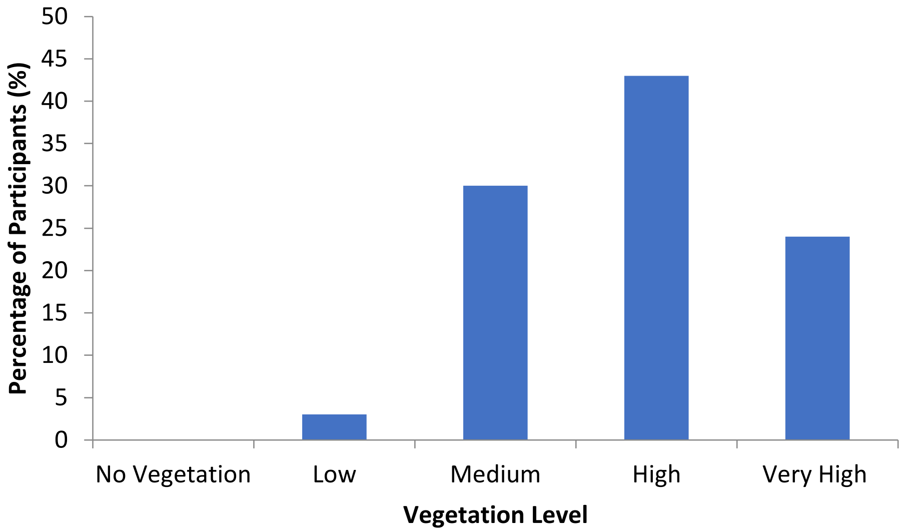

Figure 3: The percentage of participants living in different vegetation levels at 0 km from home location. Vegetation level was measured using NDVI where values are as followed; No vegetation = – 1 to 0.2, Low= 0.25 to 0.55, Medium = 0.55 to 0.74, High= 0.74 to 0.85 , Very High= 0.85 to 1

5.2 Logistic Regression Analysis

Seven logistic regressions models were competed, one for each buffer. Logistic regression results for all seven models are displayed in Tables 5 through 11 Table. For all models there was a significant association between achieving physical activity guidelines and gender and the interaction between grade and gender with P-values < 0.001. For all models the odds of achieving physical activity decreased within females and with increasing grade. This was support by daily average of MVPA observed in Table 3. Furthermore for all models, except the model looking at 1.5lm buffer, there was significant association between income level 1 ($30 000 – $49 999) and physical activity (P-values < 0.05). For the model looking at the 1.5km buffer, there was only a slight significance in income level 1 with a P-value of 0.056. For all models the odds of achieving physical activity decreased with increasing income. No significance was found in any of the other income levels.

There was no significant association between neighbourhood greenness and achieving physical activity guidelines (P-values > 0.05) in models examining buffers 0 km, 0.5 km, 1 km, 2 km, 2.5 km and 3 km. For these models it was also noted that there was no significant relationship between the odds of achieving physical activity guidelines and location (whether participants lived in urban or rural areas), or the interaction between neighbourhood greenness and location. It was however noticed there was a slight correlation between location and achieving physical activity at 0 km from the home (P-value = 0.094) where the odds of achieving physical activity increased with living in urban areas.

There was a significant association (P-value = 0.0049) between neighbourhood greenness and achieving physical activity guidelines within 1.5 km of the home location as seen in Table 8. The odds ratio was 1.0004 with a 95% confidence interval of 1.00 - 1.0008 indicating that for every one unit increase of greenness the odds of achieving physical activity guidelines increased by 0.04%. Within this model there was also a significant association between location and achieving physical activity with a P-value of 0.031. However, the large 95% CI of 1.46 – 2040 indicates that not much can be explained on location alone.

Table 5: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 0 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	0.0002 (-0.0001, 0.0004)	1.0002 (1.00, 1.0004)	0.15
Gender	0: Male			
	1: Female	0.28 (-0.36,0.93)	1.33 (0.69, 2.54)	0.39
Grade	0: Grade3			
	1: Grade 7	-1.76 (-2.32, -1.24)	0.17 (0.098, 0.29)	< 0.001*
	2: Grade 11	-3.65 (-4.28, -3.06)	0.026 (0.014, 0.05)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.51 (-1.02, -0.014)	0.60 (0.36, 0.99)	0.044*
	2: 50 k – 79, 999	-0.19 (-0.66, 0.28)	0.83 (0.52, 1.32)	0.43
	3: 80 k or more	0.18 (-0.29, 0.634)	1.19 (0.76, 1.88)	0.44
	4: no response	0.07 (-0.46, 0.603)	1.07 (0.63, 1.83)	0.80
location	0: Rural			
	1: Urban	2.14 (-0.35, 4.65)	8.47 (0.704, 104)	0.094
NDVI: location	Interaction	-0.0002 (-0.0005, 0.0001)	1.00 (0.999, 1.0001)	0.168
Grade1:sex1	Interaction	-1.54 (-2.28,-0.805)	0.214 (0.102, 0.447)	< 0.001*
Grade2:sex1	Interaction	-1.74 (-2.67, -0.82)	0.176 (0.069, 0.44)	< 0.001*
AIC = 1336.8				

Table 6: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 0.5 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	0.0002 (-0.0001, 0.0005)	1.0002 (1.00, 1.0005)	0.27
Gender	0: Male			
	1: Female	0.344 (-0.310, 1.002)	1.41 (0.734, 2.72)	0.30
Grade	0: Grade3			
	1: Grade 7	-1.75 (-2.32, -1.23)	0.173 (0.0986, 0.293)	<0.001*
	2: Grade 11	-3.58 (-4.21, -2.99)	0.028 (0.015, 0.05)	<0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.544 (-1.05, -0.0402)	0.581 (0.349 0.961)	0.034*
	2: 50 k – 79, 999	-0.243 (-0.718, 0.228)	0.784 (0.488, 1.26)	0.31
	3: 80 k or more	0.108 (-0.354, 0.568)	1.11 (0.702, 1.77)	0.64
	4: no response	-0.008 (-0.548, 0.530)	0.991 (0.578, 1.70)	0.98
Location	0: Rural			
	1: Urban	1.7119 -1.5117 4.9515	5.54 (0.22, 141)	0.30
NDVI: Location	Interaction	-0.0002 (-0.001, 0.0002)	1.00 (0.999, 1.0002)	0.45
Grade1:Sex1	Interaction	-1.59 (-2.34, -0.846)	0.204 (0.096, 0.429)	< 0.001*
Grade2:Sex1	Interaction	-1.89 (-2.84, -0.957)	0.15 (0.058, 0.384)	< 0.001*
AIC = 1305.9				

Table 7: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 1 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	-0.579 (-2.24, 0.897)	1.0002 (1.00, 1.0006)	0.202
Gender	0: Male			
	1: Female	0.282 (-0.366, 0.930)	1.33 (0.694, 2.53)	0.39
Grade	0: Grade3			
	1: Grade 7	-1.74 (-2.31, -1.22)	0.175 (0.099, 0.296)	< 0.001*
	2: Grade 11	-3.63 (-4.26, -3.04)	0.0265 (0.014, 0.046)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.537 (-1.04, -0.0352)	0.584 (0.35, 0.965)	0.037*
	2: 50 k – 79, 999	-0.191 (-0.664, 0.279)	0.826 (0.515, 1.32)	0.43
	3: 80 k or more	0.171 (-0.289, 0.631)	1.19 (0.749, 1.88)	0.46
	4: no response	0.069 (-0.465, 0.604)	1.07 (0.628, 1.83)	0.80
Location	0: Rural			
	1: Urban	2.51 (-0.839, 5.85)	12.26 (0.432, 348)	0.14
NDVI: Location	Interaction	-0.0003 (-0.001, 0.0002)	1.00 (0.999, 1.0002)	0.22
Grade1:Sex1	Interaction	-1.55 (-2.29, -0.815)	0.211 (0.101, 0.442)	<0.001*
Grade2:Sex1	Interaction	-1.73 (-2.67, -0.818)	0.177 (0.069, 0.441)	<0.001*
AIC = 1327				

Table 8: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 1.5 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	0.0004 (0.00, 0.0008)	1.0004 (1.00, 1.0008)	0.049*
Gender	0: Male			
	1: Female	0.28 (-0.369, 0.926)	1.32 (0.692, 2.52)	0.39
Grade	0: Grade3			
	1: Grade 7	-1.76 (-2.32, -1.23)	0.173 (0.099, 0.293)	< 0.001*
	2: Grade 11	-3.67 (-4.29, -3.07)	0.026 (0.014, 0.046)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.487 (-0.989, 0.011)	0.614 (0.372 1.01)	0.056
	2: 50 k – 79, 999	-0.155 (-0.626, 0.314)	0.856 (0.534, 1.37)	0.52
	3: 80 k or more	0.226 (-0.233, 0.685)	1.26 (0.792, 1.20)	0.33
	4: no response	0.11 (-0.424, 0.644)	1.12 (0.654, 1.91)	0.69
Location	0: Rural			
	1: Urban	3.98 (0.376, 7.62)	53.6 (1.46, 2040)	0.031*
NDVI: Location	Interaction	-0.0005 (-0.001, 0.00)	0.1 (0.999, 1.00)	0.052
Grade1:Sex1	Interaction	-1.56 (-2.30, -0.819)	0.211 (0.101, 0.441)	< 0.001*
Grade2:Sex1	Interaction	-1.72 (-2.66, -0.811)	0.178 (0.07, 0.445)	< 0.001*
AIC = 1333.6				

Table 9: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 2 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Independent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Dependent				
NDVI	Greenness	0.0003 (-0.0001, 0.0007)	1.0003 (1.00, 1.0007)	0.16
Gender	0: Male			
	1: Female	0.279 (-0.368, 0.926)	1.32 (0.692, 2.52)	0.39
Grade	0: Grade3			
	1: Grade 7	-1.77 (-2.33, -1.24)	0.171 (0.097, 0.288)	< 0.001*
	2: Grade 11	-3.68 (-4.31, -3.09)	0.025 (0.013, 0.045)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.509 (-1.01, -0.012)	0.601 (0.364, 0.988)	0.045*
	2: 50 k – 79, 999	-0.18 (-0.649, 0.288)	0.836 (0.522, 1.33)	0.45
	3: 80 k or more	0.194 (-0.263, 0.650)	1.21 (0.769, 1.92)	0.40
	4: no response	0.086 (-0.446, 0.618)	1.09 (0.640, 1.86)	0.75
Location	0: Rural			
	1: Urban	2.97 (-0.639, 6.602)	19.5 (0.528, 736)	0.11
NDVI: Location	Interaction	-0.0003 (-0.0008, 0.0001)	1.00 (0.999, 1.0001)	0.16
Grade1:Sex1	Interaction	-1.54 (-2.28, -0.803)	0.214 (0.102, 0.448)	< 0.001*
Grade2:Sex1	Interaction	-1.71, (-2.64, -0.795)	0.181 (0.071, 0.452)	< 0.001*
AIC = 1337.3				

Table 10: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 2.5 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	0.0002 (-0.0002, 0.0007)	1.0002 (1.00, 0.0007)	0.27
Gender	0: Male			
	1: Female	0.285 (-0.362, 0.932)	1.33 (0.696, 2.54)	0.38
Grade	0: Grade3			
	1: Grade 7	-1.76 (-2.33, -1.24)	0.172 (0.098, 0.291)	< 0.001*
	2: Grade 11	-3.67 (-4.30, -3.08)	0.025 (0.014, 0.046)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.51 (-1.01, -0.011)	0.601 (0.363, 0.989)	0.046*
	2: 50 k – 79, 999	-0.202 (-0.672, 0.267)	0.817 (0.51, 1.31)	0.40
	3: 80 k or more	0.201 (-0.257, 0.659)	1.22 (0.773, 1.93)	0.39
	4: no response	0.085 (-0.448, 0.619)	1.09 (0.639, 1.86)	0.75
Location	0: Rural			
	1: Urban	2.31 (-1.59, 6.21)	10 (0.204, 500)	0.25
NDVI: Location	Interaction	-0.0002 (-0.0007, 0.0002)	1.00 (0.999, 1.0002)	0.33
Grade1:Sex1	Interaction	-1.56 (-2.30, -0.83)	0.21 (0.10, 0.438)	< 0.001*
Grade2:Sex1	Interaction	-1.72 (-2.65, -0.802)	0.180 (0.0705, 0.448)	< 0.001*
AIC = 1334.6				

Table 11: Results from logistic regression looking at the association of neighbourhood greenness and physical activity at 3 km from the home location. Values of statistical significance (P-value < 0.005) are indicated with *.

Variables	Definition	β (95%)	OR (95%)	P-value
Dependent				
MVPA	0: Did not achieve PA guidelines			
	1: Achieved PA guidelines			
Independent				
NDVI	Greenness	0.0001 (-0.0003, 0.0006)	1.0001 (1.00, 1.0006)	0.54
Gender	0: Male			
	1: Female	0.277 (-0.370, 0.924)	1.32 (0.691, 2.52)	0.40
Grade	0: Grade3			
	1: Grade 7	-1.77 (-2.33, -1.25)	0.170 (0.097, 0.287)	< 0.001*
	2: Grade 11	-3.67 (-4.31, -3.09)	0.025 (0.013, 0.046)	< 0.001*
Income	0: less than 30 k			
	1: 30 k – 49, 999	-0.515 (-1.02, -0.017)	0.598 (0.362, 0.983)	0.043*
	2: 50 k – 79, 999	-0.186 (-0.656, 0.281)	0.830 (0.519, 1.32)	0.44
	3: 80 k or more	0.186 (-0.272, 0.643)	1.205 (0.762, 1.90)	0.42
	4: no response	0.08 (-0.453, 0.613)	1.083 (0.636, 1.85)	0.77
Location	0: Rural			
	1: Urban	1.70 (-2.33, 5.74)	5.48 (0.097, 312)	0.41
NDVI: Location	Interaction	-0.0002 (-0.0007, 0.0003)	1.00 (0.999, 1.0003)	0.52
Grade1:Sex1	Interaction	-1.54 (-2.28, -0.803)	0.214 (0.102, 0.448)	< 0.001*
Grade2:Sex1	Interaction	-1.71 (-2.64, -0.795)	0.181 (0.071, 0.452)	< 0.001*
AIC = 1339.7				

6.0 Discussion

The main of objective of this study was to investigate if there was a relationship between neighbourhood greenness and physical activity among a sample of Nova Scotia youth in grades 3, 7, and 11 (ages 8, 12 and 16). The major findings of this study were that there was no significant association (P-valve > 0.05) between neighbourhood greenness and physical activity in youth 0 km, 0.5 km, 1 km, 2 km, 2.5 km, and 3 km from home locations. A positive association between neighbourhood greenness and achieving physical activity guidelines was seen at 1.5 km distance from participants home (P-value 0.049), with an odds ratio was 1.0004 indicating that for every one unit increase of greenness the odds of achieving physical activity guidelines increased by 0.04%. Living in a rural or urban area did not have a significant impact on the relationship between physical activity and neighbourhood greenness.

6.1 Comparison with Other Studies

This study is one of the larger studies addressing this question (n = 1591). Other studies have varied from a sample size of 57 (Roemmich *et al*, 2006) to 13, 927 (Foster *et al*, 2009). This study is also addressing this question at a provincial scale. Majority of studies address this question at a local scale. However, a few were identified as national wide studies, two being located in Canada (McMorris *et al*, 2014; Janssen and Rosu, 2015). Like similar studies, this study only looked at youth ages 8 to 16 (Roemmich *et al*, 2006; Wheeler *et al*, 2010; Almanza *et al*, 2012). However, majority of studies addressing this question look at adult populations. As previously mentioned, methods used to measure physical activity and neighbourhood greenness varied across studies making it difficult to compare results.

The positive association between neighbourhood greenness and physical activity in youth found within in this study was consistent with Janssen and Rosu (2015) were the proportion of neighbourhood land covered by treed areas was associated with physical activity outcomes (P-value = 0.02) with a 5% increase in the odds of increasing physical activity outside school hours for every 5% increase in the proportion of neighbourhood land covered by treed areas. Janssen and Rosu (2015) study looked at Canadian students in grade 6 to 8 (ages 11 to 13) using self-reported data was used to measure physical activity and 1 km circular buffers were used to measure neighbourhood accessibility. The results from this study were also consistent with Wheeler et al (2010) were a significant increased odds of MVPA (OR = 1.37) occurring green spaces was observed in 10 – 11 years boys. These authors used land use data to classify green space, accelerometers to measure physical activity and GPS to determine locations of activity within participant's neighbourhood.

Out of studies using NDVI to quantify neighbourhood greenness results from this study were consistent with Almanza et al (2012) where neighbourhood greenness was positively associated with physical activity with a 34% to 39% increase in odds of MVPS for every 0.11 value increase in NDVI. This study used accelerometers to measure physical activity and GPS to determine locations of activity in the participant's neighbourhood. Results from this study, however, were not consistent with Besenyi et al (2014) where no association between NDVI greenness measure and physical activity in urban and rural middle-school youth (n = 303). This study also used accelerometers to measure physical activity and 0.5 mile (~ 0.8 km) network buffer to measure neighbourhood access.

6.2 Interpretation of Results

Multiple buffers to measure accessibility to greenness where used within in this study. This was done in order to consider the range of buffers used in past studies, ranging from 0.4 km to 3 km, averaging around 1 km. Using multiple buffers can also aid in assess if there is a threshold at what distance from a home location will affect the relationship between physical activity and neighbourhood greenness. McMorris *et al* (2014) stated that if urban greenness promotes increased participation in physical activity, the strength of the association should vary across different buffer distances. From this it could be expected that buffer sizes should cause a variation in results. This could explain why there was an association found between neighbourhood greenness and physical activity at 1.5 km away from participants home and no other buffers. This could suggest that 1.5 km is the threshold at which neighbourhood greenness influences physical activity in youth. However, previous studies using multiple buffers found little difference in strength of the association between buffers (McMorris *et al*, 2014).

It was noted that although there was a correlation found between neighbourhood greenness and physical activity in youth at 1.5 km away from the home location, the odds ratios was 1.0004 only indicating a 0.04% increase in odds of achieving physical activity with increasing greenness. This was quit small in comparison to the study done by Almanza *et al* (2012) were a 34% increase in odds of achieving physical activity with increasing greenness was observed. This suggests that although a significant, the relationship between neighbourhood greenness and odds of achieving physical activity is very weak and that not much conclusion can be dawn on this result.

There are some mechanisms that could have influenced the results of this study. One possible explanation could be the exposure measure. For this study NDVI data at 250 m resolution was used, giving this study a benefit over previous work. NDVI is able to capture all vegetation in an area, avoid bias introduced by self-reported measure and can be assigned to all participants. However, when looking at previous studies using NDVI most studies used data that was at 30 m to 90 m resolutions (Tilt *et al*, 2007; Almanza *et al*, 2012; Besenyi *et al*, 2014). This would result in a more precise measure of neighbourhood greenness within these studies. These used NDVI data from Landsat while this study used NDVI data from MODIS. This study was looking at the entire province on Nova Scotia and NDVI data taken in the same year and month was desired. MODIS provided a NDVI dataset that spanned across the whole province while Landsat did not. Although Landsat provides a higher resolution within the data, Landsat datasets do not cover all of Nova Scotia thus multiple datasets would have been needed. However, due to could cover and missing data, no Landsat data could have been processed for Nova Scotia that was taken in the same time frame. This was not an issue for other studies as the majority of them were only looking at neighbourhood greenness within a city or urban area resulting only one Landsat image necessary. It is recognized that an NDVI dataset with a smaller resolution would have given a more precise measurement of neighbourhood greenness and possible influenced the results.

It was also observed within this study that the mean NDVI value for all of Nova Scotia was 0.823 which is considered a very high vegetation level. Furthermore the majority of participants lived in high vegetated areas (NDVI value of 0.74 to 0.85) with very few (3%) living in low vegetated areas. This suggests that there may be insufficient heterogeneity of greenness level. This could explain the inclusions results found within this study. Previous studies using NDVI data as a measure of greenness had an equal amount of participants living in both low and high vegetated areas (Almanza *et al*, 2012; McMorris *et al*, 2014). However, these studies only looked at individuals living in urban areas. Including participants in rural areas could have caused the significant difference in participants living in high or low vegetated areas. It is also possible that parents choose to live in greener neighbourhoods because they had families resulting in majority of participants living in high vegetated areas.

Another possible mechanism causing the inclusive results could exclusion of light physical activity in the physical activity measurement. Currently the Canadian physical activity guideline (used to assess physical activity) does not consider light physical activity in its measure of physical fitness. However, light physical activity, such as walking or light biking, may play a major role in health and could be equally as import as meeting the necessary MVPA guidelines. There has been some evidence that greener environment influence light physical activity such as walking, biking or gardening. A recent Canadian wide study using accelerometers and NDVI data found that residential proximity to greenness was associated with increased participation in leisure-time physical activities and that the association was strongest among young adults (McMorris *et al*, 2014). Maas *et al* 2008 found a positive association with cycling and gardening with increase access to green spaces with in an individual's neighbourhood. However, overall there have been few studies looking at light physical activity and the influence of neighbourhood greenness. Including a light physical activity measure within the model could have provided more information on physical activity in youth and impact of neighbourhood greenness.

6.3 Strengths and Weaknesses of the Study

The strengths of this study include the use of a large dataset from a provincial wide sample. This study used an objective validated measure of neighbourhood greenness that was taken close in time to the physical activity variable. This study also used an objective measure of physical activity. Participants living in both urban and rural areas were including within in this study. This aspect makes this study unique as majority of past work only evaluated the relationships between neighbourhood greenness and physical activity in youth living in urban areas. Finally this study had a diverse income range. This was particularly important for working towards understanding activity behaviors of low-income minorities who are especially vulnerable to obesity (Cohen *et al*., 2007).

Weaknesses of this study include accelerometers where not worn during water based activity, such as swimming or sailing, resulting in an underestimation of physical activity. Accelerometers were also worn during all waking hours, providing physical activity data that takes place outside of the neighbourhood setting. However, within in this study only the effect of neighbourhood greenness on physical activity was evaluated. Finally, only postal codes were available for home locations. Although postal codes are widely accepted variable for determining home location, the accuracy of home location decreases with participants living in rural communities since rural postal code areas are very large.

This study was delimited to only investigating the relationship between neighbourhood greenness and its influence on physical activity within youth. This was due to the time constraint of the study. Self-reported questioners from Keeping Pace included additional variables, such as safety barriers, that could have further explain the relationship between neighbourhood greenness and physical activity in youth, However, these were not included in the model. The relationship between physical activity in youth and its impact on greenness of their residing neighbourhoods was not investigated as children cannot choose where they live. This study also did not consider the impact of the home, school or outside neighbourhood environments. Analyses with the excluded data could improve understanding of children's overall activity behavior. Furthermore, physical activity was only be assessed during spring and summer seasons, as season variation has been shown to impact physical activity (Wheeler et al, 2010).

7.0 Conclusion

7.1 Research Focus

Physical activity has been declining at an alarming rate in youth, particularly in the transition from adolescents to adulthood. This trend is also seen in youth within Nova Scotia where many youth do not meet the recommended physical activity guidelines defined by the Canadian Government. As physical activity is an important factor of child growth, there is a high demand for research that investigates the causes behind variations in levels of physical activity. Exposure to green environments has shown to have positive health benefits. However, it is unclear how neighbourhood greenness influences this trend. With mixed findings within in the literature, there is still some uncertainty about whether there is a causal relationship between neighbourhood greenness and physical activity. More research is needed to understand this trend. To date there has been no research in Nova Scotia looking at the relationship between access to neighbourhood greenness and physical activity among youth. The objective of this study is to investigate the relationship between access to neighbourhood greenness and physical activity levels among a sample of youth in Nova Scotia.

7.2 Main Findings

The major findings of this study were that there was no significant association (P-valve > 0.05) between neighbourhood greenness and physical activity in youth 0 km, 0.5 km, 1 km, 2 km, 2.5 km, and 3 km from home locations. A positive association between neighbourhood greenness and achieving physical activity guidelines was seen at 1.5 km distance from participants home (P-value 0.049), with an odds ratio was 1.0004 indicating that for every one unit increase of greenness the odds of achieving physical activity guidelines increased by 0.04%. This suggests that although a significant, the relationship between neighbourhood greenness and odds of achieving physical activity is very weak and that not much conclusion can be dawn on this result. It was also found that living in a rural or urban area did not have a significant impact on the relationship between physical activity and neighbourhood greenness.

7.3 Implication, Significance and Future Research

With the increase in physical inactivity and rates of obesity among youth in Nova Scotia, research is needed to investigate underlying causes as well as ways to increase physical activity levels. Although findings were inclusive, this study contributes to the current literature on the relationship between neighbourhood greenness and physical activity in youth, thus furthering our understanding of the relationship. Knowledge of this relationship can have a direct result on polices or strategies that aim to improve physical activity in youth, particularly in terms of increasing greenness in residential locations, such as increasing tree cover or designated green spaces. Results from this study also open up areas for future research. Future studies are recommended to build on this study design. It is recommended that studies use a higher resolution NDVI to get a more precise measurement of neighbourhood greenness. It is recommended that a light physical activity measurement be included in the model to provide a better understanding of the impact neighbourhood greenness has on overall physical activity levels. Future studies should also look at how perceptions of neighbourhood safety impact physical activity in youth. In previous studies it has been found that higher perceived neighborhood safety is associated with higher odds of the physical activity outcome (Carver *et al*, 2008). However, to date there is no study in Nova Scotia looking at the relationship between perceived neighbourhood safety and physical activity in youth. Furthermore, research should explore the specific dimensions of green environments that contribute to greater physical activity and health among youth.

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9.0 References

Allison, K. R., Adlaf, E. M., Dwyer, J. J., Lysy, D. C., and Irving, H. M. (2007). The decline in physical activity among adolescent students: a cross-national comparison. *Canadian Journal of Public Health/Revue Canadienne de Sante'e Publique*, 97-100.

Almanza, E., Jerrett, M., Dunton, G., Seto, E., and Ann Pentz, M. (2012). A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. *Health & place*, *18*(1), 46-54.

Bedimo-Rung, A. L., Mowen, A. J., and Cohen, D. A. (2005). The significance of parks to physical activity and public health: a conceptual model. *American journal of preventive medicine*, *28*(2), 159-168.

Besenyi, G. (2014). Associations of neighborhood greenness with objectivity measured physical activity in urban and rural middle school youth. In 142nd APHA Annual Meeting and Exposition (November 15-November 19, 2014). APHA.

Bell, J. F., Wilson, J. S., and Liu, G. C. (2008). Neighborhood greenness and 2-year changes in body mass index of children and youth. *American journal of preventive medicine*, *35*(6), 547-553.

Biddle, S. J., Gorely, T., and Stensel, D. J. (2004). Health-enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of sports sciences*, *22*(8), 679-701.

Brodersen, N. H., Steptoe, A., Boniface, D. R., and Wardle, J. (2007). Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. *British journal of sports medicine*, *41*(3), 140-144.

Bow, C. J. D., Waters, N. M., Faris, P. D., Seidel, J. E., Galbraith, P. D., Knudtson, M. L., and Ghali, W. A. (2004). Accuracy of city postal code coordinates as a proxy for location of residence. *International Journal of Health Geographics, 3(1),* 5.

Campagna, P., Ness, G. W., and Murphy, R. J. (2002). *Physical activity levels in children and youth in the province of Nova Scotia* (pp. 1-27). Sport and Recreation Commission, Government of Nova Scotia.

Carver, A., Timperio, A., & Crawford, D. (2008). Playing it safe: The influence of neighbourhood safety on children's physical activity—A review. *Health & place*, *14*(2), 217-227.

Cohen, D. A., Ashwood, J. S., Scott, M. M., Overton, A., Evenson, K. R., Staten, L. K., Porter, D., McKenzie, T.L, and Catellier, D. (2006). Public parks and physical activity among adolescent girls. *Pediatrics*, *118*(5), e1381-e1389.

Cohen, D. A., McKenzie, T. L., Sehgal, A., Williamson, S., Golinelli, D., and Lurie, N. (2007). Contribution of public parks to physical activity. *American Journal of Public Health*, *97*(3), 509-514.

Colley, R. C., Garriguet, D., Janssen, I., Craig, C. L., Clarke, J., and Tremblay, M. S. (2011). Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey.

Coombes, E., Jones, A. P., and Hillsdon, M. (2010). The relationship of physical activity and overweight to objectively measured green space accessibility and use. *Social science & medicine, 70(6),* 816-822.

Cooper, A. R., Page, A. S., Wheeler, B. W., Hillsdon, M., Griew, P., and Jago, R. (2010). Research Patterns of GPS measured time outdoors after school and objective physical activity in English children: the PEACH project.

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., and Brage, S. (2008). Assessment of physical activity in youth. *Journal of Applied Physiology*,*105*(3), 977-987.

CSEP. (2011). *Physical Activity Guidelines Handbook*. Retrieved from http://www.csep.ca/CMFiles/Guidelines/CSEP_Guidelines_Handbook.pdf

Deckelbaum, R. J., & Williams, C. L. (2001). Childhood obesity: the health issue. *Obesity research*, *9*(S11), 239S-243S.

Dehghan, M., Akhtar-Danesh, N., and Merchant, A. T. (2005). Childhood obesity, prevalence and prevention. *Nutrition journal*, *4*(1), 24.

Dietz, W. H. (2005). Physical Activity Recommendations: Where do we go from here?. *The Journal of pediatrics*, *146*(6), 719-720.

Ding, D., Sallis, J. F., Kerr, J., Lee, S., and Rosenberg, D. E. (2011). Neighborhood environment and physical activity among youth: a review.*American journal of preventive medicine*, *41*(4), 442-455.

Dunton, G. F., Liao, Y., Intille, S., Wolch, J., and Pentz, M. A. (2011). Physical and social contextual influences on children's leisure-time physical activity: an ecological momentary assessment study. *Journal of physical activity and health*, *8*(Suppl. 1), S103-8.

Dunton, G. F., Almanza, E., Jerrett, M., Wolch, J., and Pentz, M. A. (2014). Neighborhood Park Use by Children: Use of Accelerometry and Global Positioning Systems. *American journal of preventive medicine*, *46*(2), 136-142.

Esri. (2012). Zonal Statistics as Table (Spatial Analyst). Retrieved November 28, 2014 from http://resources.arcgis.com/en/help/main/10.1/index.html#/Zonal_Statistics_as_Table/009z000000w8000000/

Esri, Clark, S., and The Wetlands Conservancy. (2012). ZonalStatsOverlappingPolys. Retrieved on February 20, 2015 from http://www.arcgis.com/home/item.html?id=b859b33c616a47d2b99b5e133942db02

Foster, C., Hillsdon, M., Jones, A., Grundy, C., Wilkinson P., White, M., Sheehan, B., and Thorogood, M. (2009). Objective measures of the environment and physical activity—results of the environment and physical activity study in english adults. *Journal of Physical Activity and Health, 6 (suppl 1)* S70–S80

Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., and Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American journal of preventive medicine*, *28*(2), 117-125.

Giles-Corti, B., Broomhall, M. H., Knuiman, M., Collins, C., Douglas, K., Ng, K., Lange, A., and Donovan, R. J. (2005). Increasing walking: how important is distance to, attractiveness, and size of public open space?. *American journal of preventive medicine*, *28*(2), 169-176.

Goran, M. I., Reynolds, K. D., and Lindquist, C. H. (1999). Role of physical activity in the prevention of obesity in children. *International Journal of Obesity*, *23*, S18-S33.

Herman, K. M., Craig, C. L., Gauvin, L., and Katzmarzyk, P. T. (2009). Tracking of obesity and physical activity from childhood to adulthood: the Physical Activity Longitudinal Study. *International Journal of Pediatric Obesity*, *4*(4), 281-288.

Hillsdon, M., Panter, J., Foster, C., and Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. *Public health*, *120*(12), 1127-1132.

Hoehner, C. M., Brennan Ramirez, L. K., Elliott, M. B., Handy, S. L., and Brownson, R. C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American journal of preventive medicine*,*28*(2), 105-116.

Janssen, I. (2014). Crime and perceptions of safety in the home neighborhood are independently associated with physical activity among 11–15year olds. *Preventive medicine*, *66*, 113-117.

Janssen, I., and Rosu, A. (2015). Undeveloped green space and free-time physical activity in 11 to 13-year-old children. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 26.

Joens-Matre, R. R., Welk, G. J., Calabro, M. A., Russell, D. W., Nicklay, E., and Hensley, L. D. (2008). Rural–urban differences in physical activity, physical fitness, and overweight prevalence of children. *The Journal of rural health*,*24*(1), 49-54.

Kaczynski, A. T., Potwarka, L. R., Smale, B. J., and Havitz, M. E. (2009). Association of parkland proximity with neighborhood and park-based physical activity: Variations by gender and age. *Leisure Sciences*, *31*(2), 174-191

Kelly, L. A., McMillan, D. G., Anderson, A., Fippinger, M., Fillerup, G., and Rider, J. (2013). Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC medical physics*, *13*(1), 5.

Klinker, C. D., Schipperijn, J., Kerr, J., Ersbøll, A. K., and Troelsen, J. (2014). Context-specific outdoor time and physical activity among school-children across gender and age: using accelerometers and GPS to advance methods. *Frontiers in public health, 2*.

Lachowycz, K., and Jones, A. P. (2011). Greenspace and obesity: a systematic review of the evidence. *Obesity reviews*, *12*(5), e183-e189.

Lackey, K. J., and Kaczynski, A. T. (2009). Correspondence of perceived vs. objective proximity to parks and their relationship to park-based physical activity. *International Journal of Behavioral Nutrition and Physical Activity*, *6*(1), 53.

Lee, I. M. (2003). Physical activity and cancer prevention--data from epidemiologic studies.

Medicine and Science in Sports and Exercise, *35(11)*, 1823-1827.

Lee, A. C. K., and Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health, 33*(2), 212-222.

Liu, G. C., Wilson, J. S., Qi, R., and Ying, J. (2007). Green neighborhoods, food retail and childhood overweight: differences by population density. *American Journal of Health Promotion*, *21*(4s), 317-325.

Maas, J., Van Dillen, S. M., Verheij, R. A., and Groenewegen, P. P. (2009). Social contacts as a possible mechanism behind the relation between green space and health. *Health & place*, *15*(2), 586-595

Maas, J., Verheij, R. A., Groenewegen, P. P., De Vries, S., and Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation?.*Journal of epidemiology and community health*, *60*(7), 587-592.

Maas J.,Verheij R.A., Spreeuwenberg P, and Groenewegen P, P. (2008). Physical activity as a possible mechanism behind the relationship between green space and health: A multilevel analysis. *BMC Public Health, 8(206)*

Mackett, R., Brown, B., Gong, Y., Kitazawa, K., and Paskins, J. (2007). Children's independent movement in the local environment. *Built Environment (1978-)*, 454-468.

McCormack, G. R., Giles-Corti, B., and Bulsara, M. (2008). The relationship between destination proximity, destination mix and physical activity behaviors.*Preventive medicine*, *46*(1), 33-40.

McMorris, O., Villeneuve, P. J., Su, J., and Jerrett, M. (2015). Urban greenness and physical activity in a national survey of Canadians. Environmental research, 137, 94-100.

Mitchell, R., and Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *Lancet*, *372 (9650*), 1655–1660

Mytton, O.T., Townsend, N., Rutter, H., and Foster, C. (2012) Green space and physical activity: an observational study using Health Survey for England data. *Health & Place*, *18 (5)*, pp. 1034–1041

Nader, P. R., O'Brien, M., Houts, R., Bradley, R., Belsky, J., Crosnoe, R., and Susman, E. J. (2006). Identifying risk for obesity in early childhood. *Pediatrics*,*118*(3), e594-e601.

Oliver, L. N., Schuurman, N., and Hall, A. W. (2007). Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. *International journal of health geographics*, *6*(1), 41.

Ord, K., Mitchell, R., & Pearce, J. (2013). Is level of neighbourhood green space associated with physical activity in green space?. *Int. J. Behav. Nutr. Phys. Act*, *10*, 127.

PHAC. (2011). The Chief Public Health Officer's Report on the State of Public Health in Canada, 2011. Retrieved on November 28, 2014 from http://www.phac-aspc.gc.ca/cphorsphc-respcacsp/2011/index-eng.php

Potwarka, L. R., Kaczynski, A. T., and Flack, A. L. (2008). Places to play: association of park space and facilities with healthy weight status among children. *Journal of community health*, *33*(5), 344-350.

Rainham, D. G., Bates, C. J., Blanchard, C. M., Dummer, T. J., Kirk, S. F., and Shearer, C. L. (2012). Spatial classification of youth physical activity patterns. *American journal of preventive medicine*, *42*(5), e87-e96.

Rhew, I. C., Vander Stoep, A., Kearney, A., Smith, N. L., and Dunbar, M. D. (2011). Validation of the normalized difference vegetation index as a measure of neighborhood greenness. *Annals of epidemiology*, *21*(12), 946-952.

Richardson, E.A., Mitchell, R., Hartig, T., de Vries, S., Astell-Burt, T., and Frumkin, H. (2012). Green cities and health: a question of scale? *Journal Epidemiology Community Health, 66 (2),* pp. 160–165

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J., and Winiewicz, D. (2006). Association of access to parks and recreational facilities with the physical activity of young children. *Preventive Medicine, 43,* 437–441.

Roberts, K. C., Shields, M., de Groh, M., Aziz, A., and Gilbert, J. A. (2012). Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian Health Measures Survey. *Health rep*, *23*(3), 37-41.

Rothman, K. J. (2012). *Epidemiology: an introduction*. Oxford University Press.

Rowlands, A. V. (2007). Accelerometer assessment of physical activity in children: an update. *Pediatric Exercise Science*, *19*(3), 252.

Shields M. (2006). Overweight and obesity among children and youth. *Health Reports;17(3):* 27- 42.

Solano, R., Didan, K., Jacobson, A., and Huete, A. (2010). MODIS vegetation index user's guide

(MOD13 series). *The University of Arizona*.

Steinbeck, K. S. (2001). The importance of physical activity in the prevention of overweight and obesity in childhood: a review and an opinion. *Obesity reviews*, *2*(2), 117-130.

Sugiyama, T., Francis, J., Middleton, N. J., Owen, N., and Giles-Corti, B. (2010). Associations between recreational walking and attractiveness, size, and proximity of neighborhood open spaces. *Journal Information*, *100*(9).

Telama, R., and Yang, X. (2000). Decline of physical activity from youth to young adulthood in Finland. *Medicine and science in sports and exercise*, *32*(9), 1617-1622.

Thompson, A. M., Campagna, P. D., Rehman, L. A., Murphy, R. J., Rasmussen, R. L., and Ness, G. W. (2005). Physical activity and body mass index in grade 3, 7, and 11 Nova Scotia students. *Medicine and science in sports and exercise*, *37*(11), 1902-1908.

Thompson, A. M., and Wadsworth, L. A. (2012). *Keeping Pace: Physical Activity and Healthy Eating Among Children and Youth: Key Findings from the 2009-2010 Study*. Government of Nova Scotia.

Tilt, J. H., Unfried, T. M., and Roca, B. (2007). Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington. *American Journal of Health Promotion, 21(4s*), 371-379.

Timperio, A., Crawford, D., Telford, A., and Salmon, J. (2004). Perceptions about the local neighborhood and walking and cycling among children. *Preventive Medicine, 38*, 39–47.

USGS. (2015). NDVI, the Foundation for Remote Sensing Phenology. Retrieved on March 10, 2015 from http://phenology.cr.usgs.gov/ndvi_foundation.php

Van den Berg, A. E., Maas, J., Verheij, R. A., and Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social science & medicine*, *70*(8), 1203-1210.

Van der Horst, K., Paw, M. J. C. A., Twisk, J. W., and Van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine and science in sports and exercise*, *39*(8), 1241.

Veugelers, P. J., and Fitzgerald, A. L. (2005). Prevalence of and risk factors for childhood overweight and obesity. *Canadian Medical Association Journal*,*173*(6), 607-613.

Warburton, D. E., Nicol, C. W., and Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *Canadian medical association journal*, *174*(6), 801-809.

Wen, L.M., Kite, J., Merom, D., and Rissel, C. (2009). Time spent playing outdoors after school and its relationship with independent mobility: a cross-sectional survey of children aged 10-12 years in Sydney, Australia. *International Journal of Nutrition and Physical Activity*, 6:15.

Witten, K., Hiscock, R., Pearce, J., Blakely, T. (2008). Neighbourhood access to open space and physical activity of residents: a national study. Preventive Medicine, 47, 299–303

Wheeler, B. W., Cooper, A. R., Page, A. S., and Jago, R. (2010). Greenspace and children's physical activity: a GPS/GIS analysis of the PEACH project. *Preventive medicine*, *51*(2), 148-152.

10.0 Appendix – Approved Ethics Application

DALHOUSIE UNIVERSITY

Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

February 19, 2015

Ms Allison Welk
Science\General (Science)

Dear Allison,

REB #: 2015-3479
Project Title: Association Between Access to Neighbourhood Greenness and Physical Activity in Nova Scotia Youth

Effective Date: February 19, 2015
Expiry Date: February 19, 2016

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

Dr. Valerie Trifts, Chair

UNDERGRADUATE STUDENT SUBMISSION

RESEARCH ETHICS BOARDS

DALHOUSIE UNIVERSITY

This form should be completed using the guidance document http://researchservices.dal.ca/research_7776.html

SECTION 1. ADMINISTRATIVE INFORMATION [File No: _______________]

Office Use

Indicate the Research Ethics Board to review this research:

☐ Health Sciences OR ☐ Social Sciences and Humanities

Project Title:
Association between access to neighbourhood greenness and physical activity in Nova Scotia youth

1.1 Student researcher: Allison Welk			
Department	Environmental Science		
Degree program	Bachelors of Science with Honours in Environmental Science		
Email	allison.welk@dal.ca	Phone	613-857-7542
I agree to conduct this research following the principles of the Tri-Council Policy Statement *Ethical Conduct for Research Involving Humans* and consistent with the University *Policy on the Ethical Conduct of Research Involving Humans*. Student signature:			

1.2 Supervisor Name: Daniel Rainham			
Department	Environmental Science		
Email	Daniel.Rainham@Dal.Ca	Phone	
I have reviewed the attached ethics application prior to its submission for ethics review, including the scientific/scholarly methods of the research project which is described in the ethics application, and believe it is sound and appropriate. I will ensure this research will be conducted following the principles of the Tri-Council Policy Statement *Ethical Conduct for Research Involving Humans* and consistent with the University *Policy on the Ethical Conduct of Research Involving Humans*. Supervisor signature:			

1.3 Department/unit ethics review (if applicable). Minimal risk research only.
This submission has been reviewed and approved by the research ethics committee.

Authorizing name and signature:

Date of approval:

SECTION 2. PROJECT DESCRIPTION

2.1 LAY SUMMARY [500 words]

In lay language, briefly describe the rationale, purpose, study population and methods.

The primary objective of my study will be to explore the relationship between neighborhood greenness and physical activity levels within Nova Scotia youth.

Physical activity data will be obtained from the Keeping Pace study, carried out in 2009-2010 in Nova Scotia Canada. Keeping Pace was funded by the Department of Health and Wellness and the Department of Education and was carried out at St. Francis Xavier University by two principal researchers, Dr. Angie Thompson in the Department of Human Kinetics and Dr. Laurie Wadsworth in the Department of Human Nutrition. The main purpose of this study was to monitor provincial and regional trends in the physical activity and body mass index of children and youth in grades 3, 7 and 11 and dietary intake and behavior of students in grades 7 and 11 within Nova Scotia. 1,855 students volunteered to participate in the study.

Within my study physical activity data, behavioral data and demographic variables obtained from Keeping Pace will be used to explore the relationship between neighborhood greenness and physical activity levels in Nova Scotia youth. The sample size of my study will be 1,855 participants. Neighborhood greenness will be objectively measured using a Normalized Difference Vegetation Index retrieved form U.S Geological Survey using the online search and order tool Global Visualization Viewer. The amount of greenness within each participant's neighborhood will be measured using the geographic information system package, ArcGIS 10.2. Binary logistic regression will be completed within the statistical program R to evaluate the relationship between access to neighborhood greenness and physical activity in Nova Scotia youth.

Understanding physical activity patterns of youth is critical as youth health behaviors are predictive of the same adulthood behaviors, and physical activity levels decline during the transition from adolescence to adulthood. My study will look at whether the physical activity levels of Nova Scotia youth are influenced by neighborhood greenness. It aims to contribute to the current body of literature and strengthen our knowledge on the relationship between access to neighborhood greenness and youth physical activity. This study will also provide important information for government, municipalities, schools and organizations that can be used in the future for urban planning, policies making, and programs/ services development in order to improve physical activity levels in youth.

2.2 RESEARCH QUESTION

State the hypotheses, the research questions or research objectives.

The objective of my study is to investigate the relationship between access to neighborhood greenness and physical activity levels within Nova Scotia youth. It is hypothesized that Nova Scotia youth with greater accessibility to neighborhood greenness will have significantly higher physical activity levels then youth with little accessibility to neighborhood greenness. It is predicted that Nova Scotia youth who obtain 60 minutes of moderate to vigorous physical activity for at least 5 days of the week will have a greater area of greenness around their home while youth that do not obtain recommended physical activity levels will have significantly less greenness around their home.

2.3 RECRUITMENT

2.3.1 Describe how many participants are needed and how this was determined.

Not Applicable

2.3.2 Describe recruitment plans and append recruitment instruments. Describe who will be doing the recruitment and what actions they will take, including any screening procedures. Describe any inclusion / exclusion criteria.

Not Applicable

2.4 METHODS AND ANALYSIS

2.4.1 Discuss where the research will be conducted, what participants will be asked to do and the time commitment, what data will be recorded using what research instruments (append copies). Discuss any blinding or randomization measures. Discuss how participants will be given the opportunity to withdraw.

Not Applicable

2.4.2 Describe your role in this research and any special qualifications you have that are relevant to this study (e.g. professional experience, methods courses, fieldwork experience).

My role within this research will be to conduct a statistical analysis and present a paper on my findings. I have taken a variety of methods courses that qualifies me to carry out these duties. Some of these courses included ENVS 3502 Campus as a Living Laboratory where I conducted my own research project and learned how to effectively write a research paper, BIOL 4062 Analysis of Biological Data where I learned the statistical program R and how to run and interpret logistic regression and ENVS 3500 where I learned the basics of ArcGIS.

2.4.3 Describe plans for data analysis in relation to the hypotheses/questions/objectives.

Binary logistic regression model will be used to examine the relationship between access to neighborhood greenness and physical activity in Nova Scotia youth. Three models will be completed based on the grade of the participants. The regression model will be as follows:

Physical activity ~ Area of greenness + sex + age + household income + ethnicity/race + barriers to physical activity + time spent outdoors

Additional variables will be included in the statistical model to take into consideration other factors that could explain physical activity within the participants

All models will be analyzed in the statistical software R (version 3.0.1) and significance will be determined at $p < 0.05$.

2.4.4 Describe and justify any use of deception or nondisclosure and explain how participants will be debriefed.

Not applicable

2.4.5 Describe any compensation, reimbursement or incentives that will be given to participants (including those who withdraw).

Not applicable

2.5 INFORMED CONSENT PROCESS

Describe the informed consent process (i.e. how and when the research will be described to the prospective participant and by whom, how the researcher will ensure the prospective participant is fully informed of what they will be asked to do). If non-written consent is proposed, describe why and the process. If a waiver of informed consent is sought, address the criteria in the guidance document and TCPS articles 3.7 and/or 5.5. Address how any third party consent (with or without assent) will be managed. Describe any plans for ongoing consent, and/or community consent. Discuss how participants will be given the opportunity to withdraw (their participation and/or their data, and any limitations on this).

Append copies of all consent forms or any oral consent script.

Not applicable

2.6 PRIVACY & CONFIDENTIALITY

2.6.1 Describe how data will be stored and handled in a secure manner, how long data will be retained and where, and plans for its destruction.
The data obtained from the Keeping Pace study will consist of physical activity levels, postal codes, age, sex, ethnicity/ race, household income, time spent outdoors and possible barriers to physical activity for 1855 participants between ages 8 and 16 across Nova Scotia. The data will be stored electronically on password safe devices. Only my honours supervisor, Denial Rainham, and I will have access to the data. The data will be reported as aggregate statistics with no risk to participant identification and data confidentiality. The data will be retained from January 2015 to April 2015. All data will be destroyed with the completion of the project.
2.6.2 Address any limits on confidentiality, such as a duty to disclose abuse or neglect of a child or adult in need of protection, and how these will be handled. Such limits should be described in consent documents.
Not applicable
2.6.3 Does your use of any survey company or software to help you collect, manage, store, or analyze data mean that personally identifiable information is accessible from outside of Canada?
No Yes. If yes, describe your use of the company or software and describe how you comply with the University *Policy for the Protection of Personal Information from Access Outside Canada*.
2.6.4 Describe the measures to be undertaken for dissemination of research results and whether participants will be identified (either directly by name or indirectly). If participants will be quoted in reports from the data, address consent for this, including whether quotes will be identifiable or attributed. Describe how participants will be informed of results that may indicate they may be at risk (in screening or data collection), if applicable.
Not applicable

2.7 RISK & BENEFIT ANALYIS
2.7.1 Discuss what risks or discomforts are anticipated for participants, how likely risks are and how risks will be mitigated.
Not Applicable
2.7.2 Identify any direct benefits of participation to participants (other than compensation), and the indirect benefits of the study (e.g. contribution to new knowledge)
Not Applicable

2.8 CONFLICT OF INTEREST Describe whether any conflict of interest exists for any member of the research team in relation to potential research participants (e.g., TA, fellow students), and/or study sponsors, and how this will be handled.
Not applicable

SECTION 3. APPENDICES

3.1 Appendices Checklist. Append all relevant material to this application. This may include:

- ☐ Recruitment Documents (posters, verbal scripts, online postings, any invitations to participate, etc.)
- ☐ Screening Documents
- ☐ Consent Forms (see section 3.2 below)
- ☐ Research Instruments (questionnaires, surveys, interview or focus group questions, etc.)
- ☐ Debriefing Forms

☐ Permission Letters (Aboriginal Band Council, School Board, Director of a long-term care facility)